The state of circular economy implementation in the building and construction sector in Aotearoa New Zealand

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Abstract

The building and construction (B&C) sector is pivotal in achieving a global shift towards a circular economy (CE) and moving away from a linear or 'take-make-dispose' model that drives unsustainable consumption rates and degrades vital ecosystem services. However, little is known about the extent to which B&C businesses implement the CE concept in Aotearoa New Zealand. Therefore, this study assessed the current level of implementation of the CE concept among businesses in Aotearoa New Zealand's B&C sector. An exploratory sequential mixed-methods research design was utilised, beginning with the synthesis of circular strategies derived from existing literature. Experts representing seven business types (manufacturing, architecture and engineering, construction, design-build, fit-out, demolition, and waste management companies) were interviewed to explore the relevance of circular strategies, informing the development of a survey distributed to professionals from across Aotearoa New Zealand's B&C sector.

Most circular strategies were considered relevant by interviewees and were subsequently included in the survey. Interviewees also suggested that CE implementation is insufficient, inconsistent, uncoordinated, and limited by a narrow focus on recycling, necessitating more education, emphasis on the design phase, and a systemic and collaborative approach. According to the survey responses from 213 professionals, most businesses are at a 'beginner' stage of maturity regarding CE implementation, and most circular strategies receive minimal to moderate levels of implementation. Therefore, most circular strategies require greater attention, particularly service-based models, sharing platforms, material passports, remanufacturing, take-back schemes, organic recycling, and regenerating nature. These findings suggest that CE implementation among businesses in Aotearoa New Zealand's B&C sector is still in its early stages. In this context, there is significant potential to increase engagement in circular strategies, especially at the higher levels of the waste hierarchy and 9Rs, to accelerate the shift towards a more sustainable and circular economy.

Keywords: Building and construction, circular economy, implementation, New Zealand, circular strategies

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List of Abbreviations

3Rs	Reduce, reuse, and recycle
9Rs/10Rs	Refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, and recover
AI	Artificial Intelligence
ANZSIC	Australian and New Zealand Standard Industrial Classification
B&C	Building and Construction
BAMB	Buildings as Material Banks
BIM	Building Information Modelling
BSI	British Standards Institution
C&D	Construction and Demolition
C2C	Cradle to Cradle
CBM	Circular Business Model
CE	Circular Economy
DfX	Design for X
EMF	Ellen MacArthur Foundation
EPD	Environmental Product Declaration
EPR	Extended Producer Responsibility
ERP	Emissions Reduction Plan
GHG	Greenhouse gas
IoT	Internet of Things
ISO	International Organisation for Standardisation
LCA	Life Cycle Assessment
LEED	Leadership in Energy and Environmental Design
BREEAM	Building Research Establishment Environmental Assessment Method
MFA	Material Flow Analysis

MfE	Ministry for the Environment
MBIE	Ministry of Business, Innovation & Employment
NZWS	New Zealand Waste Strategy
PACE	Platform for Accelerating a Circular Economy
PROs	Producer Responsibility Organisations
ReSOLVE	Regenerate, share, optimise, loop, virtualise, and exchange
RFID	Radio Frequency Identification
SBN	Sustainable Business Network
SDGs	Sustainable Development Goals
UNEP	United Nations Environment Programme
WBCSD	World Business Council for Sustainable Development
WGBC	World Green Building Council
WMA	Waste Management Act 2008
WMMP	Waste Management and Minimisation Plan

1. Introduction

1.1 Implications of a Linear Economy

Since the beginning of industrialisation, the economy has been characterised by a linear model that involves extracting natural resources to manufacture products that are eventually discarded as waste (Ellen MacArthur Foundation [EMF], 2013, p. 6). This ‘take-make-dispose’ consumption pattern has contributed to increased market volatility and pricing levels, deforestation, soil degradation, pollution, water stress, biodiversity loss, resource scarcity, and climate change (Circle Economy, 2023, p. 13; EMF, n.d.-b, 2013, p. 2). Additionally, the linear model is energy-intensive, generates unnecessary waste, and drives consumption beyond what the Earth can sustainably provide, threatening the ecosystem services that current and future generations depend upon (EMF, 2013, pp. 15–17).

In 2023, Earth Overshoot Day, or the day of the year when humanity's demand for ecological resources and services exceeds Earth’s capacity to regenerate them, was August 2 (Earth Overshoot Day, 2024). Maintaining this demand would require 1.7 Earths. The International Resource Panel predicts that without significant changes, global material use will reach 190 billion tonnes annually by 2060, up from 100 billion tonnes in 2023 (Oberle, 2019, p. 9). However, the OECD (2019) suggests it could surpass 300 billion tonnes by 2060 (p. 19). Factoring in structural and technological shifts, this estimate lowers to 167 billion tonnes by 2060, doubling environmental impacts and disrupting economies and societies (OECD, 2019, pp. 15–16). Environmental impacts will include failure to limit global temperature rise to two degrees and significant increases in air pollution, acidification, eutrophication, land use, and toxic impacts on humans and aquatic and terrestrial ecosystems.

Under current linear production and consumption patterns, the building and construction (B&C) sector has a significant environmental footprint. Globally, this sector is responsible for about 50% of raw material consumption; 37% of CO_2 emissions, including emissions associated with the production of materials such as concentre, steel, aluminium, glass, and bricks; and 35% of landfill waste (Chen et al., 2022; United Nations Environment Programme [UNEP], 2022, p. xvi). In addition, the sector is responsible for ocean acidification, biodiversity loss, pollution, water stress, altered hydrology, about one-quarter of land system change, one-fifth of nitrogen emissions, and more than half of atmospheric aerosol loading (Circle Economy, 2023, p. 34, 2024, p. 28).

In Aotearoa New Zealand, economic growth has predominantly relied on exploiting natural resources, leading to increased greenhouse gas (GHG) emissions, water pollution, and threats to biodiversity (OECD, 2017, p. 15). Moreover, the Earth Overshoot Day for Aotearoa New Zealand was earlier than the global average, falling on April 11 (Earth Overshoot Day, 2024). Driven by growing demand for infrastructure, the B&C sector contributes 20% of total carbon emissions (Ministry of Business, Innovation & Employment [MBIE], 2020, p. 2), and construction and demolition (C&D) waste represents around 50% of total waste generation (BRANZ, 2023), including 33% of waste going to class one municipal waste landfills (Ministry for the Environment [MfE], 2021). Waste generation is expected to continue increasing in the next seven years (Purchase et al., 2022).

The scale of the environmental externalities imposed by the B&C sector suggests that it has a significant role in any endeavour to ensure cleaner production and address climate change (Norouzi et al., 2021). Additionally, the built environment is one of four key systems that have a role in reversing the overshoot of planetary boundaries (Circle Economy, 2023, p. 28). Material efficiency alone will only delay the loss of finite materials under the status quo (EMF, 2013, p. 22). Thus, a paradigm shift is essential to conserve resources and ensure humanity thrives in the future (EMF, n.d.-b, 2013, p. 2).

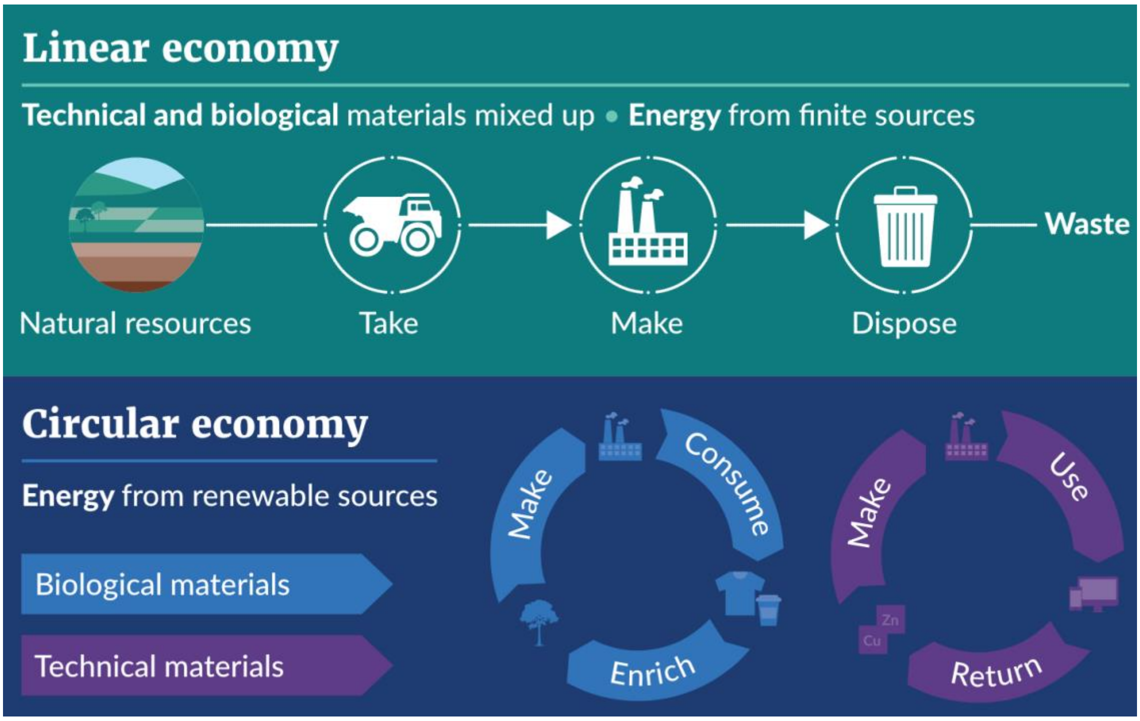
1.2 Towards a Circular Economy

The circular economy (CE) concept offers a promising alternative to the current linear economy (Murray et al., 2017; Winans et al., 2017). The CE concept also provides a potential solution to global sustainability challenges and a way of harmonising environmental, economic, and social aspirations (Ghisellini et al., 2016; Lieder & Rashid, 2016). For example, adopting CE principles could reduce virgin material extraction by 34%, contribute to limiting global warming to two degrees, and reverse the overshoot of five planetary boundaries (Circle Economy, 2023, p. 30). The

Ellen MacArthur Foundation (EMF), which has been instrumental in disseminating the concept (Geissdoerfer et al., 2017; Winans et al., 2017), describes a CE as “an industrial system that is restorative or regenerative by intention and design” (EMF, 2013, p. 7).

Compared to the linear model, one of the most notable differences of a CE is that materials at the end of a product’s life become inputs for a new cycle instead of creating waste and extracting new resources (EMF, 2013, p. 22). In a CE, biological or bio-based materials should generally be returned to the soil to build natural capital for a new cycle. In contrast, technical or human-made materials incompatible with nature’s circular systems should be reused and their quality maintained. Figure 1 illustrates how the ‘take-make-dispose’ pattern represents a linear economy, while a CE represents a circular process for biological and technical materials.

Figure 1: *The Linear Economy Versus a Circular Economy (MfE, 2022b, p. 158)*



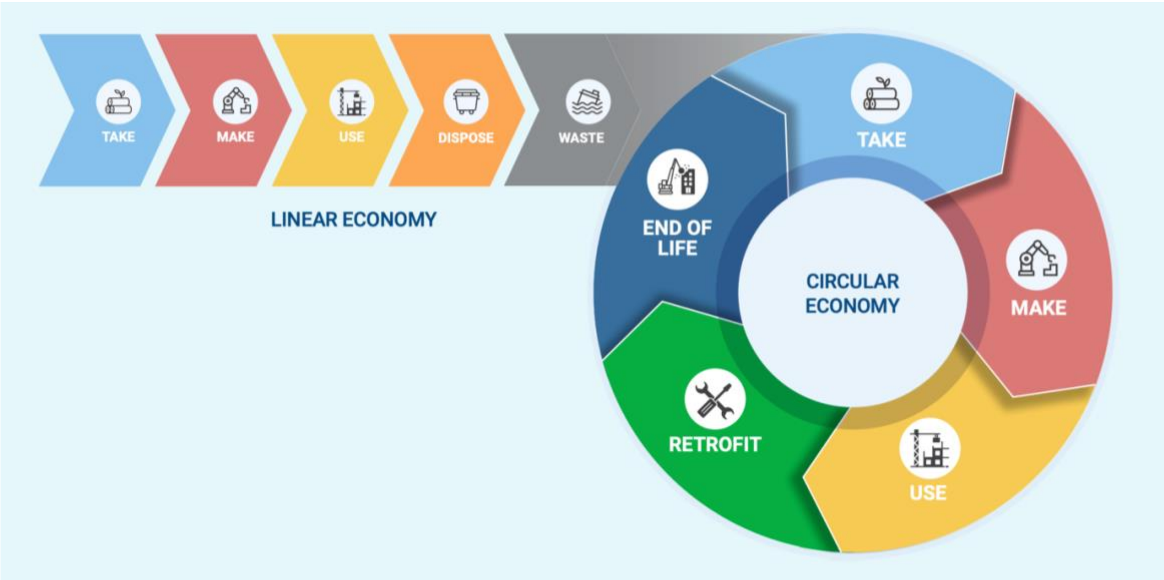
Although relatively new, the CE concept has received significant attention from industry, policymakers, and academia worldwide (Geissdoerfer et al., 2017; Ghisellini et al., 2016; Kirchherr et al., 2017). It represents a billion-dollar economic opportunity, benefiting companies, economies, natural capital, and consumers (EMF, 2013, p. 82). According to Lacy and Rutqvist (2015), if a CE were to substitute the linear economy, it could generate an extra $4.5 trillion in economic output by 2030. Many businesses have been promoting the CE concept to realise its potential value for the company, stakeholders, and customers (Geissdoerfer et al., 2017; Korhonen et al., 2018). Transitioning to a CE is also an opportunity to engage in sustainable business practices and enhance initiatives to reduce, reuse, and recycle (Murray et al., 2017; Winans et al., 2017). In addition, the risks of the linear model, such as rising resource prices, supply disruptions, regulatory pressure, tarnished reputations, and reduced market share, can be avoided (EMF, 2013, p. 6; Sustainable Business Network [SBN], 2021, p. 6). In 2008, China was the first country to introduce a national CE policy, following CE recycling policies implemented in Germany and Japan in the 1980s and 1990s (Korhonen et al., 2018; Murray et al., 2017). The European Commission and several other national governments followed suit. The number of academic articles relating to the CE concept has also grown dramatically over the past decade (Geissdoerfer et al., 2017).

However, despite widespread interest, engagement, and investment, global circularity, or the percentage of secondary materials cycled back into the global economy, declined from 9.1% in 2018 to 7.2% in 2023 with "almost unprecedented" rates of material extraction and consumption (Circle Economy, 2023, p. 8, 17). Circularity is hindered by using non-renewable materials and biomass, the use of fossil fuel energy carriers to produce energy, and the rapid accumulation of in-use material stocks, predominantly in the form of buildings and infrastructure (Circle Economy, 2023, pp. 17–19; Haas et al., 2015). Therefore, recycling and strategies that merely address material outputs will have a limited impact on improving circularity alone (Circle Economy, 2023, p. 8; Haas et al., 2015). Instead, minimising material inputs, shifting to renewable energy, and careful design are necessary to achieve a CE.

Achieving a CE in the built environment calls for a significant reduction in resource consumption; product and material optimisation; design for disassembly, reuse, and recycling; complete elimination of waste; and the regeneration of nature (World Green Building Council

[WGBC], 2023, p. 19). Shifting to a circular life cycle requires a 'take-make-use-retrofit' pattern instead of the linear 'take-make-use-dispose' pattern (see Figure 2). This shift is particularly crucial in the B&C sector due to its significant environmental impacts (Norouzi et al., 2021). It is also crucial to make progress on multiple United Nations Sustainable Development Goals (SDGs) (Ogunmakinde et al., 2022; Circle Economy & World Business Council for Sustainable Development [WBCSD], 2018, p. 7).

Figure 2: *The Linear Economy and a Circular Economy in the Built Environment (WGBC, 2023, p. 7)*



Aotearoa New Zealand is only at the beginning stages of a CE transition (Jamieson & MacEwan, n.d.), and progress is occurring slowly, particularly in industries where products tend to have long life cycles, such as the B&C sector (SBN, 2021, p. 6, 13). There is a lack of system-wide urgency and collaboration that climate change, resource depletion, and environmental degradation necessitate. As a result, businesses primarily focus on waste diversion and recycling instead of designing out waste or exploring more circular strategies such as reuse and repair. Action is limited in the space between high-level conceptualisations and grassroots activity (Diprose et al., 2022). Where early adopters use CE language, it is often directed at recycling problem materials and climate action rather than an economy-wide transformation. In this context, there is a need for greater focus on increasing collaboration, regenerating nature, and challenging growth (Diprose et al., 2022). The Emissions Reduction Plan (ERP) and the new Waste Strategy acknowledge the need for a more sustainable and circular economy, with both documents articulating a vision for achieving a CE by 2050 (MfE, 2022b, p. 157, 2023a, p. 18).

1.3 Scope and Justification for the Research

The significant negative environmental externalities associated with the B&C sector call for CE implementation to close the global circularity gap and support sustainable development for current and future generations. In addition, the significant environmental impacts of the sector in Aotearoa New Zealand indicate that much needs to be done to achieve circularity. Therefore, the primary focus of this research is to understand the extent to which businesses in the B&C sector are implementing CE practices in Aotearoa New Zealand.

A considerable gap exists between CE theory and practice, particularly at the micro-level (i.e., businesses, products, and consumers) (Barreiro-Gen & Lozano, 2020). A CE in the B&C sector has become an area of great interest among academics in recent years, with publications increasing annually by 21% on average (Norouzi et al., 2021). However, whilst there are some examples of B&C companies that have recently embraced CE initiatives, the sector as a whole has struggled to adopt CE principles, and CE implementation remains unsatisfactory and fragmented, with many circular strategies yet to be exploited (Bilal et al., 2020; Çimen, 2021; Eberhardt et al., 2022; Guerra et al., 2021; Hjaltadóttir & Hild, 2021; Osobajo et al., 2020). Furthermore, there is an urgent need for the private sector to focus on developing and adopting business models that reduce resource consumption to manage resource scarcity (Benachio et al., 2020; EMF, 2013, p. 2; Nuñez-Cacho et al., 2018). Therefore, there is a clear need to explore CE implementation in the B&C sector to understand which practices require greater attention.

Research on CE and the B&C sector in New Zealand has been relatively limited (e.g., Balador et al., 2020; Berry et al., 2022; Finch et al., 2018, 2021; Finch, 2023; Fitwi, 2023; Gade et al., 2020;

Gade, 2022; Low et al., 2020; Purchase et al., 2022; Roy, Dani, et al., 2022; Roy, Su, et al., 2022; Shanks, 2022; Zaman et al., 2018). Whilst circular assessment criteria for building envelope layers have been explored (Finch et al., 2021), it appears that no research has been undertaken that specifically explores the state of CE implementation in B&C businesses in New Zealand. Little is known about the extent to which B&C businesses implement the CE concept. Therefore, this study will contribute to the literature on CE implementation in the B&C sector, particularly in the context of Aotearoa New Zealand. It will also provide real-world value by highlighting shortcomings that businesses need to address. In turn, this will help encourage the implementation of strategies that increase circularity and address the environmental impacts on local and international ecosystems caused by the current linear approach.

1.4 Research Aim and Question

This study aims to assess the current level of implementation of the CE concept among businesses in the B&C sector in Aotearoa New Zealand. An exploratory sequential mixed-methods research design will be used to qualitatively explore key circular strategies and their relevance in the Aotearoa New Zealand context before quantitatively determining their implementation by businesses. This is in order to understand the gap between CE theory and practice and to pinpoint the strategies that need improvement to accelerate the transition to a more circular sector. The following central research question and sub-questions are designed to achieve this aim:

What is the current level of CE implementation among businesses in Aotearoa New Zealand's B&C sector?

1. What circular strategies are relevant in supporting a CE transition among selected business types in the B&C sector in Aotearoa New Zealand?
2. What are experts' perceptions on the current state of CE implementation among selected business types in the B&C sector in Aotearoa New Zealand?
3. How do professionals perceive the maturity of CE implementation in their business/place of employment?

4. What is the current level of implementation of identified circular strategies among businesses in the B&C sector in Aotearoa New Zealand, and which circular strategies require greater attention to accelerate the transition?
5. Are there any associations between business age, size, or sub-sector and the maturity of CE implementation or implementation of circular strategies?

1.5 Outline of the Thesis Structure

This thesis contains seven chapters. After this introduction chapter, Chapter 2 provides background information on the CE concept, including CE history, definitions, principles, and policy. Chapter 3 reviews the international literature, including circular strategies, business models, the state of awareness and implementation, recycling and alternative building materials, technologies, barriers and enablers, CE policy, guidelines, frameworks, and measuring and assessment. It then reviews New Zealand literature, including barriers and challenges, evidence of progress, and actions to accelerate a CE transition. Chapter 4 describes the methods used in this research, including the research design and the data collection and analysis methods. Chapter 5 then presents the findings of this research, and Chapter 6 discusses these results to address the research questions and suggest recommendations for accelerating a CE transition. Finally, Chapter 7 concludes this thesis by summarising the main findings, discussing the contributions and implications, and suggesting future work and research opportunities.

2. Background

2.1 Introduction

This chapter provides background information to introduce the CE concept and contextualise this research. It is divided into four main sections. Firstly, Section 2.2 introduces the history of the CE concept and related concepts. Section 2.3 then describes how the CE concept is conceptualised by providing definitions and identifying core principles. Next, Section 2.4 outlines the policy context in Aotearoa New Zealand. Finally, Section 2.5 introduces the te ao Māori perspective for an inclusive and holistic CE shift.

2.2 CE History and Related Concepts

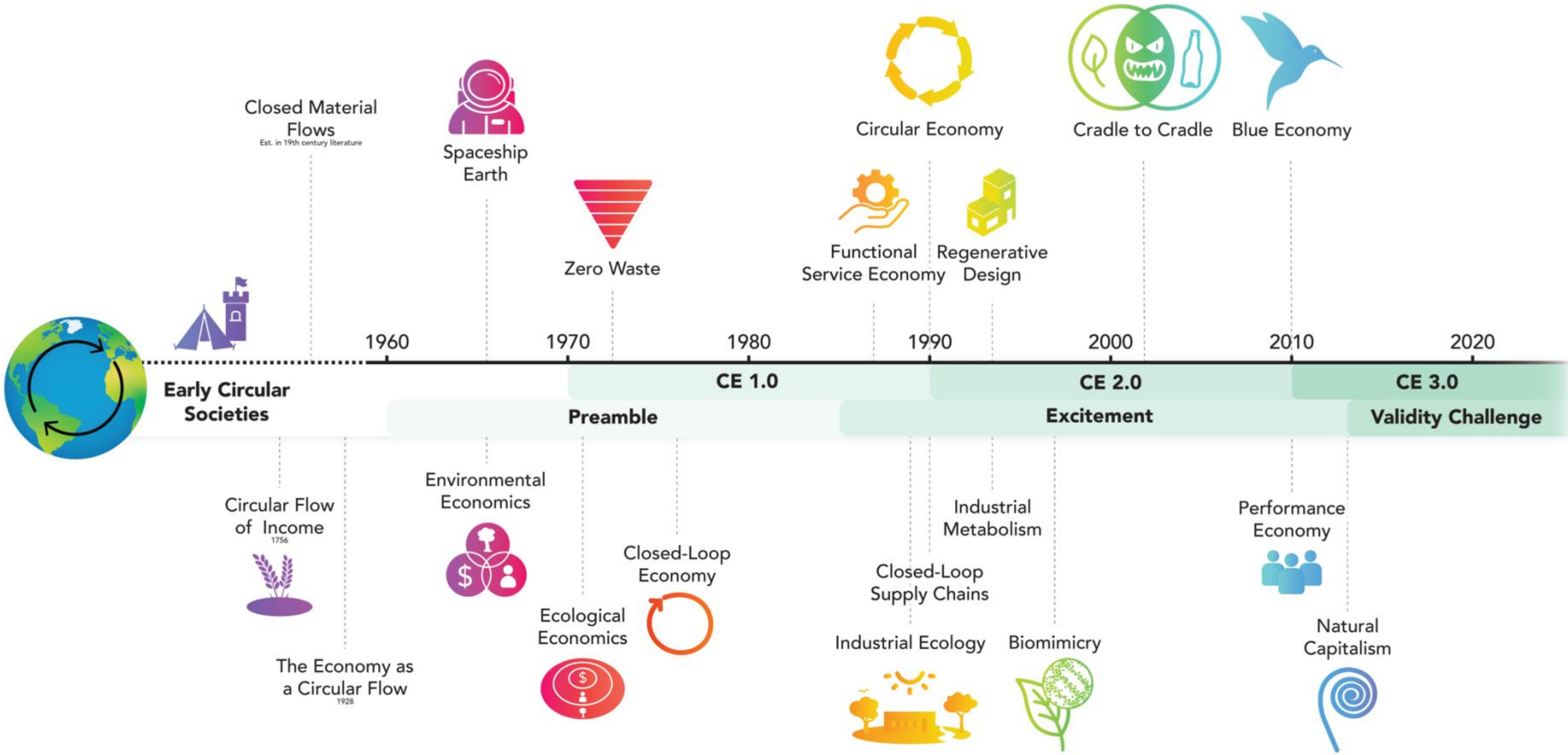
The CE and related concepts emerged to address linear consumption patterns that grew from the first Industrial Revolution (Casson & Welch, 2021). However, circularity has been observed long before the CE concept emerged in modern economic and environmental discourse. Circularity has always existed through the continual cycling of molecules in biogeochemical cycles, and early societies depended upon frugality and material optimisation for their development amidst resource scarcity (Murray et al., 2017; Stahel, 2019, s. 1). Throughout history, reusing and repurposing building materials have been common practices (WGBC, 2023, p. 16). For example, the stones of old castles and cathedrals were recovered to construct houses, bridges, and roads (Stahel, 2019, s. 1). Additionally, indigenous knowledge of the lifeforce of nature and its closed-loop systems has transcended generations, guided by observations of natural phenomena such as the water cycle and reciprocity and kinship with the land (Beamer et al., 2021, 2023).

The CE is an umbrella concept for numerous related concepts that acknowledge closed material flows and closed-loop systems as crucial components of a sustainable future (Blomsma & Brennan, 2017; Homrich et al., 2018). While the French physiocrat, François Quesnay, introduced the theory of a circular flow of income in *Tableau économique* in 1758, the idea of closed material flows was predominantly established in 19th-century literature (e.g., Simmonds, 1862, as cited in Antikainen et al., 2018; Murray et al., 2017; Reike et al., 2018, 2022). Another early reference to circular flows was Leontief's (1928) thesis, *The Economy as a Circular Flow* (Barreiro-Gen & Lozano, 2020). By 1930, the idea of factories utilising the waste products of other companies as inputs, now referred to as industrial symbiosis, appeared in the literature (for example, Parkins, 1930 as cited in Murray et al., 2017). From the 1960s onwards, the history of the CE and its related concepts can be divided into a preamble period, an excitement period, and a validity challenge period, or CE 1.0, CE 2.0, and CE 3.0 (Blomsma & Brennan, 2017; Calisto Friant et al., 2020; Reike et al., 2018, 2022). Figure 3 illustrates key related concepts according to these periods.

In the 1960s and 1970s, seminal publications emphasised the need to investigate economic systems and resource management in light of environmental issues and resource scarcity (Blomsma & Brennan, 2017; Reike et al., 2018, 2022; Tuladhar et al., 2022). Boulding's (1966) Spaceship Earth analogy was particularly influential to the CE concept and a key milestone in environmental economics (Antikainen et al., 2018; Calisto Friant et al., 2020; Geisendorf & Pietrulla, 2018; Murray et al., 2017; Tuladhar et al., 2022). Boulding (1966) labelled the modern economy the *cowboy economy* for its exploitative, open, one-way system of inputs and outputs that results in a loss of natural stocks. In contrast, the future economy was referred to as a closed *spaceman economy* in which outputs are recycled, acknowledging that resources are limited. These two economies could be interpreted as linear and circular economies, respectively.

Drawing on Boulding (1966), the idea of a closed-loop economy was developed by Stahel and Reday-Mulvey (1976). The importance of closed cyclical flows and recycling outputs was also recognised by ecological economists (e.g., Daly, 1997; Georgescu-Roegen, 1971) and the industrial metabolism concept proposed by Ayres (1994) (Ghisellini et al., 2016). However, Pearce and Turner (1990) were the first to use the CE term to describe the need for a closed circular system instead of an open linear economy (Geisendorf & Pietrulla, 2018; Geissdoerfer et al., 2017; Ghisellini et al., 2016; Tuladhar et al., 2022).

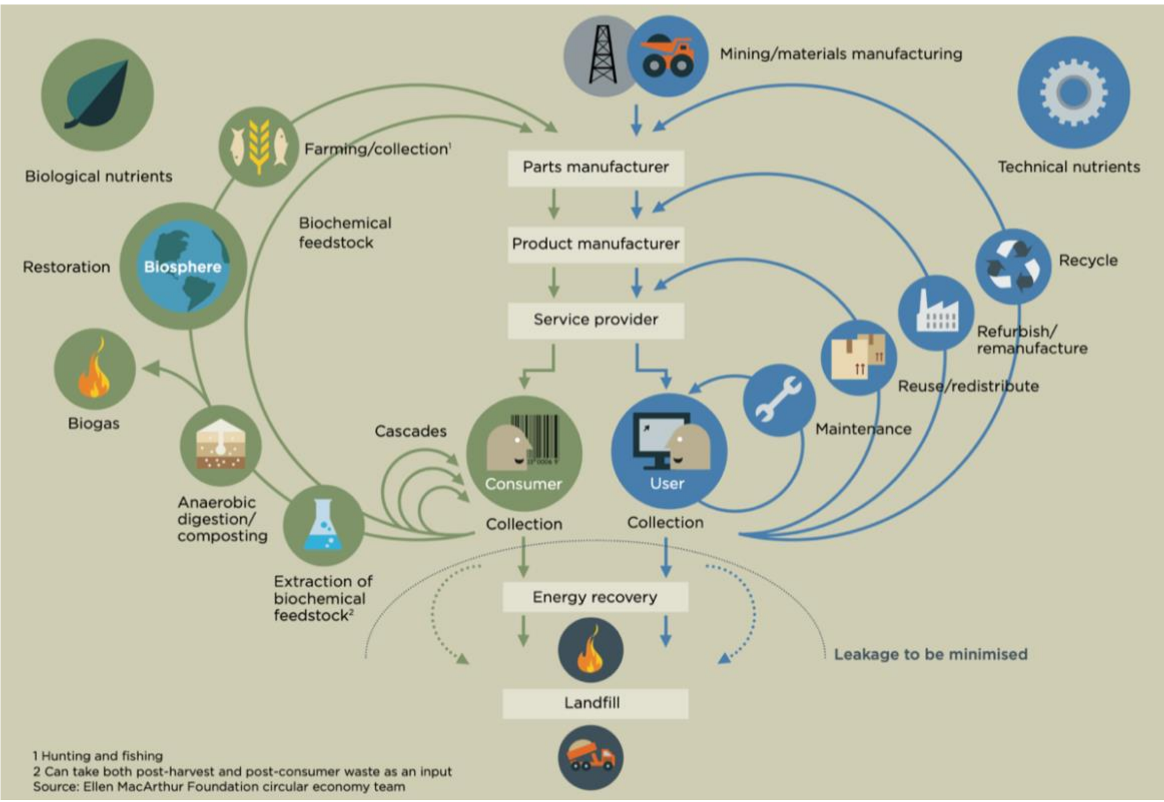
Figure 3: *A Timeline of the CE Concept and Related Concepts*



Credit: Author's Own (Antikainen et al., 2018; Barreiro-Gen & Lozano, 2020; Blomsma & Brennan, 2017; Calisto Friant et al., 2020; Geisendorf & Pietrulla, 2018; Geissdoerfer et al., 2017; Ghisellini et al., 2016; Murray et al., 2017; Reike et al., 2018, 2022; Stahel, 2019, 2020; Ellen MacArthur Foundation, 2013; Tuladhar et al., 2022; Zaman, 2015)

The Industrial Ecology and Cradle to Cradle (C2C) movements have played a pivotal role in the development of the CE concept (Antikainen et al., 2018; Geisendorf & Pietrulla, 2018; Geissdoerfer et al., 2017; Ghisellini et al., 2016; Murray et al., 2017). Established by Frosch and Gallopoulos (1989), industrial ecology is a closely related concept that seeks to modify industrial systems and processes to optimise and close material and energy flows. C2C similarly considers material flows and the efficiency of industrial systems (McDonough & Braungart, 2002). A central tenet of C2C and CE theory is the differentiation between biological and technical cycles (see Figure 4). Materials designed to return to biological cycles must safely biodegrade and reintegrate with nature’s cyclical systems to support new plant life. Materials designed to return to the technical cycle are typically forged by humans and can be infinitely reused and recycled in the Technosphere. Products with inseparable biological and technical nutrients are *monstrous hybrids* that must be avoided.

Figure 4: *CE Butterfly Diagram Illustrating Biological and Technical Cycles (EMF, 2013, p. 24)*



The concept of a performance economy is also adopted within the CE concept to ensure the maximum utility of products (Stahel, 2010). Building upon earlier works that refer to a functional service economy (Börlin & Stahel, 1987; Giarini & Stahel, 1989; Stahel, 1994), the performance economy entails the servitisation of products, or selling the performance of products as a service instead of selling the objects themselves, for example, car sharing rather than car ownership (Stahel, 2020). Such product service systems enable product-life extension and dematerialisation, reducing resource and energy consumption (Geisendorf & Pietrulla, 2018).

First coined by Paul Palmer in 1973, Zero Waste is another relevant concept that shares conceptual overlap with the CE concept, particularly concerning sustainable waste management systems and eliminating waste (Zaman, 2015). Only essential items designed for a longer lifespan would be produced in a zero waste CE. However, the CE concept differs from the Zero Waste concept as it involves a broader, regenerative approach (Veleva et al., 2017). The Zero Waste movement has spread worldwide through grassroots organisations, NGOs, and municipalities (Blumhardt & Prince, 2022). In Aotearoa New Zealand, organisations such as Para Kore and the Zero Waste Network Aotearoa have contributed to the movement's growth.

Numerous other schools of thought have also inspired the development of the CE concept (Antikainen et al., 2018; Geissdoerfer et al., 2017; Tuladhar et al., 2022). A concept applied to the built environment is regenerative design (Lyle, 1996), which calls for systems thinking, careful consideration at the design stage, and renewable materials and energy to ensure closed material loops (Geisendorf & Pietrulla, 2018; Tuladhar et al., 2022). This can be realised through biomimicry (Benyus, 1997) or embracing nature as an inspiration to develop products that serve in harmony with ecosystems. Similar to biomimicry, the blue economy (Pauli, 2010) proposes that environmentally beneficial solutions can be devised based on locality, efficiency, and mimicking the surrounding nature (Geisendorf & Pietrulla, 2018). This concept shares several overlaps with the CE concept, much like natural capitalism (Hawken et al., 2013), which aims at increasing the productivity of natural capital, extending the life of products, closing loops, servitisation, and regenerating nature (Geisendorf & Pietrulla, 2018; Tuladhar et al., 2022). Other influential ideas include, but are not limited to, closed-loop supply chains, cleaner production, reverse logistics, permaculture, the sharing economy, systems theory, the green economy and the bioeconomy, and life cycle thinking (Antikainen et al., 2018; Calisto Friant et al., 2020; EMF, 2013, pp. 26–27; Geisendorf & Pietrulla, 2018; Reike et al., 2022).

The future of the CE concept will involve further concept development, including CE metrics and assessment, enhancing the social dimension, and encouraging a socio-institutional shift (Blomsma & Brennan, 2017). Governance options and policy instruments, technological innovations, eco-design, the right to repair, communication strategies, virtual platforms, land use planning, and consumer information may guide progress (Antikainen et al., 2018; Casson & Welch, 2021). Furthermore, Stahel (2020) predicts that resource optimisation in a mature CE will introduce an 'era of the R' or the adoption of reuse, repair, remarket, remanufacture, reprogramme, refine, and recycle strategies. An 'era of the D' or efforts to recover atoms for reuse, such as de-link, depolymerise, de-alloy, delaminate, de-vulcanise, de-coat, and deconstruct, will follow. In addition, a sustainable future requires a shift to a product-service economy that is separated from the linear economy, governed by rules that deter abuse, and gains from big data and artificial intelligence (AI) (Stahel, 2020).

2.3 Conceptualising a CE

2.3.1 CE Definition

Numerous CE interpretations exist as the concept is currently undergoing a period of critical engagement in which conceptual clarity and consensus are not yet apparent (Blomsma & Brennan, 2017). It is necessary to distinguish comprehensive conceptualisations from those that do not imply a hierarchy and risk perpetuating business-as-usual (Kirchherr et al., 2017). For instance, the common misinterpretation that CE is synonymous with recycling can impede meaningful progress, as recycling alone is a low-value CE strategy that can degrade material quality and fail to prompt changes to linear practices in the earlier stages of product life cycles (Kirchherr et al., 2017;

Morseletto, 2020b). Therefore, Kirchherr et al. (2017) proposed a definition incorporating reuse, recycle, and recover activities based on 114 definitions:

> A circular economy describes an economic system that is based on business models which replace the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operating at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations. (pp. 224–225)

Nobre and Tavares (2021) also propose an all-encompassing definition based on the definitions stated in frequently cited CE papers:

> Circular Economy is an economic system that targets zero waste and pollution throughout materials lifecycles, from environment extraction to industrial transformation, and to final consumers, applying to all involved ecosystems. Upon its lifetime end, materials return to either an industrial process or, in case of a treated organic residual, safely back to the environment as in a natural regenerating cycle. It operates creating value at the macro, meso and micro levels and exploits to the fullest the sustainability nested concept. Used energy sources are clean and renewable. Resources use and consumption are efficient. Government agencies and responsible consumers play an active role ensuring correct system long-term operation. (s. 4.1)

While a hierarchy of reduce, reuse, and recycle activities is not implied, this definition recognises that a CE addresses waste and pollution throughout the entire life cycle of a product instead of the end-of-life stage exclusively. In addition, it differentiates between biological and technical materials and incorporates regeneration, renewable energy, and efficient resource use.

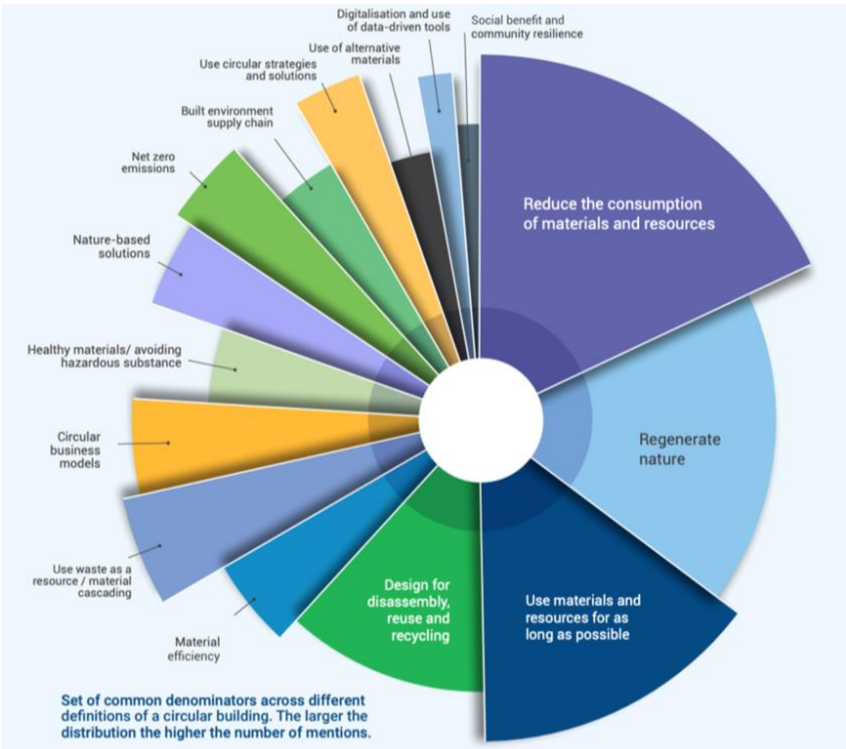
The definition outlined in a recently developed ISO standard defines a CE as an "economic system that uses a systemic approach to maintain a circular flow of resources, by recovering, retaining or adding to their value, while contributing to sustainable development" (International Organisation for Standardisation [ISO], 2023b, 3.1.1). *Circular flow of resources* is defined as the "systemic cycling of the provision and use of resources within technical and biological cycles" (s. 3.1.5). *Circular* is defined as "aligned with the principles for a circular economy" (s. 3.1.13).

2.3.2 Circular Building Definition

CE adoption for buildings can be defined as "a lifecycle approach that optimises the buildings' useful lifetime, integrating the end-of-life phase in the design and uses new ownership models where materials are only temporarily stored in the building that acts as a material bank" (Leising et al., 2018, p. 978). This definition was considered more comprehensive than the definition stated by Pomponi and Moncaster (2017): "a building that is designed, planned, built, operated, maintained, and deconstructed in a manner consistent with CE principles" (p. 978). An analysis of circular building definitions revealed that the most common themes include reducing resource consumption, regenerating nature, using materials and resources for as long as possible, and designing for disassembly, reuse, and recycling (WGBC, 2023, p. 19; see Figure 5). The WBCSD developed the final definition adopted by the WGBC (2023):

> A circular building optimizes the use of resources while minimizing waste throughout its whole life cycle. The building's design, operation and deconstruction maximize value over time using:
>
> - Durable products and services made of secondary, non-toxic, sustainably sourced, or renewable, reusable or recyclable material;
> - Space efficiency over time through shared occupancy, flexibility and adaptability;
> - Longevity, resilience, durability, easy maintenance and repairability;
> - Disassembly, reuse or recycling of embedded material, components and systems;
> - Life-cycle assessment (LCA), life-cycle costing (LCC) and readily available digital information (such as building material passports). (p. 18)

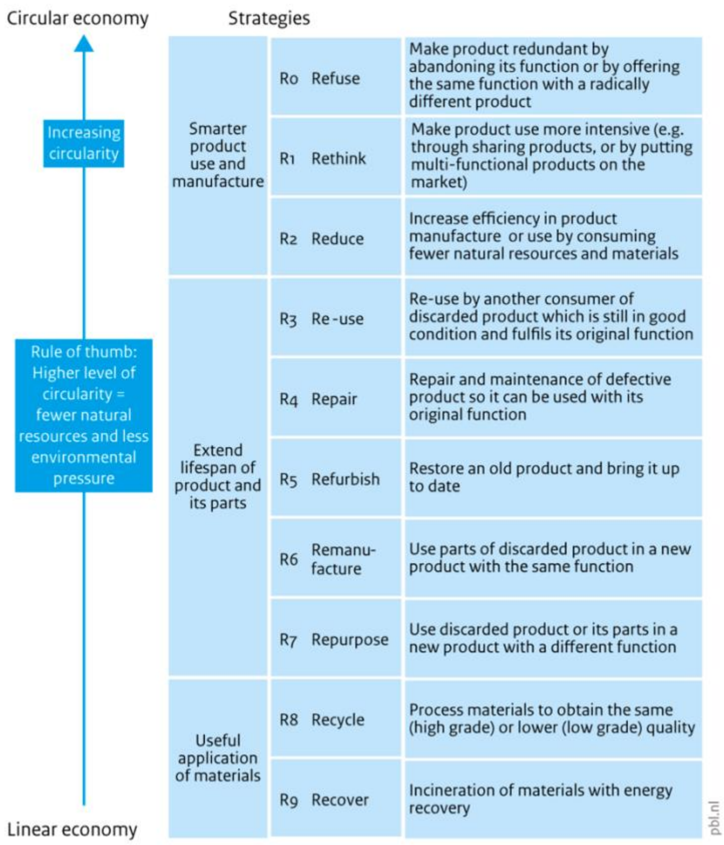
Figure 5: *Themes Found in Circular Building Definitions (WGBC, 2023, p. 19)*



2.3.3 CE Principles

Numerous principles characterise the CE concept. The most frequently cited principles are the ‘3Rs’ or reduce, reuse, and recycle (Kirchherr et al., 2017; Prieto-Sandoval et al., 2018). Various other frameworks of ‘re-principles’ guide CE implementation, each listed, implying a hierarchy (Kirchherr et al., 2017). While most CE definitions commonly refer to reuse and recycling, a CE must be viewed as more than effective waste management to ensure its success (Ghisellini et al., 2016; Prieto-Sandoval et al., 2018). Re-principles higher in the waste hierarchy, such as refuse, redesign, and rethink, should be prioritised to prevent waste initially and ensure a CE. At least 38 ‘re-principles’ exist in varying combinations from 3Rs to 16Rs (Hannon, 2022; Kirchherr et al., 2017). For example, the 9Rs/10Rs include (R0) refuse, (R1) rethink, (R2) reduce, (R3) reuse, (R4) repair, (R5) refurbish, (R6) remanufacture, (R7) repurpose, (R8) recycle, and (R9) recover—from most to least circular (Potting et al., 2018; see Figure 6).

Figure 6: *The 9Rs (Potting et al., 2018)*

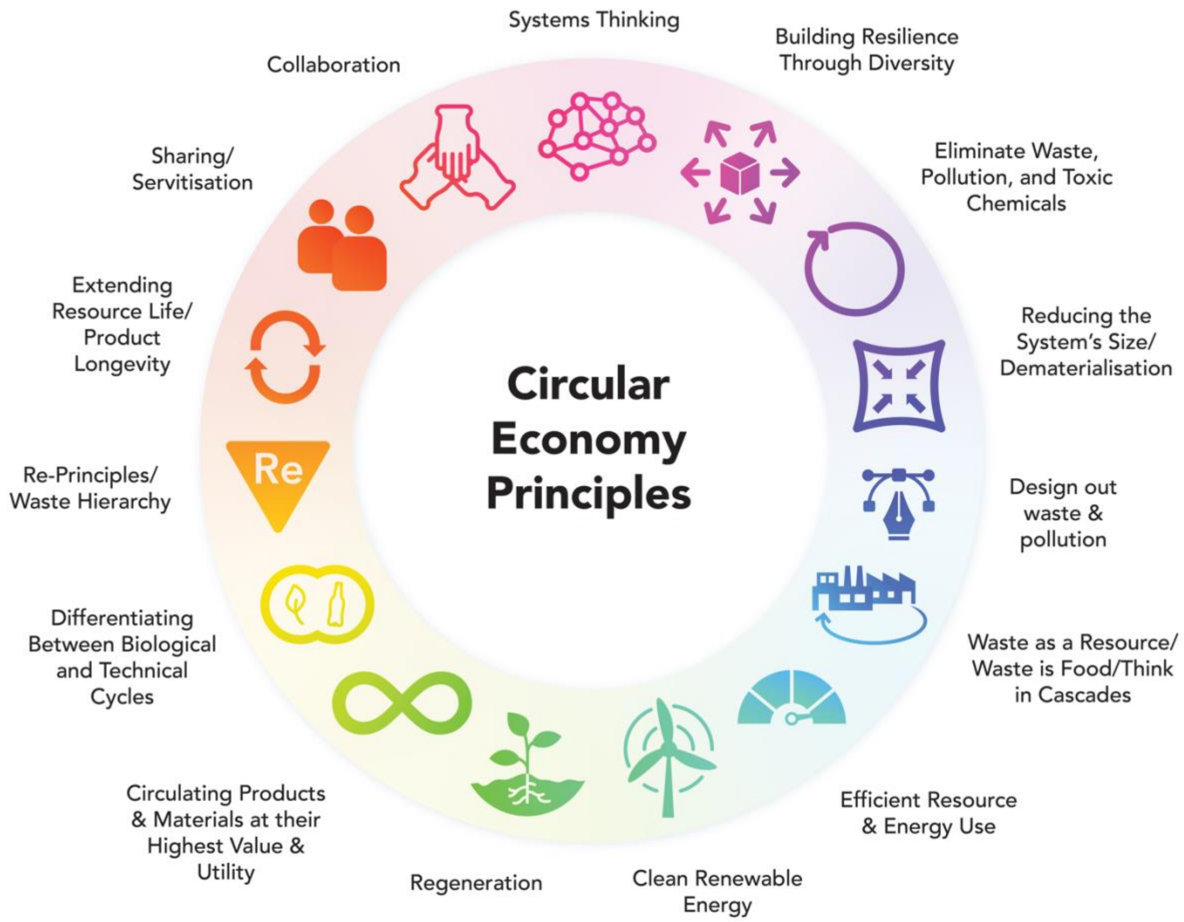


EMF's principles are also frequently cited (Ghisellini et al., 2016; Tuladhar et al., 2022). The three core principles are (1) eliminating waste and pollution, (2) circulating products and materials at their highest value, and (3) regenerating nature (EMF, n.d.-a). The first and second principles are essential to form a closed system, encourage efficient resource consumption, and reduce negative environmental externalities. Both principles are associated with other principles, such as differentiating biological and technical materials, thinking in cascades, the waste hierarchy, and using renewable energy (EMF, n.d.-a, 2013; Kristensen & Mosgaard, 2020). Extending resource life, product longevity, dematerialisation, and the servitisation of products also encourage efficient resource consumption (EMF, 2013; Kristensen & Mosgaard, 2020; Pesce et al., 2020; Suárez-Eiroa et al., 2019). The third principle, regeneration, extends the CE concept beyond merely addressing negative environmental externalities to developing a regenerative system and building natural capital (EMF, 2013; Geisendorf & Pietrulla, 2018; Kirchherr et al., 2017; Morseletto, 2020b). A regenerative system calls for reducing resource extraction rates according to regeneration rates and ensuring system outputs returning to the Earth do not exceed absorption rates (Suárez-Eiroa et al., 2019; Velenturf & Purnell, 2021). Other principles identified by EMF include 'waste is food', building resilience through diversity, the product-service economy, and systems thinking (Antikainen et al., 2018; Cayzer et al., 2017; EMF, 2013, pp. 22–23; Homrich et al., 2018).

Design is a particularly crucial principle in avoiding or 'designing out' waste and pollution in the first instance (EMF, n.d.-a, 2013; Kalmykova et al., 2018; Kristensen & Mosgaard, 2020; Pesce et al., 2020). A broad range of eco-design and circular design strategies exist, many of which draw from a Design for X (DfX) context (Moreno et al., 2017; Shahbazi & Jönbrink, 2020). For example, *design for recyclability* or *design for disassembly* strategies can improve circularity throughout a product's lifecycle (Ghisellini et al., 2016). The European Union has demonstrated that incentivising or mandating circular design strategies through product policies supports CE implementation (Cordella et al., 2018; Talens Peiró et al., 2020; Tecchio et al., 2017).

Other principles are directed at supporting CE implementation. For instance, transitioning to a CE requires resource availability, resource traceability, digital technology, innovation, stewardship, collaboration, transparency, biomimicry, education, and circular business models (British Standards Institution [BSI], 2017; ISO, 2023b; Pesce et al., 2020; Suárez-Eiroa et al., 2019; Velenturf & Purnell, 2021). In addition, political-economic systems must strive for sustainable development instead of short-term economic growth (Velenturf & Purnell, 2021). Ultimately, scaling up green practices alone is insufficient. A CE calls for holistic, systemic change to production and consumption, requiring solutions at all life cycle stages and systems thinking across micro, meso, and macro systems (Ghisellini et al., 2016; Kirchherr et al., 2017). Figure 7 illustrates frequently cited principles.

Figure 7: *Key CE Principles*



Credit: Author's Own (British Standards Institution, 2017; Circle Economy, 2023; Ellen MacArthur Foundation, 2013, n.d.-a; Geisendorf & Pietrulla, 2018; Ghisellini et al., 2016; Homrich et al., 2018; Kalmykova et al., 2018; Kristensen & Mosgaard, 2020; Morseletto, 2020a; Nobre & Tavares, 2021; Pesce et al., 2020; Potting et al., 2017; Prieto-Sandoval et al., 2018; Suárez-Eiroa et al., 2019; Velenturf & Purnell, 2021)

2.4 Policy Context

Policy frameworks and instruments enable a CE by addressing barriers and encouraging circularity (Peck et al., 2020, p. 54). Governments also enable the conditions required for a CE to develop through top-down, bottom-up, and integrated approaches (Winans et al., 2017). Germany first incorporated the idea of closed materials loops into waste management policy in 1996, and Japan followed with the *Basic Law for Establishing a Recycling-Based Society* in 2002, which included quantitative recycling and dematerialisation targets (Antikainen et al., 2018; Geissdoerfer et al., 2017; Heshmati, 2017). However, China and Europe have the most influential and frequently cited examples of policies aimed at accelerating CE implementation (Domenech & Bahn-Walkowiak, 2019; Heshmati, 2017; McDowall et al., 2017; Murray et al., 2017; Zhao, 2020). China's 2009 *Circular Economy Promotion Law* was centred on the 3Rs to promote sustainable CE development and resource efficiency (Antikainen et al., 2018). The European Commission's 2015 *Circular Economy Action Plan* has implications for the B&C sector, including waste regulations, carbon reduction and material recovery targets, and introducing LCA in public procurement (WBCSD, 2020). National CE strategies and policy packages have also been introduced in numerous countries, such as Finland, Scotland, Denmark, the Netherlands, Japan, the United Kingdom, Portugal, Poland, Austria, Slovenia, Greece, France, South Korea, and Colombia (Antikainen et al., 2018; Fitch-Roy et al., 2021).

The most relevant legislative policy framework for the CE concept in Aotearoa New Zealand is the *Waste Minimisation Act 2008* (WMA). This is the national waste reduction legislation that directs priority products, product stewardship, the waste levy, responsibilities of territorial authorities and the development of Waste Management and Minimisation Plans (WMMPs), enforcement powers, reporting on waste minimisation, and the establishment of an independent waste advisory board. WMMPs must be aligned with the outcomes of Long Term Plans developed by territorial authorities under the Local Government Act 2002 (Palmerston North City Council, 2012). Territorial authorities must also ensure that waste is collected and disposed of for public health protection under the Health Act 1956. Additionally, waste minimisation activities and any associated resource consents must comply with the Resource Management Act 1991.

The WMA has narrow, vague, and often unexploited provisions for setting bans, permitting mandates and obligations, specifying circular design considerations, setting resource recovery standards for reuse, requiring product transparency, or the creative use of economic instruments (Blumhardt, 2023, pp. 24–57). In addition, the WMA does not contain targets or target-setting powers, and the *Consumer Guarantees Act 1993* should be amended to encourage product durability and the right-to-repair. It is expected that the WMA and the Litter Act 1979 will be replaced with new waste legislation in 2024 to deliver initiatives in the updated Waste Strategy and Emission Reduction Plan (MfE, 2023b). The new Act will improve certain pre-existing powers and introduce product regulation powers such as product bans, landfill bans, mandatory recycling, environmental performance standards, requirements to provide environmental performance information, and Extended Producer Responsibility (EPR).

New Zealand's ERP has dedicated a chapter to the CE and the bioeconomy. This is accompanied by the vision: "By 2050, Aotearoa New Zealand will have a circular economy with a thriving bioeconomy that seizes the opportunities from global trends and shifting consumer preferences" (MfE, 2022b, p. 157). A national CE and bioeconomy strategy is being developed over the first emissions budget period (2022–2025) to support this vision (MfE, 2022b, p. 161). This strategy will encourage the public sector to lead by example, identify how businesses will align with regulations, empower Māori to participate in and benefit from the CE transition, provide a bioeconomy framework, and outline the required skills, innovation, and investment. The ERP includes other relevant actions, such as integrating circular practices across businesses and supporting businesses to adopt CE models. The ERP also includes a B&C chapter that recognises the need to require waste minimisation plans in building consents, investigate barriers to reusing and recycling building materials, and explore CE initiatives for the sector. Another chapter on waste highlights the need to scope measures to reduce and divert C&D waste through the Building for

Climate Change Programme, invest in infrastructure to sort and process C&D waste, and introduce obligations to separate C&D waste.

Another vision for a CE is stated in New Zealand's Waste Strategy (NZWS:2023): "By 2050, Aotearoa New Zealand is a low-emissions, low-waste society, built upon a circular economy" (MfE, 2023a, p. 18). Based on several key points from the Waste Strategy, it can be inferred that companies in the B&C sector should:

- Contribute to 2030 targets on waste generation, waste disposal, and biogenic methane emissions and other future targets;
- Ensure by 2050 that products and systems are as circular as possible, do not pose harm to the environment, and if virgin resources are used, they are renewable and sustainably sourced;
- Apply the waste hierarchy to materials and products;
- Rethink and redesign processes, services, products, packaging, and business models;
- Extend the life of materials and products through durability, enabling easy and affordable repair, developing reuse systems, and supporting sharing and repurposing;
- Accept responsibility for the use, management, and disposal of their products;
- Establish data sources and set targets;
- Provide transparent data and consistently measure and report progress;
- Protect and regenerate nature by integrating regeneration into business models, opting for renewable resources, reducing GHG emissions throughout material lifecycles, replenishing natural resources, and repairing environmental damage;
- Ensure all outcomes are equitable and inclusive;
- Think across systems, places and generations;
- Promote significant behaviour change;
- Ensure sufficient infrastructure to manage C&D waste;
- Ensure new builds have adequate space for bins and collection vehicles;

- Abide by upcoming changes to waste legislation;
- Make products from a single material or allow easy separation of materials;
- Promote the development of supply chains for collecting and processing materials;
- Engage in product stewardship schemes;
- Consume less virgin resources, promote a market for recycled materials, and demand materials containing recycled content;
- Recycle organic waste and continue efforts to reduce timber waste, such as improved designs, avoiding surplus materials, minimising offcuts, renovating, refitting, refurbishing, and deconstruction;
- Avoid soil contamination or generating surplus soils, promote sustainable remediation, and recover and reuse soils moved off-site; and
- Collaborate with governments, community groups, and NGOs and develop networks with Australia and the Pacific (MfE, 2023a).

Additionally, New Zealand's Infrastructure Strategy incorporated a section on CE, which emphasised the importance of minimising C&D waste and reusing and recycling construction materials (New Zealand Infrastructure Commission, 2022). Other points emphasised include:

- Improving waste data;
- Increasing the waste disposal levy;
- Upgrading resource recovery infrastructure;
- Adhering to the waste hierarchy;
- Procurement specifications to prioritise products that are low-waste, prefabricated, and designed for deconstruction;
- Exploring resource exchange services;
- Utilising secondary materials and ensuring building-material regulations allow their use;
- Improving behaviours and avoiding contamination;
- Encouraging prefabrication and standardised products;

- Providing government guidance on waste to energy;
- Reducing landfill emissions from organic waste; and
- Requiring waste minimisation plans for all infrastructure projects (New Zealand Infrastructure Commission, 2022).

Requiring waste minimisation plans for building construction or demolition was included in the proposed climate change amendment to the Building Act 2004 (MBIE, 2022b, p. 9). The Building Act (2004) is also a relevant piece of legislation that refers to the efficient and sustainable use of building products and reducing waste generated during construction.

There are several concerns despite developments towards a CE. While it is positive that the CE agenda is not limited to a single ministry, it is dispersed across climate and waste portfolios as well as different government agencies with different interpretations and priorities (Blumhardt & Prince, 2022, p. 77). All involved entities must comprehensively understand CE theory to avoid diminished ambitions and ensure a unified stance. Another concern relates to the recent shift from a centre-left government (2017–2023) to a right-wing coalition government (2023–present). The current government's coalition agreements regarding environmental policies have been criticised for not reflecting the prevailing public sentiment and setting back environmental action by decades (Prickett & Hales, 2023; Wannan, 2023; White, 2023). Thus, such policies may exacerbate the already significant challenges in addressing environmental goals. Additionally, apprehensions regarding the progression of a CE can be framed within the context of actions taken, as well as the omissions of the previous centre-right government (2008–2017), which means New Zealand is now playing 'catch-up' (Hannon, 2018, p. 27). The 2010 Waste Strategy (NZWS:2010), which can be described as a "business-centric and risk-based approach", abandoned the prior objective of moving "towards zero waste and a sustainable New Zealand" promoted by the previous centre-left government (NZWS:2002) (Hannon, 2018, p. 27). Moreover, the CE agenda has already been subject to extensive lobbying efforts from vested interest industry groups regarding product stewardship (Hannon, 2018) and the now-abandoned Container Return Scheme (Espiner, 2023).

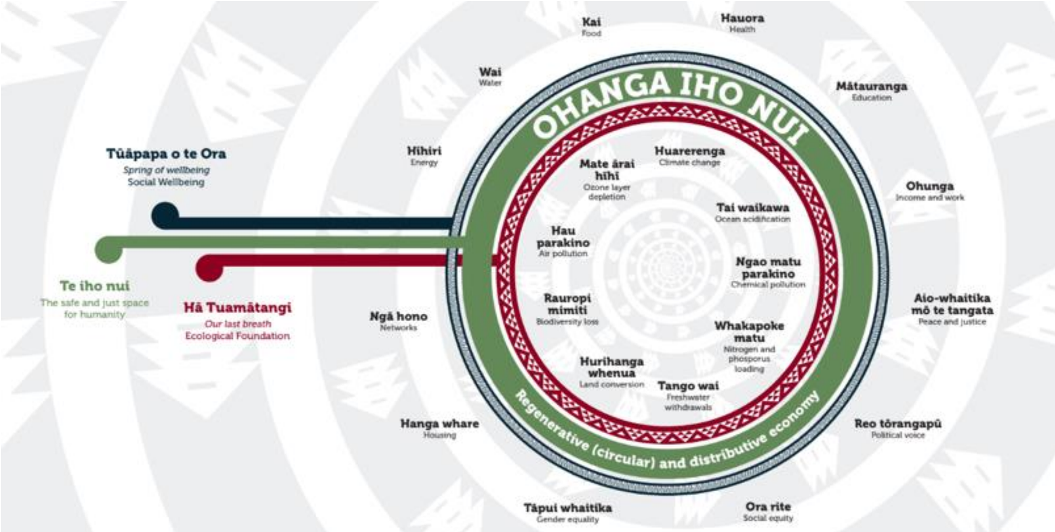
2.5 Incorporating Te Ao Māori

In the Aotearoa New Zealand context, te ao Māori, the Māori worldview, enriches our understanding of the CE concept, also referred to as ōhanga āmiomio (MfE, 2023a, p. 17). Circular principles and te ao Māori values both aim to regenerate nature and avoid waste generation. The Māori approach to waste predates the CE concept and carries the significance of whakapapa (genealogical linkages) between humans and the environment (Bianchi & Yates, 2022, p. 2). Such kinship with the land promotes recognition of the interconnectedness between all things and how humans impact that balance, respect for the mauri (life force or essence) and mana (supernatural force) within natural resources, and kaitiakitanga (guardianship) (MfE, 2023a, p. 17). Therefore, the value of items made from natural resources is maintained, and their disposal should be done in a manner that minimises harm to Papatūānuku (Earth mother) (Bianchi & Yates, 2022, pp. 2, 11).

Increasing social and cultural equity is a crucial CE principle in Aotearoa that encourages a holistic approach in alignment with te ao Māori and the SDGs (Bianchi & Yates, 2022, p. 5). This is reflected in the guiding principles of the 2023 Waste Strategy to develop a unique platform to drive transformation (MfE, 2023a, p. 19). Mātauranga Māori, Māori knowledge, can inform CE implementation and our relationship with the environment. However, there is a risk that indigenous concepts can be adopted without complete understanding. It is recommended that partnership and participation be incorporated as integral elements of the operating frameworks for CE initiatives sponsored by the Government, according to Te Tiriti o Waitangi principles (Bianchi & Yates, 2022, p. 2). It is also crucial to recognise Māori beliefs and practices in waste management practices to reflect Māori values adequately, acknowledge cultural traditions and customary practices, and uphold Treaty obligations (Pauling & Ataria, 2010).

The importance of an equitable and inclusive CE transition is evident in the Ohanga Iho Nui framework, a reimagined version of the Doughnut Economy model that aims to ensure that we thrive within planetary means (Shareef, 2020). This version is developed from a Tūhoe Māori perspective that values connection and balance with nature. The placement of social and environmental elements is reversed, with environmental elements placed inside the ‘doughnut’ to represent humanity’s dependence on the biosphere, or Ranginui and Papatūānuku (see Figure 8).

Figure 8: The Ohanga Iho Nui Framework (Shareef, 2020)



2.6 Conclusion

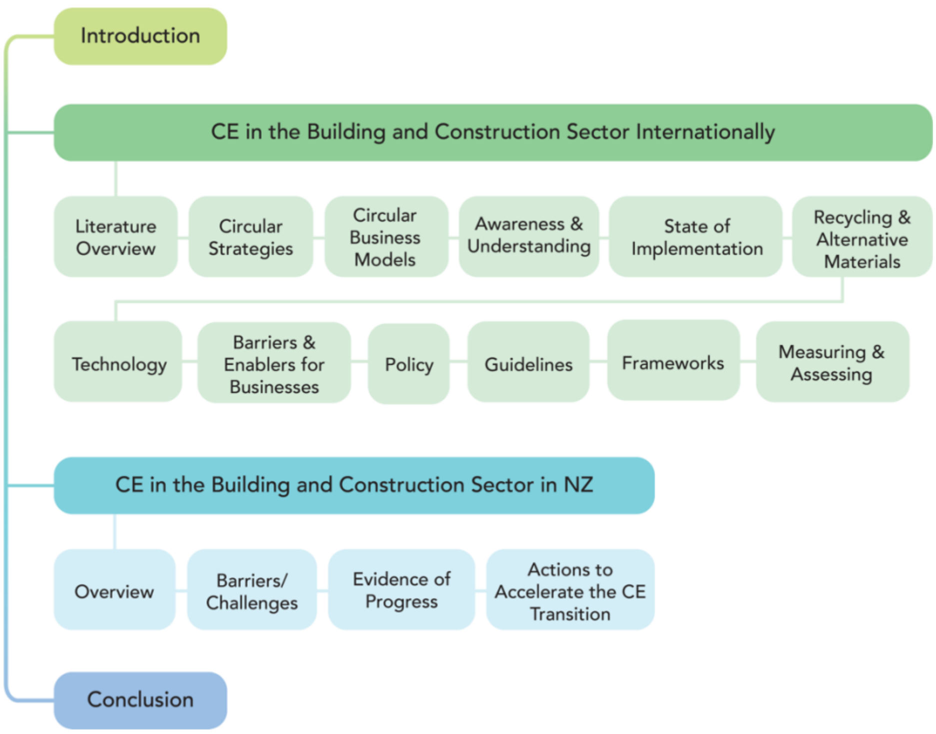
Circularity in nature and early societies had an extensive history prior to the emergence of the linear economy. The CE concept is multifaceted, with many definitions and underlying principles. The CE concept can also be considered an umbrella concept that incorporates aspects of related theories, such as servitisation associated with the performance economy and the C2C tenet of differentiating biological and technical materials. Despite conceptual complexity, it is clear that a CE aims to reduce resource consumption, extend and optimise the utilisation of materials, minimise waste and pollution throughout a product’s lifecycle, and regenerate nature. In Aotearoa New Zealand, potential upcoming waste legislation may introduce powers that have been adopted internationally to accelerate a CE transition. This new legislation, the Waste Strategy, and 2050 CE visions seek to drive a CE transition in New Zealand and its B&C sector. Progress against these visions can be informed and enriched with te ao Māori for a holistic transition. However, it is essential that Māori concepts are adopted according to Te Tiriti o Waitangi principles.

3. Literature Review

3.1 Introduction

This chapter reviews the literature on CE and the B&C sector to examine the key themes addressed in this research and explore how companies implement the CE concept. It is divided into two main sections, as shown in Figure 9. First, Section 3.2 reviews the literature on CE in the B&C sector internationally. It provides an overview of the literature before exploring circular strategies, business models, the state of awareness and implementation, recycling and alternative building materials, technologies, barriers and enablers, CE policy, guidelines, frameworks, and measuring and assessment. Section 3.3 then explores CE in the B&C sector in Aotearoa New Zealand, including barriers and challenges, evidence of progress, and actions to accelerate a CE transition.

Figure 9: *Literature Review Roadmap*



3.2 CE in the B&C Sector Internationally

3.2.1 Overview of the Literature

Review papers consistently report exponential growth in publications relating to the adoption of CE principles within the B&C sector, particularly in Europe, specifically in the United Kingdom, and China (Ababio & Lu, 2023; Akhimien et al., 2021; Benachio et al., 2020; Çimen, 2021; Hossain et al., 2020; Mhatre et al., 2021; Mrad & Frölén Ribeiro, 2022; Munaro et al., 2020; Norouzi et al., 2021; Osobajo et al., 2020; Rahla et al., 2021b). For example, according to Munaro et al. (2020), a significant majority (82%) of the articles under analysis were published within the preceding three years. Similarly, Çimen (2021) found that a substantial majority (90%) of relevant literature was published between 2017 and 2020. The rise in publications could be attributed to heightened industry awareness due to government promotion of the concept and EMF publications (Ababio & Lu, 2023). Additionally, the volume of publications in Europe and China could be attributed to CE policies and projects such as the Buildings as Material Banks (BAMB) event, which brought together partners from seven European countries to focus on circular solutions, including material passports and reversible building design (Benachio et al., 2020; Munaro et al., 2020; Rahla et al., 2021b).

Although there has been a recent increase in scholarly attention on CE and the B&C sector, it is important to note that the literature is still in its early stages (Çimen, 2021; Mrad & Frölén Ribeiro, 2022; Pomponi & Moncaster, 2017). The academic discourse on the subject has been described as fragmented and dispersed across various topics (Çimen, 2021; Munaro et al., 2020). Some notable themes in this literature include the barriers to implementation, alternative construction materials, tools and assessment, material stocks, CE in cities, green buildings, supply chains, sustainable development, renewable energy, energy efficiency, building information modelling (BIM), and LCA (Benachio et al., 2020; Çimen, 2021; Hossain et al., 2020; Mrad & Frölén Ribeiro, 2022; Munaro et al., 2020; Norouzi et al., 2021).

However, the topic most extensively covered in the literature concerns the end-of-life stage of buildings, specifically waste recycling, waste management, and reusing waste materials (Akhimien et al., 2021; Çimen, 2021; Hossain et al., 2020; Mhatre et al., 2021; Mrad & Frölén Ribeiro, 2022; Munaro et al., 2020; Norouzi et al., 2021; Osobajo et al., 2020). This is evidenced by Hossain et al. (2020), who found that 30% of publications focus on the end-of-life; Munaro et al. (2020), who found that 39% of publications concern recycled or reused materials; and Mrad and Frölén Ribeiro (2022) who found that 41% of publications promote recycling and reuse. Emphasis on recycling indicates that researchers and stakeholders are failing to grasp the essence of the CE and prioritise higher-value CE principles that reduce resource consumption and waste generation and maximise the value of resources (Çimen, 2021; Mrad & Frölén Ribeiro, 2022).

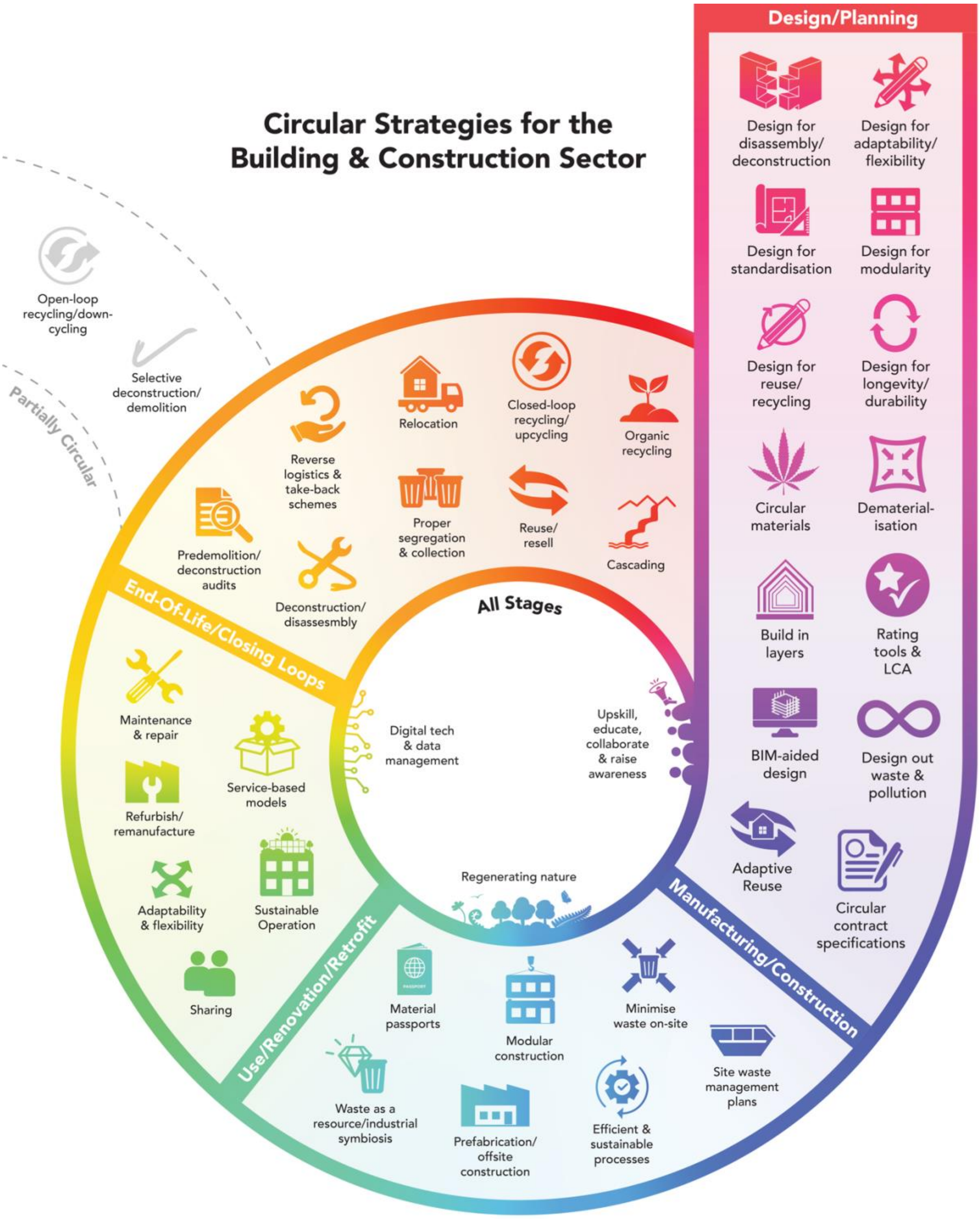
As studies tend to favour specific aspects of circularity, several areas have received less attention. These areas include the development and application of business models, the design stage, policy interventions, economic and social dimensions of sustainability, eco-efficiency indices, healthy and low-embodied energy materials, building optimisation and operation, standards for material reuse, material passports, stakeholder collaboration, and the modelling of cost reductions (Akhimien et al., 2021; Benachio et al., 2020; Çimen, 2021; Giorgi et al., 2022; Hossain et al., 2020; Mrad & Frölén Ribeiro, 2022; Osobajo et al., 2020). Furthermore, Pomponi and Moncaster (2017) point out that B&C impacts can be observed at the macro level (cities), meso level (buildings), and micro level (building products), with research neglecting the meso scale and potentially overlooking the impacts of buildings as a whole. In addition, comprehensive, systemic, and holistic studies on circularity in the built environment are lacking (Adams et al., 2017; Akhimien et al., 2021; Hossain et al., 2020). As sustainability and resource depletion concerns grow, research on this subject is anticipated to continue increasing and maturing (Ababio & Lu, 2023; Akhimien et al., 2021; Benachio et al., 2020; Norouzi et al., 2021).

3.2.2 Circular Strategies

Circular strategies, also referred to as principles (Mangialardo & Micelli, 2018), practices (Asante et al., 2022; Benachio et al., 2020; ISO, 2023c), and aspects (Adams et al., 2017), enable a CE transition by minimising resource consumption and waste generation, extending the life of materials, and closing material loops (Nußholz & Milios, 2017). The literature has identified numerous strategies B&C stakeholders can adopt to support a CE transition. For example, Charef et al. (2022) identified over 100 strategies. Circular strategies are often categorised into different life cycle stages (Akhimien et al., 2021; Benachio et al., 2020; Charef et al., 2022; Guerra et al., 2021; Guerra & Leite, 2021; Lee et al., 2023; López Ruiz et al., 2020; Nußholz & Milios, 2017; Rahla et al., 2021a; Sharma et al., 2022). Frequently cited circular strategies were consolidated and categorised into design and planning, manufacturing/construction, use/renovation/retrofit, end-of-life/closing loops, and all stages (see Figure 10).

Design and planning is a particularly critical life cycle phase, as initial decisions significantly determine resource consumption, environmental impacts, waste, pollution, and reuse potential (Kanters, 2020; Sharma et al., 2022). Over 80% of a product's environmental impact is determined at the design stage (European Commission, Directorate-General for Energy, Directorate-General for Enterprise and Industry, 2012, p. 3). DfX strategies, such as design for disassembly/deconstruction and design for adaptability/flexibility, encourage circular and eco-design (Antwi-Afari et al., 2022). When components and building structures are designed for disassembly or deconstruction, they easily disassemble from other components to avoid demolition and subsequent landfilling (Eberhardt et al., 2022; Minunno et al., 2018; Zaman et al., 2023). Connections must be easily accessible and reversible without nails and chemical adhesives, allowing for maintenance, adaptability, recovery, and reuse without damage or contamination. When components and building structures are designed for adaptability and flexibility, different user needs are accommodated by enabling modifications and alterations to maximise utilisation and extend the lifespan (Eberhardt et al., 2022; Guerra & Leite, 2021; Zaman et al., 2023). For example, standard tools could be used, or the building envelope could be designed to enable changes to window sizes (Zaman et al., 2023).

Figure 10: *Major Circular Strategies for the B&C Sector According to Life Cycle Phases*



Credit: Author's Own (Adams et al., 2017; Adi & Wibowo, 2020; Akhimien et al., 2021; Antwi-Afari et al., 2022; Arup & EMF, n.d.; Asante et al., 2022; Benachio et al., 2020; Charef et al., 2022; Cohen et al., 2022; Dewagoda et al., 2022; Eberhardt et al., 2022; Gerding et al., 2021; Ghaffar et al., 2020; Giorgi et al., 2022; Guerra & Leite, 2021; Guerra et al., 2021; ISO, 2023c; Kanters, 2020; Kyrö et al., 2019; Lee et al., 2023; López Ruiz et al., 2020; Mangialardo & Micelli, 2018; Mhatre et al., 2021; Minunno et al., 2018; Ness & Xing, 2017; Nußholz & Milios, 2017; Rahla et al., 2021a, 2021b; Sharma et al., 2022; Shooshtarian et al., 2021, 2022; WGBC, 2023; Zaman et al., 2023)

Other DfX strategies include design for standardisation, modularity, and longevity/durability. The standardisation of components and building structures, for example, through standardised uniform dimensions, streamlines production, avoids offcuts, increases compatibility with other components, and simplifies assembly, disassembly, sorting, and reuse (Eberhardt et al., 2022; Guerra & Leite, 2021). Modular building components and building structures that are designed to function both independently and as a part of a modular system simplify the building process, enhance adaptability, and enable repair or replacement without addressing the entire system (Eberhardt et al., 2022; Guerra & Leite, 2021; Guerra et al., 2021). Design for longevity/durability ensures that components and building structures are designed with high-quality and durable materials and are easy to protect, maintain, refurbish, and replace (Eberhardt et al., 2022; Zaman et al., 2023).

Several other strategies for the design and planning phase exist in the literature. Designing out waste is critical to minimising waste generation throughout the life cycle through offsite construction, appropriate materials, and optimising material use (Guerra & Leite, 2021). Any pollutants and hazardous materials to humans and natural systems should be eliminated (Zaman et al., 2023). Dematerialisation also involves optimising material use and reducing the number of material types and the amount of resource inputs and outputs (Eberhardt et al., 2022; Zaman et al., 2023). Any unnecessary construction and components are refused (Arup & EMF, n.d.). Where materials are used, circular materials should be specified and sourced (i.e., materials that are reclaimed or contain recycled content, renewable, durable, sustainable, low carbon, easily disassembled, locally sourced, non-toxic/hazardous, free of glues and contaminants, and can be returned to biological or technical cycles at the highest possible value) (Charef et al., 2022; Kanters, 2020; Sharma et al., 2022; Rahla et al., 2021a; Eberhardt et al., 2022).

Other circular requirements, such as waste management plans, procurement criteria, deconstruction, and material recovery, can be specified within the contract (Asante et al., 2022; Sharma et al., 2022; WGBC, 2023). BIM can guide the building design, model disassembly, and track the material's location (Minunno et al., 2018). Improvements can also be made to materials, components, and buildings based on LCA information and sustainability rating tools (Shooshtarian et al., 2022). Furthermore, different layers can be identified in a building according to their lifespans (i.e., site, structure (60-200 years), skin (30-60 years), services (5-30 years), space plan (5-20 years), and stuff (5-15 years) (Kanters, 2020). Building in layers, or ensuring the independence of components and materials with different lifetimes, allows for ease of maintenance, adaptability, deconstruction, and material recovery.

During the manufacturing and construction phases, minimising waste onsite is an important strategy that can be achieved by opting for offsite construction, following design plans closely, providing enough space and bins for different waste streams, and collaborating with others that will utilise the waste as a resource (Zaman et al., 2023). Waste as a resource or industrial symbiosis involves collaboration between different stakeholders or organisations to use secondary materials, waste, and by-products in producing building materials or in the construction process (ISO, 2023c, p. 30). Prefabrication or offsite construction of building structures and components in a factory creates less waste and offcuts, enhances modularity and disassembly, and improves end-of-life options (Eberhardt et al., 2022; Minunno et al., 2018). Similarly, construction with modular components allows for ease of building, adaptability, and recovery (Eberhardt et al., 2022).

Efficient and sustainable manufacturing and construction processes can be adopted to consume fewer materials, water, and energy and generate less waste and emissions (Guerra et al., 2021). Site waste management plans are also useful in minimising and managing materials during construction, renovation, and demolition (López Ruiz et al., 2020). Building material passports can also be developed at the construction stage to store information on materials and components, including material properties, maintenance history, end-of-life options, quantity, location, and environmental profile, such as Environmental Product Declaration (EPD) information (Benachio et al., 2020; Giorgi et al., 2022).

At the use/renovation/retrofit phase, it becomes evident that design decisions that consider factors such as energy efficiency, renewable energy, water circularity, and waste generation are important to reduce the environmental footprint throughout the building's use (Lee et al., 2023; Rahla et al., 2021a). In addition, adaptability and flexibility encourage continued use (Charef et al., 2022; Rahla et al., 2021a). Instead of product ownership, the performance of products or assets may be offered as a service through service-based models, such as product-service systems, leasing, renting, buy-back, and pay-per-use, to maximise product utilisation and encourage dematerialisation (Giorgi et al., 2022; ISO, 2023c, p. 31). Manufacturers retain ownership and responsibility for upkeep and the end of life. Similarly, other building products, resources, and services may be sourced by sharing with others, often through digital platforms, to maximise utilisation and encourage dematerialisation by reducing the number of products that need to be produced (ISO, 2023c, p. 32; Mhatre et al., 2021). Maintenance and repair can be undertaken throughout the use phase of materials, products, and buildings to restore their original function and extend their lifespan (ISO, 2023c, p. 31; Rahla et al., 2021b). Refurbishment can be undertaken to restore a product according to manufacturer safety and performance specifications, while remanufacturing can be undertaken to renew the expected product lifetime once used products go through an industrial process according to the original or modified product specifications (ISO, 2023c, pp. 32–33).

At the end-of-life phase, a pre-demolition audit can be carried out to identify the material types, locations, volumes, recoverability, reuse/recycling potential, and the presence of hazardous materials to minimise waste and maximise material recovery (López Ruiz et al., 2020; Sharma et al., 2022). Components and building structures are then ideally deconstructed to recover materials for reuse or recycling instead of conventional demolition (Charef et al., 2022; Guerra & Leite, 2021). Selective deconstruction or demolition, involving the removal of hazardous materials and recoverable materials before demolishing the remaining structure, is less ideal (Guerra & Leite, 2021; López Ruiz et al., 2020). Proper handling, segregation, and collection of materials are crucial to prevent contamination, preferably onsite, before being sent to the appropriate facilities (López Ruiz et al., 2020; Sharma et al., 2022). If products are associated with product-service systems and EPR or product stewardship schemes, producers are responsible for product take-back and transport (reverse logistics) (Charef et al., 2022; Sharma et al., 2022). Take-back systems incentivise manufacturers to redesign their products and encourage source separation and higher-quality waste streams (Bendix et al., 2022).

Strategies involving end-of-life pathways for materials include reuse, closed-loop recycling, open-loop recycling, cascading, and organic recycling. Products and materials may be reused in other infrastructure, avoiding resource consumption and emissions associated with new products (Eberhardt et al., 2022; Zaman et al., 2023). Reuse can also involve adaptive reuse or repurposing an existing building to maximise utilisation and avoid obsolescence (Charef et al., 2022; Sharma et al., 2022). Similarly, relocating an entire house or structure extends the period of utilisation (Kyrö et al., 2019). Closed-loop recycling (upcycling) involves transforming used products, ensuring the material is used for the same purpose and kept at the same quality or higher (Charef et al., 2022; Guerra & Leite, 2021). On the other hand, open-loop recycling (downcycling) involves transforming used products or materials into a different and typically lower-value product, for example, crushed waste concrete for roadbeds (Guerra & Leite, 2021). Cascading entails using resources as inputs in a different value stream, creating new value networks (ISO, 2023c, p. 33). Cascading often refers to the biological cycle; for example, waste cotton t-shirts are used as furniture stuffing and later as insulation (EMF, 2013, p. 33). Biodegradability and organic recycling are other strategies for using bio-based materials and closing biological loops (Rahla, 2021b).

Some strategies are relevant at all stages of the lifecycle. Stakeholder collaboration, partnerships, networking, raising awareness, training, and educating stakeholders and clients are critical CE enablers (ISO, 2023c, p. 36). Regeneration, or the active application of measures that protect and regenerate natural systems, is a crucial CE principle (Zaman et al., 2023). Regeneration involves sequestering carbon, building biodiversity, and improving air, soil, and water quality through practices such as incorporating green spaces, implementing nature-based solutions and biomimicry, soil remediation, financing conservation initiatives, adopting a net zero water approach, and selecting regenerative materials that support biological diversity (ISO, 2023c, p. 35; WGBC, 2023, pp. 58–63; Zaman et al., 2023). The use of digital technologies and data management can be used throughout the life cycle to store, share, and manage data; create trackability systems to source materials for reuse; monitor building operations; and identify maintenance requirements (Benachio et al., 2020; Rahla et al., 2021a; Sharma et al., 2022). More details on technologies are provided in Section 3.2.7.

It is worth noting that while some research has demonstrated the environmental advantages of circular strategies, buildings are complex, and analysing their environmental performance is challenging due to variations in material composition and building design (Eberhardt et al., 2022). Moreover, circular strategies do not always equally contribute to core CE principles or actions, particularly the regeneration of natural systems (ISO, 2023c; Zaman et al., 2023). Similarly, circular strategies do not equally contribute to EMF's ReSOLVE framework, which sets out the six actions: (1) regenerate, (2) share, (3) optimise, (4) loop, (5) virtualise, and (6) exchange (Dewagoda et al., 2022; Lee et al., 2023). Çimen (2021) recommends a dynamic approach that embraces adaptive solutions and prioritises circular strategies according to the specific situation. Nonetheless, R-imperatives, such as the aforementioned 9Rs, indicate the actions that the authors believe should be prioritised (Çimen, 2021; Muñoz et al., 2023; Rahla et al., 2021a).

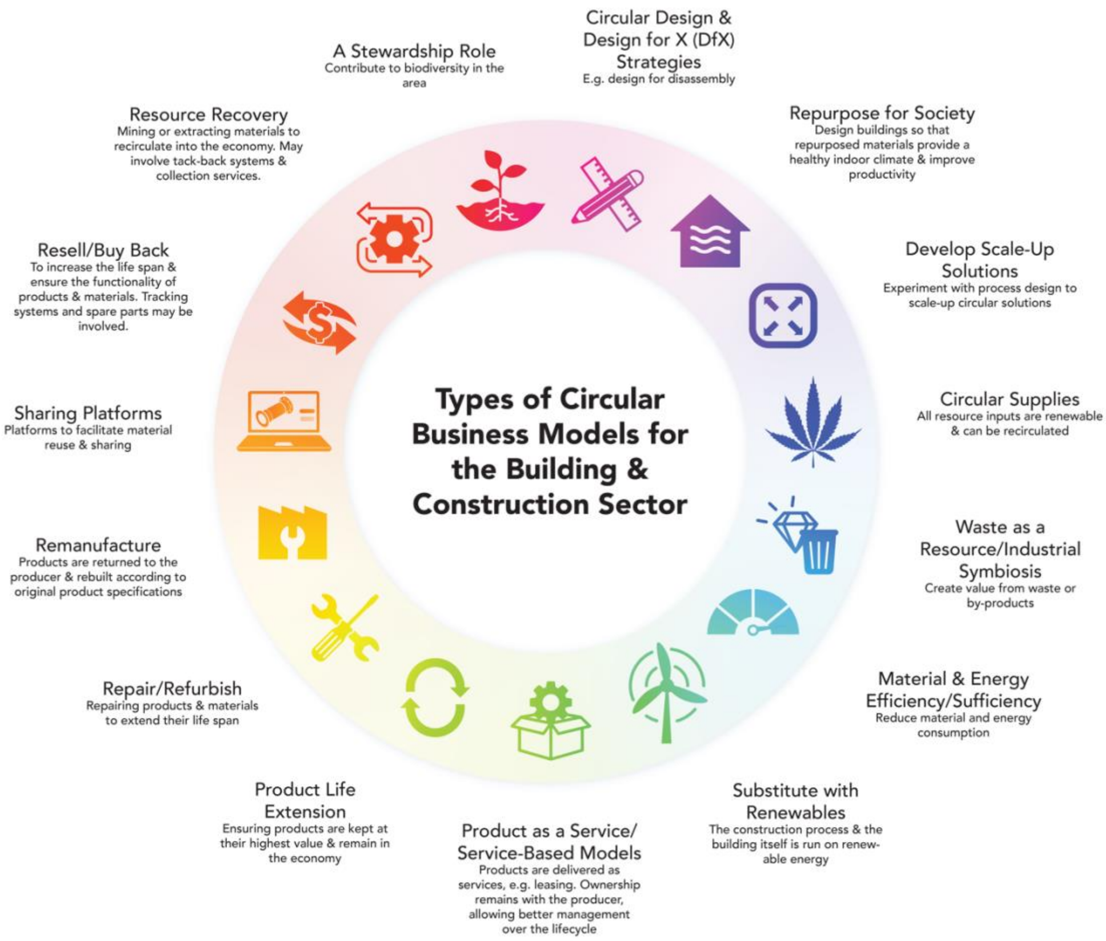
3.2.3 Circular Business Models

A circular business model (CBM) describes the business logic for creating, delivering, and capturing value in alignment with CE principles to ultimately slow, close, and narrow resource loops (Tuladhar et al., 2022; Ünal et al., 2019). Redesigning effective business models is essential to enable a business to engage in CE practices and initiate a CE transition in the B&C sector (Guerra et al., 2021; Leising et al., 2018). According to Nußholz and Milios (2017), when B&C companies adapt their business models to incorporate circularity, they tend to implement more circular strategies and maintain the value of resources. Effectively closing the loop for the long term through CBMs requires ongoing learning, creating a shared vision, collaboration, and realising CBMs and design activities (Khitous et al., 2022). Other valuable practices for shifting to a CE involve utilising recovery processes and technologies, focusing on customer segments that value products with reduced environmental impacts, developing partnership networks, and remaining flexible in the approach taken (Nußholz et al., 2019; Nußholz & Milios, 2017; Ünal et al., 2019).

CBMs can be categorised in various ways. Carra and Magdani (n.d.) categorise CBMs into three categories, depending on the lifecycle stage in which they are implemented: (1) circular design, (2) circular use, and (3) circular recovery (p. 21). Tuladhar et al. (2022) categorise CBM literature into CBM canvases and EMF's ReSOLVE framework. Any other models are referred to as 'hybrid models'. Examples of business model canvases include the BECE framework, C3 Business model canvas, and Value Hill (Shooshtarian, Hosseini, et al., 2021, p. 13). In addition, Nußholz and Milios (2017) examined the adoption of CBMs in six construction companies in terms of producing construction materials, for example, designing for long-life, recycling, and utilising secondary materials; designing buildings; and end-of-life management, for example, disassembly and reuse. Furthermore, Dewagoda et al. (2022) categorised CBMs into circular contract models requiring circular practices in contracts, circular procurement models encouraging the use of circular materials and technologies, and service-based models. Górecki et al. (2019) also differentiated CBMs as those related to the general contractor, real estate development, and integrated supply chain for project management. Several types of business models and CBM innovations exist, as outlined in Figure 11.

While there is a growing trend to explore CBMs for the built environment (Munaro et al., 2020; Norouzi et al., 2021), a lack of suitable business models is cited as an issue (Benachio et al., 2020; Giorgi et al., 2022; Hossain et al., 2020). In addition, the implementation of service-based and material-reuse models remains limited in practice (Giorgi et al., 2022; Leising et al., 2018; Nußholz et al., 2019). Most businesses operating in the built environment are not open to implementing CBMs due to concerns over insufficient investment returns and difficulties estimating profits (Mhatre et al., 2023). Further investigation into the resources and technologies required is needed to encourage companies to adopt CBMs.

Figure 11: *Types of CBMs for the B&C sector*



Credit: Author's Own (Carra & Magdani, n.d.; Giorgi et al., 2022; Guerra et al., 2021; Leising et al., 2018; Mhatre et al., 2023; Ünal et al., 2019; WBCSD, 2018, pp.10–11)

3.2.4 Awareness and Understanding of the CE Concept

Several studies have assessed B&C stakeholders' awareness and understanding of the CE concept in different countries. For example, Lee et al. (2023) found that awareness is generally lacking among executives of construction companies in Taiwan. However, senior employees and small companies demonstrated higher levels of awareness. In the United States, Guerra and Leite (2021) found that awareness of circular strategies is highest among project managers, while designers/architects and 'others' demonstrated the least awareness. Similarly, Adams et al. (2017) found that designers, clients, and subcontractors in the United Kingdom possess little knowledge of adopting CE principles, whereas manufacturers and main contractors had higher levels of awareness. Another study in the United Kingdom found that only 15% of respondents were aware of closed-loop construction and CE concepts, while 100% agreed that closed-loop construction is not promoted enough (Ghaffar et al., 2020).

Studies also uncovered a lack of knowledge of what the CE concept encompasses and its benefits. Adams et al. (2017) also found that awareness and understanding are lacking among organisations and across the industry as a whole. A more complete understanding is hindered by ambiguity on what a CE encompasses, its benefits, and the differentiation of related terms such as reuse and recycling. A survey of construction practitioners in Indonesia (Adi & Wibowo, 2020) and construction industry consumers in Poland (Tomaszewska, 2020) also identified a need for education and transparent demonstration of the benefits of a CE. In addition, Bertozzi (2022) also acknowledged that construction stakeholders in Brussels lack knowledge of what the CE encompasses, including confusion with other sustainability concepts, such as energy efficiency. This is despite 98% of stakeholders having some understanding of CE principles and 43% having a clear understanding.

A couple of scholars identified moderate levels of awareness. Bilal et al. (2020) found that most individuals in the building sector in developing countries had some level of awareness, with 40% of respondents recording a moderate understanding of the CE concept. However, nearly 30% had no understanding, and 31% had a slight understanding. In Ghana, professionals working in the built environment were also moderately aware of CE principles (Amudjie et al., 2022). However, Asante et al. (2022) argue that a lack of knowledge of the CE concept in Ghana negatively impacts environmental performance. Similarly, knowledge and awareness of the concept were considered primitive in Sri Lanka (Wijewansha et al., 2021). Overall, it is clear that awareness and understanding of the CE concept in the sector internationally need to be improved for the scale of the transition required.

3.2.5 State of CE Implementation

Effective CE implementation in the B&C sector is still in its infancy (Akhimien et al., 2021). The construction industry has generally struggled to adopt circular practices, which are being introduced slowly due to a lack of understanding of applying CE principles in construction (Benachio et al., 2020; Çimen, 2021; Munaro et al., 2020). A global scan of CE adoption in the construction sector revealed that while companies are beginning to adopt circular principles, early adopters must pursue unexplored opportunities to improve circularity (Guerra et al., 2021). Newer and smaller companies are leading the transition, with limited examples of larger companies implementing CE principles despite more established companies having better access to resources. Additionally, in Taiwan, stakeholders from small companies exhibit greater awareness of the importance of circular strategies (Lee et al., 2023). In contrast, medium- and large-sized companies tend to be more conservative, preferring tried-and-tested strategies that are straightforward to implement.

Several scholars have surveyed professionals in the B&C sector to build a picture of CE implementation in specific countries (Adi & Wibowo, 2020; Amudjie et al., 2022; Bilal et al., 2020; Cohen et al., 2022; Guerra & Leite, 2021; Lee et al., 2023). For example, Guerra and Leite (2021) found that in the United States, specifying reusable and recyclable materials, prefabrication, and design for prefabrication were the most adopted circular strategies among designers and architects, while design in layers and design for disassembly were the least adopted. Among construction professionals, selective demolition was the most adopted, and closed-loop recycling was the least adopted. Interviews also revealed that open-loop recycling is commonly practised. In Taiwan, Lee et al. (2023) discovered that while some circular strategies, such as equipment maintenance and management, received attention from construction companies, most circular strategies received low adoption, particularly aquaponics system design.

There are also examples of CE implementation in emerging economies. For example, Bilal et al. (2020) found that the implementation of CE indicators in 16 developing countries is unsatisfactory, with an average score of 2.9 out of 5.0 or 58%. Energy indicators received the most attention, while waste and 3R indicators were neglected. Similarly, in Ghana, Amudjie et al. (2022)

found that the practice of repair/remanufacture and reuse was moderate among built environment professionals. However, the practice of reduce, recycle/recover, redesign, and renewable energy usage was considered inadequate. In Indonesia, Adi and Wibowo (2020) considered the implementation of CE aspects to be low and insignificant, with respondents indicating an average of 3.5 out of 5.0 for the implementation of 12 CE aspects. The use of secondary materials and designing out waste were least implemented, and reuse and design for standardisation and modularity were most implemented. Cohen et al. (2022) found that most C&D firms are in the early stages of adopting CE strategies in Argentina. The most implemented strategies were durable materials and designing out waste. Conversely, material passports, industrial symbiosis, and designing for disassembly were the least implemented. Further studies have indicated that implementing a CE or addressing C&D waste is a considerable challenge in advanced and emerging economies alike, including in India (Sharma et al., 2022), Malaysia (Esa et al., 2017), Santiago de Cali in Columbia (Maury-Ramírez et al., 2022), Nordic Countries (Høibye & Sand, 2018), Serbia (Petrovic et al., 2022), and Australia (Shooshtarian et al., 2022).

Several studies indicate that circular strategies are not widely adopted and are often applied to only specific projects or life cycle stages (Adams et al., 2017; Benachio et al., 2020; Guerra et al., 2021; Guerra & Leite, 2021). In addition, businesses tend to implement circular strategies alone in silos, with limited collaboration with other stakeholders (Guerra et al., 2021). As a result, the adoption of circular strategies tends to be unbalanced, fragmented, uncoordinated (Eberhardt et al., 2022; Giorgi et al., 2022), and lacking holistic and systemic application (Akhimien et al., 2021). For example, a study of two large contracting companies in Denmark and Sweden revealed that circular principles are implemented through specific applications in a 'somewhat hesitant' manner rather than integrated into a programme-wide approach (Buser et al., 2021). Likewise, in Sri Lanka, the implementation of circular principles is selective and ad hoc (Wijewansha et al., 2021). Scholars also observed that specific strategies, namely open-loop recycling, are 'low-hanging fruit' and more frequently adopted (Akhimien et al., 2021; Guerra et al., 2021; Guerra & Leite, 2021; Rahla et al., 2021b). This is despite other circular strategies, such as modular building and design for disassembly, being more likely to reduce the overall environmental footprint than recycling (Minunno et al., 2020).

Several papers that have explored CE implementation indicated that the implementation of circular strategies requires greater focus on the early stages of the life cycle (Asante et al., 2022; Bilal et al., 2020; Gerding et al., 2021; Wijewansha et al., 2021). For example, Gerding et al. (2021) examined the construction process in the Netherlands and emphasised the importance of early decision-making in the pre-construction stage, particularly regarding material and energy efficiency, dematerialisation, product-as-a-service, extending product and resource value, and industrial symbiosis. Asante et al. (2022) found that firms in emerging economies must focus on reduce and recover principles by implementing circular strategies in the design stage, such as design to improve energy efficiency, design to increase lifespan, design for disassembly, and standardisation of designs. A lack of focus on the design stage is further corroborated by Bilal et al. (2020), who found that designing in accordance with CE principles received poor results from respondents. The authors attributed this to the novelty of the CE concept. All stakeholders in the sector must undertake significant measures to enhance the uptake of CE principles at all life cycle phases to attain a more circular and sustainable sector (Bilal et al., 2020; Munaro et al., 2020).

3.2.6 Recycling and Alternative Building Materials

Recycling C&D waste is crucial for minimising resource consumption and waste generation (Oluleye et al., 2022). However, recycling can be a low-value, tedious, and costly CE strategy that destroys a product’s integrity, creates adverse environmental impacts, compromises material quality, results in material losses, and makes only marginal adjustments to the linear approach instead of driving substantial systemic change (Kirchherr et al., 2017; Morseletto, 2020b; Oluleye et al., 2022). Despite being the most prevalent CE strategy in the sector, recycling rates remain low due to inadequate infrastructure and incentives, high costs, obstructive codes and regulations, management challenges, undesirable economic conditions, and intrinsic properties of resources.

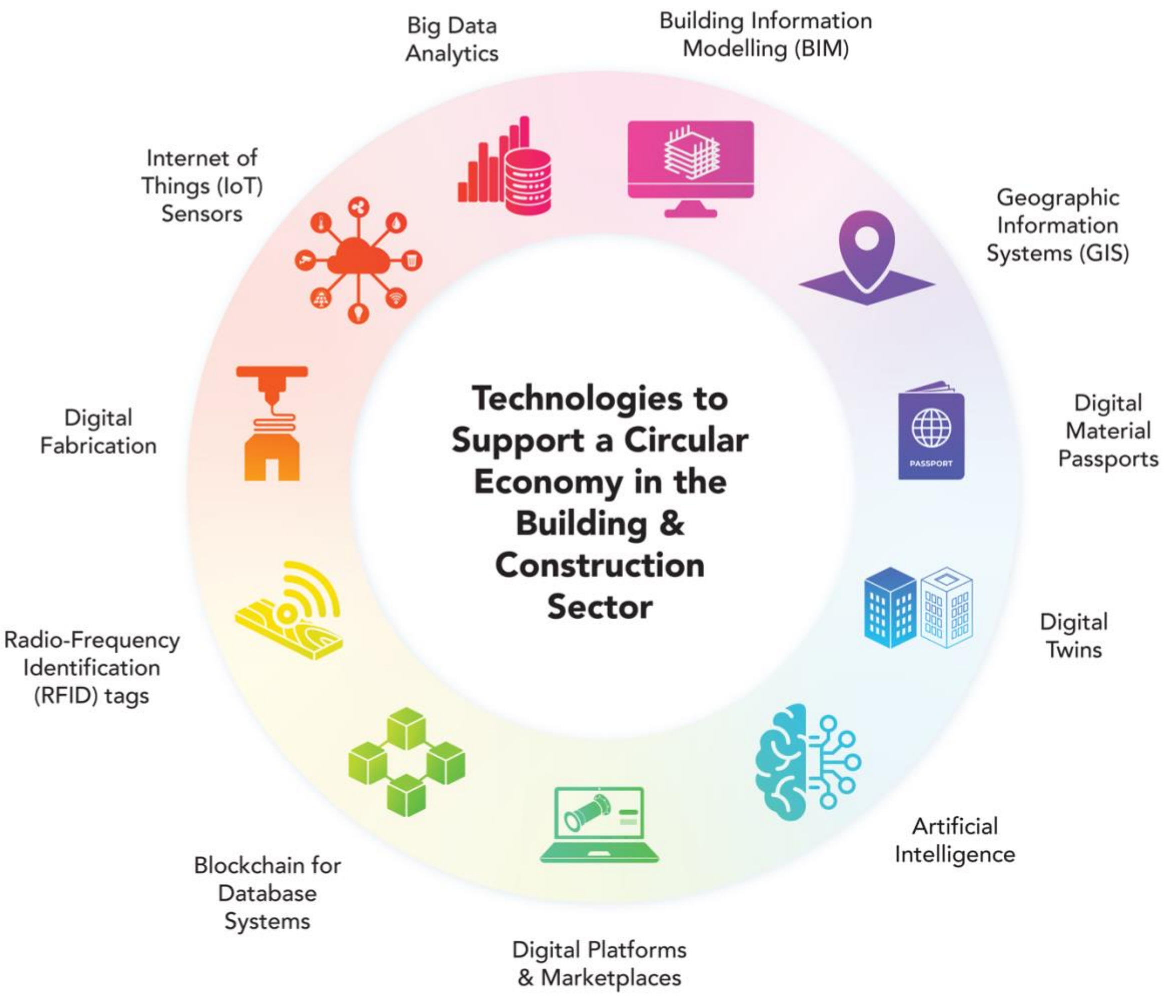
Moreover, recycled and alternative materials are not widely used due to the perception that they have reduced mechanical properties despite their potential for superior results and cost reductions (Oluleye et al., 2022). Product certifications, standards, and end-user guidance for recycled C&D material streams will be helpful in overcoming these barriers (Ghisellini et al., 2022). C&D waste management can also be improved by controlling the source of waste, for example, with green construction agreements, effective CBMs, innovative technologies, economic incentives, and a top-down regulatory approach with monitoring and enforcement (Huang et al., 2018).

Lee (2020) predicts that the quantity of recycled green building materials will increase substantially by 2030. Many opportunities exist to integrate alternative materials, waste, and by-products into B&C products. Some examples of these materials include recycled aggregate (González et al., 2021; Pani et al., 2021; Silva et al., 2019); recycled and natural fibre-reinforced concrete (Merli et al., 2020); wood waste (Jahan et al., 2022); mortar from used foundry sand (Bergonzoni et al., 2021); earthen, animal, and plant materials (Pearlmutter et al., 2019); waste bricks (Fořt & Černý, 2020); plastic sand bricks (Al-Sinan & Bubshait, 2022); and silica fume, metakaolin, slag and ash, mine tailings, sewage sludge, ceramic waste, tyres, glass, and plastics (Çimen, 2021; Ferdous et al., 2021; Nodehi & Taghvaee, 2022). However, it is crucial to consider whether mixing materials creates unintended consequences that undermine closed-loop systems, such as limiting further reuse and recycling. To date, the focus on recyclability and using recycled products has not yielded significant advancement in facilitating a transformative shift to a CE (Rahla et al., 2021b).

3.2.7 Technologies

Several researchers have explored the intersection between Industry 4.0 or the Fourth Industrial Revolution and information technologies with a CE in the built environment (e.g., Çetin et al., 2021; Copeland & Bilec, 2020; Elghaish et al., 2022; Windapo & Moghayedi, 2020; Yu, Yazan, et al., 2022). While not widely adopted, several technologies are promising, if not critical, in supporting a CE transition by providing digitised information to guide product management throughout the life cycle (Yu, Yazan, et al., 2022; see Figure 12). For example, BIM has been embraced for enabling various parties to collaborate on the design and development of building plans through a parametric model (Akanbi et al., 2018; Akinade & Oyedele, 2019). While it is uncommon for BIM to be used for CE adoption, BIM has the potential to identify material flows throughout the building life cycle, link environmental information, provide end-of-life models, simulate deconstruction processes, estimate the salvageability of building elements, and aid urban mining (Akanbi et al.,2018; Charef, 2022; Charef & Emmitt, 2021; Xue et al., 2021). Geographic Information Systems can have a similar role to BIM in helping manage building materials to determine reusability and recyclability for urban mining (Çetin et al., 2021).

Figure 12: *Technologies That Support CE in the B&C Sector*



Credit: Author's Own (Akanbi et al., 2018; Akinade & Oyedele, 2019; Çetin et al., 2021; Charef, 2022; Charef & Emmitt, 2021; Chen & Huang, 2020; Copeland & Bilec, 2020; Elghaish et al., 2022; Giorgi et al., 2022; Shojaei et al., 2021; Windapo & Moghayedi, 2020; Xue et al., 2021; Yu et al., 2022b)

Material passports and databanks containing information on a materials' composition, location, and ownership history can be integrated into BIM to inform reuse and recovery at the building's end-of-life (Çetin et al., 2021; Charef & Emmitt, 2021; Giorgi et al., 2022). Alternatively, material passports can be connected with digital twins, a digital model of the building or product (Çetin et al., 2021). This virtual 'twin' is combined with wireless sensor networks, the Internet of Things (IoT), AI, and data analytics to update the model according to the physical asset (Chen & Huang, 2020; Elghaish et al., 2022). Therefore, these technologies can support decision-making, predict when maintenance is required, and assist reuse and remanufacturing of components (Çetin et al., 2021; Elghaish et al., 2022; Yu, Yazan, et al., 2022).

Database systems also have a role in realising closed loops (Shojaei et al., 2021). Blockchain provides a transparent and secure decentralised ledger system to record transactions, trace materials and products, and store product information such as the materials and energy used, life-cycle data, and ownership history. This facilitates the exchange of materials and guides planning for reusing and recycling construction materials and products, thus enabling a CE. In addition, blockchain can be integrated with BIM and Radio Frequency Identification (RFID) tags to track materials (Copeland & Bilec, 2020; Yu, Yazan, et al., 2022). Digital platforms and marketplaces for construction materials are also essential databases for a sharing economy (Çetin et al., 2021).

AI, big data analytics, and digital fabrication methods, such as additive manufacturing (3D printing) and robotic manufacturing, also have the potential to enable a CE (Çetin et al., 2021). Additive manufacturing is a material-efficient method of constructing tailored building components that allow the reuse of other building elements and can utilise bio-based or waste materials. Robotic manufacturing can be employed both in manufacturing and deconstructing a building. AI can be utilised to suggest building design solutions, predict resource requirements, identify system failures, sort waste materials, identify the composition of aggregates, and estimate the salvageability of materials prior to deconstruction (Çetin et al., 2021; Elghaish et al., 2022). The construction sector should also profit from big data analytics to manage large datasets, such as data collected over an asset's life cycle with BIM and IoT sensors (Çetin et al., 2021; Yu, Yazan, et al., 2022). Elghaish et al. (2022) recommend integrating a combination of technologies, for example, blockchain, BIM, and IoT. However, it is noted that their effectiveness depends on a wider digital ecosystem and the need for further applied research.

3.2.8 Barriers and Enablers for Businesses

Numerous articles on CE in the B&C sector identify an extensive number of barriers to implementation (e.g., Ababio & Lu, 2023; Adams et al., 2017; Bilal et al., 2020; Charef et al., 2021; Hart et al., 2019; Liu et al., 2021; Mahpour, 2018; Mhatre et al., 2023; Oluleye, Chan, Olawumi, et al., 2023; Wuni, 2022b). For instance, Bilal et al. (2020) identified 79 barriers in the literature, noting that most barriers stem from regulatory barriers or insufficient supporting regulations. Examples of regulatory barriers include low landfill taxes and a lack of national CE policies, goals, targets, and legal frameworks; circular design incentives; building standards and technical guidance; and quality standards for reclaimed products (Charef et al., 2021; Liu et al., 2021; Mahpour, 2018; Oluleye et al., et al., 2023; Wuni, 2022b). Another significant issue is a lack of support for using reclaimed materials in building codes and a lack of regulations that mandate the use of reclaimed or recycled products (Charef et al., 2021; Mhatre et al., 2023; Oluleye, Chan, Olawumi, et al., 2023).

CE implementation is also hindered by social, cultural, and organisational barriers, such as negative perceptions of alternative materials and a lack of awareness, interest, understanding, and support from the public, consumers, businesses, and stakeholders (Ababio & Lu, 2023; Adams et al., 2017; Bilal et al., 2020; Charef et al., 2021; Hart et al., 2019; Liu et al., 2021; Mahpour, 2018; Mhatre et al., 2023; Oluleye, Chan, Olawumi, et al., 2023; Wuni, 2022b). The linear model is well-established, and the sector can be considered conservative, resistant to change, and uncollaborative with a silo mentality (Ababio & Lu, 2023; Hart et al., 2019; Wuni, 2022b). In addition, supply chains tend to be fragmented and complex (Adams et al., 2017; Charef et al., 2021; Oluleye, Chan, Olawumi, et al., 2023; Wuni, 2022b). This contributes to the lack of collaboration, trust, communication, and information sharing among stakeholders and supply chain partners, as well as the reluctance to adopt CBMs and develop reverse logistics networks (Mhatre et al., 2023; Oluleye, Chan, Olawumi, et al., 2023; Wuni, 2022b). Other examples of organisational barriers include health and safety requirements, additional processes and planning, and a lack of information, resources, knowledge, skills, training, communication, and support from management (Charef et al., 2021; Liu et al., 2021; Oluleye, Chan, Olawumi, et al., 2023; Wuni, 2022b). There is also a lack of effective CBMs, design tools, and standard metrics and data collection systems to measure and assess performance (Ababio & Lu, 2023; Oluleye, Chan, Olawumi, et al., 2023; Wuni, 2022b).

Economic and technological barriers are also frequently cited in the literature. Examples of economic barriers include insufficient funding, high upfront costs, an unclear financial case, high prices for recycled or second-hand materials and lower prices for virgin materials, uncertain demand and limited availability for second-hand materials, and a lack of competition or market pressure (Ababio & Lu, 2023; Adams et al., 2017; Bilal et al., 2020; Charef et al., 2021; Hart et al., 2019; Liu et al., 2021; Mahpour, 2018; Mhatre et al., 2023; Oluleye, Chan, Olawumi, et al., 2023; Wuni, 2022b). Technological barriers include the availability of technology and infrastructure; a lack of R&D; a lack of circular product design and difficulties deconstructing, recovering, and recycling existing materials; and a lack of information on material quality and properties, product composition, and disassembly (Ababio & Lu, 2023; Charef et al., 2021; Mhatre et al., 2023; Oluleye, Chan, Olawumi, et al., 2023; Wuni, 2022b). In addition, digital tools and databases used to predict, track, count, and exchange waste materials remain in their infancy (Oluleye, Chan, Olawumi, et al., 2023; Wuni, 2022b).

Enablers, drivers, and success factors are also discussed in the literature, although to a lesser extent (Adams et al., 2017; Hart et al., 2019; Mhatre et al., 2021; Oluleye, Chan, Antwi-Afari, et al., 2023; Wuni, 2022a; Wuni & Shen, 2022). Enablers and critical success factors can also be organised into categories, such as technological, financial, regulatory, supply chain, cultural, organisational, stakeholder success, and management success (Hart et al., 2019; Wuni, 2022a). Many of these factors are the opposite of the barriers, such as more robust policies and regulations, education and awareness campaigns, sufficient financial resources, management support, and enabling technologies (Adams et al., 2017; Mhatre et al., 2021; Wuni, 2022a). However, other enablers are more specific, such as support from the client, thorough front-end planning, warranties on circular materials, industry standards and guidance, a circular procurement strategy, and a well-defined strategy for guiding CE implementation throughout the lifecycle (Wuni, 2022a). Stakeholder collaboration and supply chain integration are also frequently cited as a necessity to enable a CE transition in the B&C sector (Adams et al., 2017; Çimen, 2021; Hart et al., 2019; Leising et al., 2018; Mhatre et al., 2021; Shooshtarian et al., 2022; WGBC, 2023, pp. 73–75; Wuni, 2022a; Wuni & Shen, 2022). In addition, Nußholz and Milios (2017) note that the effective implementation of most circular strategies requires coordinated material exchange and logistics throughout the value chain.

3.2.9 CE Policy

CE policies are identified as critical enablers for a CE transition in the B&C sector (Giorgi et al., 2020; Yu, Junjan, et al., 2022; zu Castell-Rüdenhausen et al., 2021). Policy, legislation, and frameworks can motivate behavioural changes and create urgency to implement circular practices and CBMs (Wuni, 2022b). However, a lack of understanding regarding policy tools for the built environment hinders the CE transition (Bucci Ancapi et al., 2022). Thus, existing regulatory frameworks and CE policies fail to effectively encourage a CE in the B&C sector (Hossain et al., 2020; Yu, Junjan, et al., 2022). For example, previous CE policies at the European and national levels have focused on improving C&D waste management, landfill diversion, and recycling practices with landfill bans and high landfill taxes (Adams et al., 2017; Giorgi et al., 2020, 2022). This has encouraged 'end-of-pipe' solutions, namely downcycling, which results in lower-quality products than the original and neglects more effective circular strategies (Adams et al., 2017; Giorgi et al., 2020).

The over-emphasis on end-of-life activities may be due to inadequate policy implementation for actors representing earlier stages of the value chain (zu Castell-Rüdenhausen et al., 2021). This is despite the *Roadmap to a Resource Efficient Europe*, the *Communication on resource efficiency* *opportunities in the building sector*, the *Waste Framework Directive*, and the *Circular Economy Action Plan*, which aim to address the entire building life cycle (Nußholz et al., 2019). Policy measures need to consider the whole life cycle and a range of circular strategies, such as design for disassembly. However, the Waste Framework Directive is expected to be revised by 2026 and 2029, along with enhancements to the product policy framework (Eunomia, 2023, p. 24).

Previous policies have also been insufficient in other respects. For example, policies have focused on encouraging efficient resource use instead of addressing resource demand in the first instance (Hossain et al., 2020). In addition, Bucci Ancapi et al. (2022) found that most policies for a circular built environment focus on closed loops, such as those directed at energy and waste management in Europe and Asia. As a result, policies tend to overlook actions that regenerate ecosystems and enable buildings to adapt to change. This is particularly important as local access to services, adaptable buildings, multifunctional spaces, and renovating old buildings with ecologically beneficial materials are relevant approaches to achieving the European Union's 2040 CE vision (Eunomia, 2023, p. 17). Furthermore, CE policies regarding the built environment are fragmented and applied unequally across European countries (Giorgi et al., 2022). CE considerations at the building (meso) level, including design, business models, and life-cycle tools, have not yet been addressed.

More transformative, coherent, coordinated, and integrative policy approaches are required to support a CE transition in the B&C sector (Bucci Ancapi et al., 2022; Giorgi et al., 2020, 2022; Milios, 2021; Nußholz et al., 2019). Achieving a CE necessitates a level playing field that internalises environmental externalities, penalises linear practices, and sets incentives that channel private capital into enabling and mainstreaming circular solutions (Circle Economy, 2024, pp. 36–37). The sector's unique characteristics require collaboration between various stakeholders to develop innovative solutions to overcome existing barriers (Giorgi et al., 2022). Both cross-sectoral and sector-specific interventions are required (Milios, 2021). Policy measures should be implemented consistently over the long term to generate substantial impacts. A wide range of policy measures support a CE, including:

- Regulatory instruments:
  - Circular design requirements and specifications, such as minimum warranties and durability, recyclability, or repair standards.
  - Circular procurement criteria, such as recycled content targets or secondary and bio-based material requirements.
  - Circular standards and criteria for zoning and spatial planning guidelines.
  - Bans and restrictions on specific linear activities, materials, and products.
  - Circular requirements for imported materials.
  - Mandates and obligations for circular practices, such as adaptive reuse instead of building new, renovation and refurbishment instead of demolition, take-back, deconstruction, and reuse.
  - End-of-waste criteria, quality standards, and quotas for secondary materials.
  - Targets, such as resource reduction and reuse targets, guided by appropriate indicators (see Platform for Accelerating a Circular Economy [PACE], 2021).
  - Product stewardship/EPR policies.
  - Accounting standards which better capture the value of built assets, including revision of building regulations to reflect the depreciation of different building components accurately.
- Economic instruments:
  - Tax incentives and eco-modulation
  - Mission-driven financial mechanisms
  - Reduced regulations for trading circular materials
  - Levies, penalties, and producer fees to fund reuse
  - Subsidies and grants

    - Deposit return systems
    - Raw material taxes
- Information-based instruments:
    - Promotion campaigns
    - Requiring reporting, labelling, certifications, material passports, and material documentation with end-of-life information.
- Capacity-building and support mechanisms:
    - Education and training courses
    - Support for developing networks, databases, and trading platforms.
    - Infrastructure and R&D funding (Blumhardt, 2023; Circle Economy, 2024, pp. 40–41; Circle Economy, Sustainable Finance Lab, & Nederland Circulair!, 2019, p. 19; EMF, 2021, pp. 34–35; Giorgi et al., 2020, 2022; Hartley et al., 2020; Høibye & Sand, 2018; Milios, 2021; Nußholz et al., 2019; Peck et al., 2020, pp. 59–67).

3.2.10 Guidelines

A clear vision and roadmap are necessary to achieve CE goals (Ababio & Lu, 2023). While practical guidance remains limited (Çimen, 2023; Munaro et al., 2020), several guidelines have been developed for implementing CE in the B&C sector. Some of these guidelines are relevant to multiple life cycle stages or aspects of circularity. A notable example is the Circular Buildings Toolkit, developed by Arup and the Ellen MacArthur Foundation (n.d.), which provides direction on translating CE principles from theory into practice. The toolkit provides relevant strategies and actions, case studies, links to tools and relevant policies, and an outline for a circular design strategy workshop. Another notable example is the Circular Built Environment Playbook, which provides all stakeholders in the value chain with a checklist of strategies and case studies across the categories of B&C materials, design and retrofit, regenerate nature, and levers for change (WGBC, 2023). Various standards have also been developed to guide organisations with CE implementation, for example, BS 8001:2017 and ISO 59004 (BSI, 2017, pp. 43–68; ISO, 2023c). Less notable examples of guidelines relevant to multiple life cycle stages include the European Investment Bank (2023), ACR+ (Marengo, 2019), the German Sustainable Building Council (2019) (Lemaitre et al., 2019), and Zaman et al. (2023).

Some guidelines have a specific focus on design. For example, Eberhardt et al. (2021) and van Stijn et al. (2022) constructed environmental design guidelines based on LCA and Material Flow Analysis (MFA), the UK Green Building Council (2019) developed guidelines to address the front-end stage with a focus on design principles, and guidance from the New South Wales Government includes 13 circular design guidelines for professionals and stakeholders (Office of Energy and Climate Change, 2023). The European Commission (2020) also provides general principles and principles for different target groups to guide CE implementation for building design. Antwi-Afari et al. (2022) propose guidelines for designing for systemic circularity. This requires consideration of factors beyond the design phase alone. As such, these guidelines also incorporate system conditions, reverse cycles, and new business models. Design tools to guide decisions can be considered key CE enablers (Adams et al., 2017). However, the inadequate development and use of design and collaboration tools is a barrier (Hart et al., 2019).

Other guidelines focus on a particular aspect of circularity, such as modular construction (Mackenbach et al., 2020; Wuni & Shen, 2022), designing for deconstruction (Crowther, 2000), and prefabrication (Minunno et al., 2018). In addition, ISO 59010 sets out guidance on transitioning to CE business models and value networks (ISO, 2023a), and ISO 20887:2020 provides guidance on implementing design for disassembly and adaptability (ISO, 2020). Despite several guidelines, a lack of guidance remains a key barrier for businesses (Çimen, 2023; Hart et al., 2019; Hjaltadóttir & Hild, 2021). Moreover, bespoke guidelines are necessary to regulate CE implementation (Wuni & Shen, 2022).

3.2.11 Frameworks

According to Purchase et al. (2022), a pressing need is a framework to guide CE implementation in the B&C sector. A limited number of comprehensive theoretical frameworks have been developed to facilitate the development of CE strategies in the B&C sector (Dewagoda et al., 2022; Hossain et al., 2020). There is a need for frameworks that incorporate a comprehensive range of strategies, re-principles, and interventions to ensure the contributions of various stakeholders are identified and coordinated for a CE transition (Superti et al., 2021). Nonetheless, a range of frameworks can be identified. Most focus on the life cycle stages and circular strategies, including the re-principles and other interventions and processes (for example, Çimen, 2021, 2023; Fernandes & Ferrão, 2023; Jemal et al., 2023; Hossain et al., 2020; López Ruiz et al., 2020; Mrad & Frölén Ribeiro, 2022). Other frameworks are focused on the macro, meso, and micro layers (Esa et al., 2017); supply chain collaboration (Khitous et al., 2022; Leising et al., 2018); providing strategies to overcome key barriers (for example, Ababio & Lu, 2023; Bilal et al., 2020; Mahpour, 2018); and guiding the design process, such as the Design for Demand or Speedcycle frameworks (Shooshtarian, Hosseini, et al., 2021, p. 13). Furthermore, waste hierarchies (Sharma et al., 2022; Zhang et al., 2022) and the ReSOLVE framework (Dewagoda et al., 2022; Purchase et al., 2022) can also be considered frameworks for guiding CE implementation.

3.2.12 Measuring and Assessing Circularity

Measuring and assessing circularity is crucial to inform decision-making, track progress against targets, and determine the efficacy of policies or operational processes (BSI, 2017, pp. 64–65). However, while LCA and MFA are frequently used, there is no universally accepted method for measuring circularity (BSI, 2017, p. 64; Fernandes & Ferrão, 2023; Geisendorf & Pietrulla, 2018; Hossain & Ng, 2018; Lovrenčić Butković et al., 2023; Muñoz et al., 2023). This may be due to the complexity of considering every variable throughout the typically long building life cycle (Finch et al., 2021; Hossain et al., 2020). On the other hand, the newly released ISO 59020 standard aims to establish a consistent method for measuring and assessing CE performance (ISO, 2023b). Assessment involves setting the boundary of the selected system, acquiring data based on the selected indicators, and evaluating the results to report in a comprehensive statement.

While no universally accepted approach is recognised in the literature, a wide range of assessment tools exist. This is evidenced by Finch et al. (2021), who identified 74 CE assessment tools and circularity indicators for evaluating building envelope layers. These were categorised into product/assembly assessments and circularity measures for assessing buildings/materials. Among the 20 selected criteria, three types of circular assessments became evident: (1) discrete criteria that generate a true or false answer, such as whether the assembly uses mechanical, not chemical, connections; (2) qualitative and subjective criteria that call for consultation with multiple stakeholders, such as durable joints and components; and (3) measurable criteria, such as the number of different material types. Circular indicators can also be categorised into those focused on materials, modularity, fixings, and documentation (Finch, 2023, p. 43).

Six other types of metrics have been identified: (1) impact-based metrics, such as those measuring energy, carbon emissions, water use, waste generation, landfill diversion, material use, and recycled content; (2) productivity-based metrics, for example, the input of finite resources relative to the total output of the organisation; (3) attribute metrics to measure circular attributes such as average product utilisation, average product lifetime, or the ratio of recovered materials; (4) enabler-based metrics that encourage a CE transition, such as the number of CE initiatives adopted or the proportion of procurement activities that included CE requirements; (5) a maturity model to map progress; and (6) product-life extension through whole life asset management (Major Infrastructure – Optimisation Group, 2018, pp. 4–6). Indicators have also been categorised into waste and recycling, material flow, R-strategies, policy and process, environmental impact, and socio-economic impact indicators (PACE, 2021).

LCA is a common method of assessing circularity in the B&C sector due to its ability to transparently evaluate and compare the environmental impacts of building materials, products, and entire infrastructure projects over their lifetime (Lei et al., 2021; Lovrenčić Butković et al., 2023; Office of Energy and Climate Change, 2023, p. 37). However, review papers indicate no recognised method for assessing CE in the built environment using LCA (Andersen et al., 2022; Lei et al., 2021).

This is perhaps due to the emergence of several new methodologies developed to address the concerns that the existing methods from linear studies insufficiently represent a CE (Andersen et al., 2022). Several challenges also exist, such as limited inventory data, selecting appropriate allocation methods, and inaccurate results – should inconsistencies occur between the functional unit and system boundary (Lei et al., 2021). In addition, research remains limited on LCA indicators for circular buildings (Oluleye et al., 2022), particularly social and economic indicators (Lei et al., 2021). Nonetheless, the LCA method can provide a comprehensive assessment, enhance the relationship between CE and sustainable development, and identify environmental impacts. LCA is also often used in combination with other methods, such as MFA, life cycle costing, cost-benefit analysis, and social LCA (Lei et al., 2021; Lovrenčić Butković et al., 2023).

MFA and input-output analysis are also commonly used to measure circularity in the built environment by evaluating the flow of materials through systems (Hossain et al., 2020; Lei et al., 2021). MFA has become crucial in industrial ecology as it allows for evaluating a specific material's metabolism, including stock quantities, inputs, and material losses (Oluleye et al., 2022). ISO 59020 includes MFA and resource flow analysis in its assessment process while ensuring no overlap with other methods like LCA (ISO, 2023b, p. 53). Other common assessment tools include the Ellen MacArthur Foundation's Material Circularity Indicator, the Building Circularity Indicator, the Circular Transitions Indicator, and the CIRCelligence Indicators Framework (Lei et al., 2021; Office of Energy and Climate Change, 2023, p. 37; WGBC, 2023, p. 48). Certain CE principles have also been incorporated into sustainability evaluation methods, such as the European Union's Level(s) Framework, the EN17680 Standard (Fernandes & Ferrão, 2023), the Leadership in Energy and Environmental Design (LEED) rating system, and the Building Research Establishment Environmental Assessment Method (BREEAM) (Çimen, 2023).

According to Bilal et al. (2020), indicators used in CE assessment are crucial in guiding, measuring, and monitoring a CE transition. However, some scholars note that there is a lack of meso-level indicators or indicators relevant to the material level (Bilal et al., 2020; Hossain et al., 2020), while others highlight a lack of micro-level indicators (Kristensen & Mosgaard, 2020; Lei et al., 2021). In addition, there is a lack of comprehensive and holistic CE indicator sets and evaluation frameworks that meaningfully integrate sustainability aspects (Abadi et al., 2022; Fernandes & Ferrão, 2023; Hossain et al., 2020; Lei et al., 2021; Superti et al., 2021). As such, assessment frameworks have been developed by combining several methodologies (for example, Geldermans et al., 2019; Lei et al., 2022; Medina & Fu, 2021; Meglin et al., 2022; Nadazdi et al., 2022). However, Muñoz et al. (2023) listed 249 indicators relevant to the material and product level.

Several authors also select sustainability indicators across a range of categories and criteria, such as materials, resources, waste, recycling, energy, 3Rs–10Rs, greenhouse emissions, and water usage (Bilal et al., 2020; Muñoz et al., 2023; Nuñez-Cacho et al., 2018; Superti et al., 2021; Yi & Liu, 2017; zu Castell-Rüdenhausen et al., 2021). ISO 59020 follows suit by providing indicators and their calculations across resource inflows, resource outflows, energy, water, and economic categories (ISO, 2023b, pp. 34–52). In addition, complementary methods can be applied to assess social, environmental, and economic impacts, such as those standardised by ISO or other reputable organisations (p. 53). Other authors focus on indicators specific to circularity, such as standardisation, modularity, adaptability, durability, maintainability, resilience, deconstruction, disassembly, reusability, recyclability, and material properties (Dams et al., 2021; O'Grady et al., 2021; Rahla et al., 2021b). However, ultimately, no assessment method can wholly and accurately depict the actual level of circularity (BSI, 2017, p. 64), or not at least until the building has reached its end-of-life (WGBC, 2023, p. 24).

3.3 CE in the B&C Sector in Aotearoa New Zealand

While a CE has the potential to address numerous environmental and economic challenges, limited research has been conducted on CE implementation in the B&C sector in Aotearoa New Zealand (Purchase et al., 2022). The sector's environmental impacts are a significant concern despite efforts by the government to address sustainability and waste minimisation through various acts, regulations, and guidelines (Gade et al., 2020). Environmental challenges are compounded by rapid urbanisation and demand for infrastructure, which are expected to persist for at least the next seven years (Purchase et al., 2022). In addition, stakeholders are not sufficiently aware of the significant pollution caused by the sector (Balador et al., 2020).

The sector has failed to efficiently apply the waste hierarchy and consider a life-cycle perspective over the years (Gade et al., 2020). Based on deconstruction tests and an evaluation of conventional platform timber framing against circular assessment criteria, Finch et al. (2021) concluded that the dominant approach to construction is alarming. Additionally, there is a lack of widespread implementation of CE principles and a lack of incentives to reduce C&D waste (Griffin et al., 2018, p. 41). Instead, there is an emphasis on cost, speed, and custom builds, with many small businesses and contractors involved. The B&C sector contributes to around 50% of New Zealand's total waste (BRANZ, 2023), significantly higher than the world average (35%; Chen et al., 2022). Concrete is the most significant contributor to C&D waste by mass of the buildings consented in 2021, followed by aggregates, timber, and plasterboard (Dixon & Vickers, 2022, p. 17). Contributions to GHG emissions were primarily from concrete, steel, and plasterboard.

3.3.1 Barriers and Challenges

Numerous barriers and challenges have been identified for hindering a CE in the B&C sector in Aotearoa New Zealand, including but not limited to:

- A lack of sorting and recycling culture;
- A lack of knowledge and C2C/lifecycle/9R thinking;
- A lack of education and training;
- Poor material selection and overordering;
- A lack of early stakeholder involvement;
- The rising cost of land and construction;
- Labour and capital shortage;
- Greenwashing;
- High plastic waste volumes;

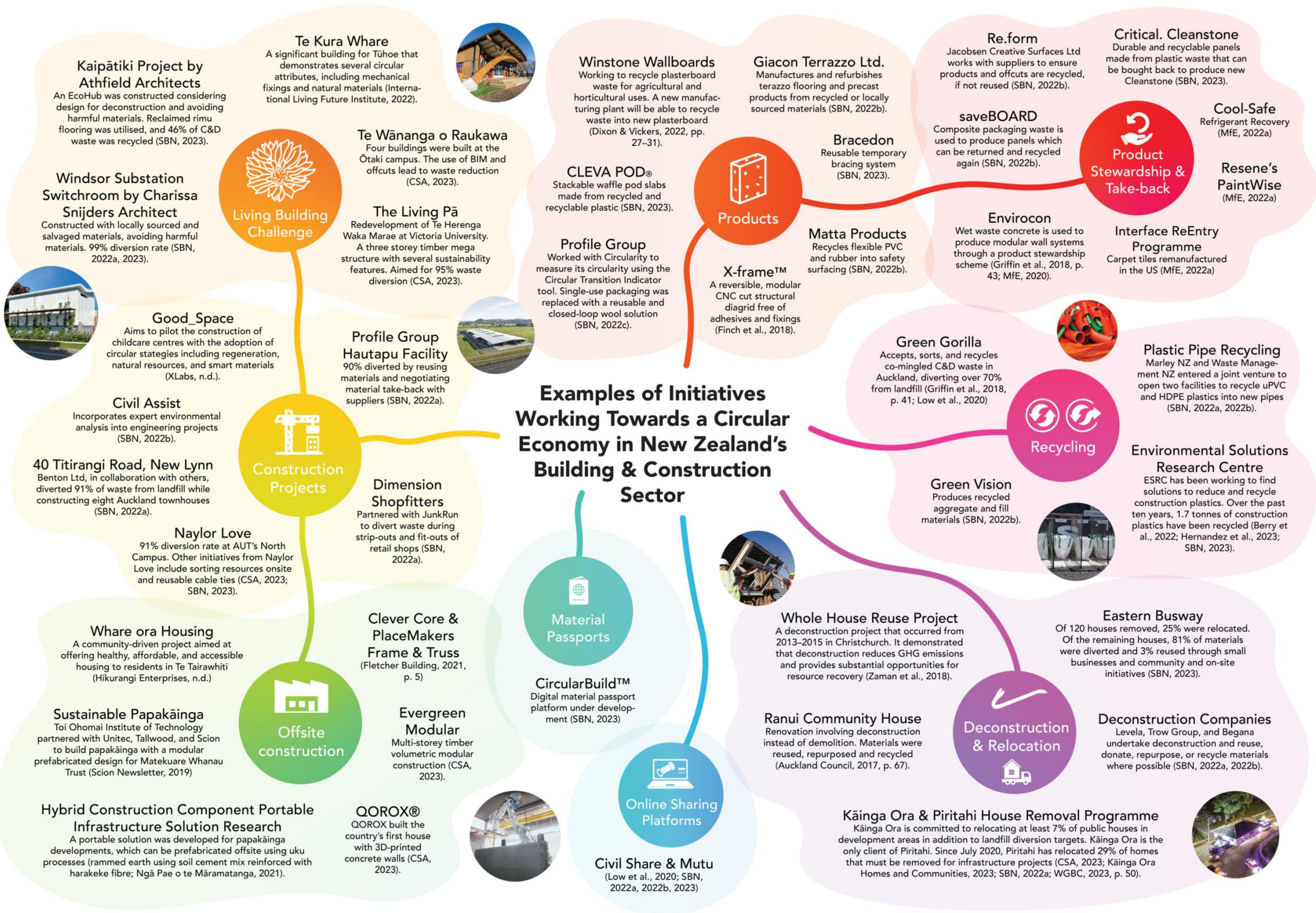
- An underdeveloped secondary market, which faces issues regarding a lack of demand, cost, availability, low profit, and infrequent advertising;
- The Building Code, specifications, standards, and permits that limit the use of secondary materials and encourage timber treatments that prevent recycling;
- Uncertainty about whether alternative materials and products perform according to environmental claims;
- A lack of accessible product information regarding compliance with building codes and standards;
- Conventional construction methods and the widespread use of adhesives, spray foams, sealants, and nails that cause contamination and irreversible damage to materials;
- Contamination from asbestos and lead-based products;
- A lack of circular construction methods, such as prefabrication, modular design, and standardised product sizes, which would improve the consistency of recovered supply at the end-of-life;
- Material expansion and contraction with changes in moisture, compromising the structural integrity of modular components;
- A lack of deconstruction and manual material separation to ensure quality secondary materials, which involves more time, space, and labour costs;
- The demolition of well-designed buildings after earthquakes instead of repairing and restoring them where possible;
- The costs associated with advanced design software, waste minimisation, transportation, sorting, and recycling;
- A lack of advanced recycling technologies and sufficient infrastructure;
- A lack of waste data and adequate monitoring and reporting systems; and
- A lack of incentives to encourage businesses to make positive changes (Balador et al., 2020; Berry et al., 2022; Finch et al., 2018, 2021; Fitwi, 2023; Fletcher Building, 2021, p. 3; Gade et

al., 2020; Gade, 2022, p. 100; Hernandez et al., 2023; Low et al., 2020; Purchase et al., 2022; Shanks, 2022; Zaman et al., 2018).

3.3.2 Evidence of Progress

While multiple barriers hinder CE implementation in the B&C sector, there is some evidence of progress. For example, the Green Building and Green Star certifications have brought some success in encouraging C&D waste reduction (Purchase et al., 2022). However, green building practices are not widely adopted in New Zealand, and the number of certified green buildings is considered modest (Abdelaal & Guo, 2021). Nonetheless, recent trends in the B&C sector indicate that interest in sustainability is increasing (MBIE, 2022a, pp. 29–40). These trends include green buildings, prefabrication, BIM, low-carbon emission buildings, circular building design, retrofitting, virtual and augmented reality, digital twins, and waste-based construction materials. There are also examples of iwi developing sustainable papakāinga (communal development on ancestral Māori land), which demonstrate elements of circularity. As kaitiaki (guardians) of the land, green design and design for sustainability are encouraged in papakāinga developments, including sustainable material selection (Te Puni Kōkiri et al., 2008, p. 50). Figure 13 provides examples of innovative products, offsite and modular construction, and other construction projects, initiatives, pilots, and case studies that have adopted circular practices or the diversion of materials from landfills. Collaboration and partnership were clear themes among these examples. Griffin et al. (2018) note an increased level of coordination occurring in different parts of the system to improve the circularity of buildings (p. 41).

Figure 13: *Examples of Initiatives Working Towards a CE in New Zealand's B&C Sector*



3.3.3 Actions to Accelerate a CE Transition

As discussed in Section 3.2, successful CE implementation can be achieved through its application at the micro, meso, and macro levels (Purchase et al., 2022). Efficient handling and onsite sorting of C&D waste, selective demolition of hazardous materials, and government intervention were recommended actions to accelerate a CE in the sector. Waste materials were also discussed as effective aggregate and cement supplements. In the long term, transitioning to a CE requires the adoption of CE principles in building design and processes, off-site standardised construction methods, and action plans to tackle problematic waste streams such as treated timber (Griffin et al., 2018, p. 44). Short-term actions include increasing the Waste Levy to disincentivise landfill and stipulating waste plans as part of the consent process. In addition, there is a need to consider prefabricated housing and 3D printing, eco-labels, product stewardship, designing out waste, allowing time for deconstruction, and space for sorting and reusing materials (Griffin et al., 2018, pp. 42–44). LCA can have a role in informing the environmental impacts of circular solutions, as demonstrated by studies calculating the impacts of New Zealand steel products at the end-of-life stage (Roy, Dani, et al., 2022 & Roy, Su, et al., 2022) and comparing scenarios of building refurbishment in New Zealand (Ghose et al., 2017).

Several other authors identify actions that would accelerate a CE transition in New Zealand's B&C sector. For example, Gade (2022) identifies a range of remedial measures, including actions for policymakers and influencers, such as guidelines for prefabricated and standardised materials; actions for clients, such as demanding sustainable materials and deconstruction; and actions for contractors, such as using BIM (pp. 200–201). Low et al. (2020) recognise the importance of establishing resource markets and enhancing waste management practices to promote reclaimed materials as valuable and quality resources for future builds. Shanks (2022) discusses practices including design for reuse and recovery, planning for deconstruction, modular building, optimisation, LCA, offsite construction and prefabrication, and design for disassembly. Fletcher Building (2021) also identifies various factors that could improve C&D waste reduction, including:

- Good segregation practices, including improvements to on-site or off-site facilities;
- Provision of regional infrastructure to sort and reprocess waste;
- More product stewardship schemes for building materials and their packaging;
- Modular design;
- Indicated rises to the landfill levy;
- Site waste management plans integrated into building consent;
- Minimum public procurement standards;
- Digital design tools, including BIM;
- Off-site manufacturing and prefabricated elements;
- Design for deconstruction;
- Materials exchanges; and
- Waste minimisation education and training in industry courses and apprenticeships.

Other factors the sector must consider include stakeholder involvement and communication, specification writing, changes to the design process, secondary material markets, safely handling and storing materials, and resource management and sorting (Gade et al., 2020). Other scholars, although not using CE language, have explored C&D waste management (Doan et al., 2023), biodegradable materials (Coleman, 2021; Hall, 2019); prefabrication (Luo & Shahzad, 2020); BIM and refurbishment, lean principles, and modular and offsite construction (Ghalenoei et al., 2022a, 2022b; Likita et al., 2022; Okakpu et al., 2019; Shahzad et al., 2023); and adaptive reuse of historical buildings (Aigwi et al., 2018, 2019, 2020; Paschoalin & Isaacs, 2020).

3.4 Conclusion

This chapter has delved into the literature on CE in the B&C sector internationally and in Aotearoa New Zealand. While numerous review papers have demonstrated exponential growth in the number of publications on this topic in recent years, the literature is fragmented and still in its early stages. Nonetheless, there are an extensive number of circular strategies and various CBMs identified in the literature that can be applied to the B&C sector. However, the implementation of circular strategies is fragmented, uncoordinated, focused on recycling, and often only targets specific projects or life cycle stages, namely the end-of-life phase. Frameworks such as the 9Rs should be adopted to ensure priority is not given to lower-value strategies.

In many countries, B&C construction stakeholders' awareness and understanding of the CE concept is moderate and ultimately inadequate for the scale of change a CE requires. Even in Brussels, where awareness was comparatively high, the CE concept was often mistaken for other sustainability concepts. Accordingly, the sector has struggled to implement CE principles, and CE implementation remains in its infancy, requiring significant measures to accelerate the transition. Recycling receives significant attention in the literature but should not be prioritised before higher-value strategies and CBMs. Attention is also given to technologies that can inform decisions throughout the life cycle and keep materials at their highest value.

While there are many enablers for the transition in the sector, it is also clear that numerous barriers exist, most notably a lack of CE policies that effectively encourage circularity. More transformative, coordinated, and integrative policy approaches are necessary to address the whole life cycle and various circular strategies. There are several guidelines for CE implementation in the B&C sector, although there is still a need for comprehensive frameworks to guide implementation. Despite a potential lack of indicators at the meso and micro levels, numerous assessment tools and types of criteria exist. The emergence of ISO 59020 may encourage greater consistency. In Aotearoa New Zealand, there is a lack of widespread implementation of CE principles. While some initiatives divert waste or adopt circular practices, numerous barriers must be dissolved, and both the government and the sector can undertake various actions to accelerate the CE transition. Key points on CE implementation gained from the literature review and background are grouped and presented in Appendix A.

4. Methodology

4.1 Introduction

As outlined in Chapter 1, this research aims to assess the current level of implementation of the CE concept by businesses in the B&C sector in Aotearoa New Zealand. This chapter explains the research methods used to achieve this aim. First, Section 4.2 describes the research design employed. Section 4.3 then explains the data collection process, including the sampling procedure and the qualitative and quantitative data collection methods. Section 4.4 outlines how the data was analysed. Section 4.5 explains the considerations regarding research ethics, and finally, Section 4.6 discusses the limitations.

4.2 Research Design

Mixed-methods research offers a robust approach to addressing research questions by collecting and integrating qualitative and quantitative data (Creswell & Creswell, 2018, p. 213). This research employs a mixed-method approach informed by a pragmatic worldview. Pragmatism is associated with mixed-methods research as it concentrates on practical action-oriented beliefs and methodological concerns rather than committing to a specific set of philosophical beliefs (Morgan, 2014). Therefore, mixed-method researchers can focus on the research problem and select the most suitable methods and procedures for their study (Creswell & Creswell, 2018, p. 10). A three-phase exploratory sequential mixed-methods design was considered the most suitable approach for this research. This involves (1) collecting and analysing qualitative data, (2) developing an instrument informed by the qualitative data, and (3) administering an instrument to collect quantitative data from a sample of the population (Creswell & Creswell, 2018, p. 224). In this study, circular strategies were drawn from the key points on implementation from the literature review and background, particularly Section 3.2.2 (see Appendix A). Qualitative data was then collected through short semi-structured expert interviews, which was used to develop and administer an online survey that collected primarily quantitative data on the strategies implemented by businesses (see Figure 14).

Figure 14: *The Exploratory Sequential Mixed-Methods Design Employed in this Research*

An exploratory sequential mixed-methods research design was employed as it allows further exploration into the topic, uncovering insights about the population or other factors that might not be present in the literature (Creswell & Creswell, 2018, p. 224). This is particularly relevant as conceptual clarity and consensus are not yet apparent (Blomsma & Brennan, 2017), with the literature in its early stages (Çimen, 2021), particularly in New Zealand. Therefore, interviews with local experts provided valuable insights to inform the development of the survey instrument. Additionally, mixed-methods research provides a flexible, comprehensive, and enriched bi-focal approach to address the research aims and questions (Sarantakos, 2013, p. 55).

This thesis assesses the current level of implementation of the CE concept among businesses in the B&C sector in Aotearoa New Zealand in order to understand the gap between CE theory and practice and pinpoint the strategies that need improvement to accelerate the transition to a more circular sector in New Zealand. Semi-structured interviews were used to:

- Identify which circular strategies were relevant to support a CE transition among selected business types in New Zealand's B&C sector
- Explore experts' perceptions on the current state of CE implementation among selected business types in New Zealand's B&C sector

The online survey was used to:

- Understand how professionals perceive the maturity of CE implementation in their business
- Assess the current level of implementation of circular strategies among businesses in New Zealand's B&C sector and determine which circular strategies require greater attention

- Determine if there are any associations between business age, size, or sub-sector and the maturity of CE implementation or implementation of circular strategies

4.3 Data Collection

4.3.1 Sampling Procedure

As previously indicated, the target population was businesses in the B&C sector in Aotearoa New Zealand. Construction businesses make up 12.6% of all businesses in New Zealand, with 70,629 registered construction businesses in February 2021 (MBIE, 2022a, p. 11). As such, identifying a more manageable sample of business types was necessary. There are a wide range of different business types and stakeholders in the sector, including manufacturers, suppliers, investors, developers, insurance providers, architects and engineers, construction companies, design-build companies, fit-out companies, regulators, local authorities, public agencies, industry associations, R&D institutes, owners, users, real estate investors, facility managers, deconstruction and demolition companies, and waste management companies (European Commission, 2020, pp. 10–15; Shooshtarian, Hosseini, et al., 2021, p. 21; Circle Economy & WBCSD, 2018, p. 15).

Past papers on CE implementation in the B&C sector in other countries included one to seven business types in their sample, with most focusing on businesses or stakeholders in the private sector, such as architects and engineers, construction companies, developers, and C&D waste processors (Adi & Wibowo, 2020; Amudjie et al., 2022; Bertozzi, 2022; Bilal et al., 2020; Cohen et al., 2022; Ghaffar et al., 2020; Giorgi et al., 2022; Guerra et al., 2021; Guerra & Leite, 2021; Kanters, 2020; Lee et al., 2023). In this context, this thesis focuses on businesses that directly implement circular strategies. In particular, seven business types were included in this research:

(1) Building product/material manufacturers

(2) Architecture and engineering firms

(3) Construction companies

(4) Design-build companies

(5) Fit-out companies

(6) Demolition companies (including deconstruction)

(7) Waste management companies

4.3.1.1 Interviewee Sampling Procedure. Non-probability purposive sampling was employed to select potential interviewees. This form of sampling allows researchers to identify the most relevant subjects (De Vaus et al., 2013, p. 88; Sarantakos, 2017, p. 177). In this research, relevant subjects were those with expertise in their field and CE. Seven experts were identified through supervisor recommendations. Another three experts were approached for their knowledge of circular products and deconstruction, and a further two contacts were referred by another participant as a form of snowball sampling. In total, 12 industry experts were approached, and nine agreed to participate in an interview: two from manufacturing companies, two from architecture and engineering companies, and one from each of the other business types.

4.3.1.2 Survey Sampling Procedure. Professionals from businesses across the seven business types were invited to participate in the online survey. As with other studies, a purposive sampling method was also adopted (e.g., Amudjie et al., 2022; Lee et al., 2023). Whilst a random sample is preferable for obtaining a representative sample and generalisable results, probability sampling methods are often not relevant or feasible, particularly when sampling frames are unavailable (De Vaus et al., 2013, pp. 66-67, 88). As such, quantitative researchers frequently use non-probability sampling, even though it may not be the preferred method (Creswell & Creswell, 2018, p. 150). Given time and resource constraints, developing a comprehensive sampling frame was deemed impossible in this research, with hundreds or thousands of businesses from multiple types of businesses and a lack of registered business lists or member directories for some business types.

The purposive sampling strategy involved prioritising the selection of major players as they may be more closely linked with larger production volumes or a greater influence over environmental impact, material consumption, and waste. The study was, therefore, less concerned with representativeness and more focused on gaining insight into where the most impact could be made for a CE transition—should such players implement the strategies that require greater attention. After major players were identified, further businesses were identified through extensive internet searches and member association lists. To further enhance representativeness and obtain a wide breadth of responses, businesses were identified across the sub-sectors outlined in the Australian and New Zealand Standard Industrial Classification (ANZSIC) code, including residential (e.g., houses and flats), non-residential (e.g., shops and offices), and heavy and civil engineering (e.g., roads, bridges, tunnels, and pipes) sub-sectors (Australian Bureau of Statistics, 2013). Another sub-sector in the ANZSIC code is construction services. However, this was excluded as contractors and other construction services were not included in this research.

An adequate sample size cannot be calculated precisely for a non-probability sample, and therefore, the researcher can only ensure that the sample is large enough to gather sufficient data, which was the goal in this research (May, 2011, p. 102). The professionals invited to complete the survey on behalf of their businesses included sustainability and environment professionals, as they were most likely to have intimate knowledge of the sustainable and circular practices occurring. In addition, the survey was more likely to pique their interest and obtain a higher response rate. For companies where there were no such positions, other professionals were invited, including directors, general managers, and operational managers. A single professional per business was approached to avoid duplicates of any business.

4.3.2 The Interviews

Semi-structured interviews provide interviewers flexibility in conducting a conversation while ensuring all themes are addressed by referring to an outline of discussion topics (Corbetta, 2003, p. 270). Eight 20–30 minute semi-structured interviews were undertaken online and one in person. A PowerPoint presentation was utilised to guide interviews and present circular strategies. There were two central open-ended questions:

(1) Which of these circular strategies for [business type] are most relevant for promoting a circular economy in New Zealand? Which could be excluded? Are any missing?

(2) How would you describe CE implementation among [business type] in New Zealand?

The first question was designed to support the survey development. The semi-structured format was crucial as it allowed participants to focus on specific strategies, further indicating their importance, among other advantages, such as capturing impromptu responses or correcting misunderstandings (Sarantakos, 2013, pp. 295–296). The second question was designed to gain insights into experts' perceptions of the current state of CE implementation among the business types they represented.

4.3.3 The Survey

A survey was used to collect primarily quantitative data on the circular strategies implemented by businesses in Aotearoa New Zealand's construction sector. Surveys systematically gather information from multiple cases on the same variables, creating a rectangular data set or a 'variable by case data grid' for comparing cases (De Vaus et al., 2013, p. 3). In this instance, the cases were B&C professionals and their businesses, and the variables were predominantly circular strategies. A self-administered online questionnaire was employed as the data collection technique to efficiently attain a larger sample size, allow likely time-constrained respondents to answer in their own time, and provide anonymity to professionals and businesses. Anonymity was considered essential as the B&C sector is often considered conservative (Ababio & Lu, 2023; Hart et al., 2019) and, therefore, may be hesitant to share business practices openly.

In October 2023, an online questionnaire developed using Qualtrics was distributed to 1115 professionals from the seven types of businesses, including 190 manufacturing companies, 405 architecture and engineering firms (230 architecture and 175 engineering), 230 construction companies, 125 design-build companies, 60 fit-out companies, 80 demolition companies, and 25 waste management companies. Invitations were sent via personal and general enquiry emails and LinkedIn messages. The questionnaire was open for three weeks, and follow-up emails were sent after ten days. Careful attention was paid to the layout, questionnaire format, question wording, and measures for preventing non-response. For example, the questionnaire was designed to be concise to streamline the process while ensuring comprehensive coverage of circular strategies. It was also designed to be easy to follow with an inviting cover letter and a simple layout while avoiding prestige bias and leading, double-barrelled, or ambiguous questions, as recommended by De Vaus et al. (2013, p. 97) and Sarantakos (2013, pp. 263, 271).

The questionnaire was structured with eight main questions distributed across three pages to create organised and manageable sections. The first page asked which sub-sectors businesses contribute to, the business size, and the age of the business. Next, participants were asked how they would describe the maturity of CE implementation in their business or place of employment, providing five multiple-choice answers based on the categories of CE maturity in the draft ISO 59010 (i.e. novice, beginner, established player, well-engaged, and mature; ISO, 2023a, s. 4.5). This was designed to understand how professionals perceive the maturity of CE implementation in their business. Participants were then asked which of the seven business types best described their business or place of employment, which determined the strategies shown in the second section.

The second page was focused on the implementation of circular strategies. It asked the extent to which circular strategies were implemented by their business or place of employment, providing a 5-point Likert scale from 'not at all' to 'completely/always'. A 5-point Likert scale was considered appropriate for its ability to provide flexibility with enough options to capture a range of possible responses (De Vaus et al., 2013, pp. 106–107). In addition, the 'not applicable' and 'unsure' categories were included to provide a full range of options. Short descriptions of each strategy were provided to avoid confusion or assumptions. The third page consisted of the final two questions, which were open-ended, allowing a text response. This enabled participants to identify any other circular strategies or practices their business has implemented or if there was anything else they would like to share regarding CE implementation in their business or industry. These questions were purposely left at the end of the questionnaire, as open-ended questions should be minimised and ideally placed near the end of the survey (De Vaus et al., 2013, p. 111).

4.3.3.1 Pilot testing. There are three stages of pilot testing: (1) conducting a pretest to help develop and improve questions; (2) administering a complete questionnaire to make improvements and determine the time to complete questions; and (3) polishing and finalising the questionnaire (De

Vaus et al., 2013, pp. 114–115). A draft of the questions was pretested with supervisors and another post-graduate student from an unrelated subject. Improvements were made, including creating a more enticing email letter, increasing the text size, creating more concise descriptions of strategies, and including question 8 to ensure respondents had an opportunity to share any other thoughts on the subject. A pilot was then undertaken with another four people: an academic and professional focused on C&D waste minimisation in construction, a sustainability professional from a manufacturing company, an engineering lecturer, and a business English language teacher. Alterations were made based on feedback, including minor grammatical errors, rewording questions 7 and 8 to incorporate the wider industry as opposed to businesses alone, and feedback on different formats.

4.4 Data Analysis

The steps of qualitative data analysis can include preparing data for analysis, reading data to understand the overall meaning, coding, and producing and representing the description or themes (Creswell & Creswell, 2018, pp. 193–195). The interview data was prepared by transcribing the interview recordings using voice-to-text transcription software. Transcripts were read to comprehend the general meaning and correct mistakes. Data regarding the importance of the identified circular strategies was analysed during data collection. The circular strategies identified from the literature were used as themes to guide data analysis and subsequently inform decisions on which strategies should be included or excluded from the survey. Data from the second question regarding CE implementation among the different business types was organised into themes through open coding. Thematic analysis was utilised as it allows researchers to identify reoccurring concepts, pinpoint key themes that capture the meaning of the textual data, and uncover relationships between different themes (Sarantakos, 2013, p. 379–380). This was done manually, not utilising software due to the small sample.

Quantitative data analysis can involve preparing data, including checking and editing, coding, conducting descriptive and inferential statistics, and presenting and interpreting the findings

(Creswell & Creswell, 2018, p. 157; Sarantakos, 2013, p. 405). In this research, a total of 239 professionals responded. The data was checked, and 26 incomplete responses were excluded. Thus, 213 survey results were included in the analysis, obtaining a 19% response rate. Individual response rates from each business type ranged from 28% to 9% (see Table 1).

Table 1: *Response Rates for each Business Type*

Business Type	No. of Invitations	No. of Responses	Response Rate
Manufacturing	190	49	26%
Architecture/Engineering	405	71	18%
Construction	230	56	24%
Design-Build	125	11	9%
Fit-Out	60	8	13%
Demolition	80	11	14%
Waste Management	25	7	28%
Total	1115	213	19%

The first six questions in the survey collected ordinal and nominal data, and data analysis was undertaken using the data analysis tools in the Qualtrics platform and Microsoft Excel. Descriptive analysis included calculating means and standard deviation. Inferential statistics were not used to make inferences about the wider population due to the non-probability sampling method. However, the associations between business age, size, and sub-sector with the maturity of CE implementation and implementation of circular strategies were assessed through chi-squared tests of independence. Finally, the two open-ended questions were coded thematically.

4.5 Research Ethics

The Massey University *Code of Ethical Conduct for Research, Teaching and Evaluations Involving Human Participants* was used to identify ethical issues and inform the ethics application. This research was evaluated by peer review and deemed to be low risk. The primary ethical concern related to the privacy and confidentiality of the interviewees, survey respondents, and their employers. For the interviews, no identifying information, such as names or positions of the interviewees, was communicated in any research findings. Instead, interviewees were referred to numerically, such as 'Interviewee 1'. The survey provided anonymity by not collecting information that could directly identify a business or individual. Informed consent from interviewees was obtained by providing an information sheet that outlined participant rights (see Appendix B). The transcripts of interviewees who agreed to be recorded (through the information sheet and verbally) were kept securely. For surveys, informed consent was obtained by integrating similar information into the introduction section of the questionnaire and providing a link to a participant information sheet (see Appendix C and D). This research was not expected to cause harm or discomfort to the participants or the researcher or create adverse impacts concerning other universal principles or Treaty of Waitangi obligations and principles set out in the Code of Ethical Conduct.

4.6 Limitations

A key limitation of this research is that only a limited number of experts could be interviewed due to time constraints. Other experts may have prioritised different strategies. Therefore, some relevant circular strategies may have been omitted from the survey. Another key limitation is that the survey results are not generalisable to the wider population due to the purposive sampling method, which focused on major players from particular business types in the sector. In addition, there is a possibility that respondents possessed a greater interest in CE or that their business had a higher level of implementation than non-respondents. While the findings are not representative of the whole sector, valuable insight was gained into the level of implementation among key business types and important industry players in New Zealand.

Another limitation is that the survey was not designed to provide a precise estimate of circularity and was only a high-level investigation into the state of CE implementation based on respondents' perceptions and self-reported answers. For example, Likert scale questions may not capture the complexities of implementation over various product lines or account for varying perceptions of what complete implementation looks like. Moreover, while participants were guaranteed anonymity and confidentiality, there remains the possibility that they might be inclined to provide socially desirable answers (De Vaus et al., 2013, p. 107). However, the CE concept is relatively new (Murray et al., 2017; Winans et al., 2017). As such, a high-level approach was considered necessary to introduce circular strategies to professionals that may not be initiated with circular principles and practices. Additionally, businesses likely lacked data on circular metrics and indicators. Furthermore, the high-level approach allowed for comparison with papers on implementation in other countries and presents an opportunity for future research to explore implementation in greater depth.

4.7 Conclusions

This chapter has explained and justified the methods for gathering and analysing data in this study. A three-phase exploratory sequential mixed-methods design was employed to address the research questions. Semi-structured interviews with experts were conducted to collect qualitative data to subsequently inform the development of quantitative data collection using a survey appropriate for the New Zealand context. Purposive sampling was employed for both qualitative and quantitative phases. Qualitative data was analysed using the circular strategies as predetermined themes and thematic analysis. Quantitative data was analysed using basic descriptive and inferential statistics. Finally, ethical considerations and limitations were discussed. The following chapter will present the findings gathered from the interviews and survey.

5. Results

5.1 Introduction

This chapter presents the results of the interviews and the survey. It is divided into two main sections. First, Section 5.2 explores the findings from the interviews, including the relevance of the circular strategies for each business type and which ones the interviewees considered most relevant. It then investigates experts' perceptions of the current state of CE implementation. Next, Section 5.3 analyses the survey results, starting with an overview of business types, sub-sectors, size, and age to provide context. Professionals' perceptions of the maturity of CE implementation in their business, the implementation of circular strategies, other strategies and insights from survey respondents, and significant relationships are then presented. Finally, Section 5.4 concludes the chapter.

5.2 Interview Results

5.2.1 Circular Strategies

The key points on CE implementation within the literature were identified and grouped (see Appendix A). These points were consolidated, and the most relevant were selected, producing 38 circular strategies. Appendix E presents these strategies, indicating which ones were included for each business type. These strategies were presented to the interviewees during the interviews, and they were asked which were most important for promoting a CE transition among their business type in New Zealand, as well as if any were missing or if any should be excluded.

5.2.1.1 Circular Strategies for Building Product Manufacturers. Two experts representing manufacturers were interviewed (Interviewees 1 and 2). Interviewee 1 noted: "If you can be more efficient, you're probably going to be more profitable. … Eliminating waste is a good way to run a business. So you should be looking to use as little amount of material as possible". As such, they identified dematerialisation, efficient processes, and off-site construction as relevant strategies for building product manufacturers. This interviewee also stressed the significance of education in preventing waste generation and highlighted the need for industry-wide collaboration to encourage industrial symbiosis and develop take-back schemes. They considered the latter particularly important, as it enables manufacturers to undertake strategies such as reuse and recycling to ensure circularity. Interviewee 1 also spoke to the relevance of other strategies presented, acknowledging the need to design deconstructable elements, particularly for non-load-bearing walls and office environments, incorporate circular metrics, and practice active regeneration of natural systems for future generations.

Interviewee 2 stated that all circular strategies presented are relevant. However, they argued that some are more important than others. In particular, they considered circular materials the most important, followed by design for disassembly/deconstruction, adaptability/flexibility, and standardisation. Interviewee 2 explained that design for disassembly is an “urgent” strategy as a product that cannot be disassembled will often be contaminated, limiting recovery opportunities and the establishment of take-back schemes. If products are designed to disassemble, “then you could repair or reuse or remanufacture”. They argued that among the strategies for closing and extending loops, “takeback schemes are probably the most important because most of the building industry is dealing with technical nutrients”. Other strategies that they considered relevant included modular and off-site construction, industrial symbiosis, dematerialisation, and education, upskilling, and collaboration. They also identified measuring circularity and material passports as relevant, although they emphasised that there must be a greater focus on actual implementation.

Interviewee 2 considered sustainable operation, certifications, and social and cultural equity as lower priorities. In addition, design for longevity and maintenance and repair were considered less relevant, as building products are often already sufficiently durable. However, Interviewee 1 noted that while some certifications can be expensive and may not drive significant positive outcomes, certifications and measuring circularity are important to gain verifiable data. In addition, Interviewee 1 considered social and cultural equity a key component of sustainability strategies, namely regarding human rights and being good community participants. Based on the interviewees' views and knowledge, the strategies design for longevity, maintenance and repair, and sustainable operation were excluded from the survey for manufacturers.

5.2.1.2 Circular Strategies for Architecture and Engineering Firms. Two experts representing architecture and engineering firms were interviewed (Interviewees 3 and 4). Interviewee 3 emphasised that circular strategies in the design stage are critical to avoid problems later in the lifecycle and allow multiple cascading uses, thus promoting circularity:

> When thinking of the end of life, you are trying to think of it like a bath overflowing with water; the first thing you do is turn off the tap. If you turn off the tap in the design stage, you don't have quite as many problems at the end-of-life stage. (Interviewee 3)

This interviewee highlighted that design for disassembly/deconstruction and adaptability/flexibility is “really, really important” to enable a second life for materials. These strategies are also “attached to the narratives around climate resilience” as they allow managed retreat and relocation away from flood-prone areas and rising sea levels in preparation for an uncertain future. Interviewee 4 similarly believed that design for disassembly/deconstruction must be considered due to the uncertainty during the asset's lifespan, whether due to rising sea levels or if a building is no longer needed at its current location.

Dematerialisation and adaptive reuse were also considered relevant strategies. Interviewee 3 explained that these strategies may be challenging to encourage, as architects and engineers are “used to building new stuff”. However, they argued that “we need to make the best of the old things. That's part of the education process that's required. There's no building as low carbon as a building you don't build. So that's what you need to start with.” Interviewee 4 agreed and explained the importance of cycling materials at the highest value, arguing that refusing to build, adaptive reuse, and dematerialisation should be the first consideration, and reusing components should be prioritised before recycling.

Interviewee 3 also discussed the relevance of other strategies. They argued that circular materials are essential: “They matter to other things like decarbonising and biodiversity loss... we want it to be safe for other ecosystems and creatures... so less toxic material and all of those other benefits from circular materials are important”. As such, they considered Cradle to Cradle Certified®

the most appropriate certification. Regenerating nature can involve incorporating ecosystem services into how buildings function and providing spaces for nature to help combat species extinction, for example, butterfly gardens on facades or bus stops. Interviewee 3 noted that "making space for nature in our cities is going to be really important in the future". They also considered educating clients essential for a CE transition, as circularity differs from sustainability, arguing that: "it's not building the same thing with more sustainable materials or energy efficiency. Actually, the model itself is quite different. It's much more of an as-a-service model".

Based on these interviews, two strategies were excluded, and two strategies were altered in the survey. Interviewee 3 noted that designing out waste and pollution is an overarching principle rather than a specific circular strategy: "Designing out waste is a principle that these others [design strategies] will support". Therefore, it was excluded from the survey for all business types. Interviewee 4 also considered design for longevity a broader concept that "could mean a lot of different things", including the reuse of materials. In addition, Interviewee 3 argued that design for designing "really well for 20 plus 20 plus 20 plus 20 plus 20 years" may be a better approach than designing buildings that last for 100 years to provide flexibility with the unknown of the future. As such, design for adaptability/flexibility and disassembly/deconstruction enable relocation and, subsequently, a longer life. This indicated that design for longevity could be accounted for through other circular strategies. Therefore, it was excluded for architecture and engineering firms, in addition to design-build and fit-out companies which operate at the design stage. Interviewee 4 noted that there is a range of possible technologies, including BIM. Thus, 'BIM-aided design' was changed to 'digital design tools' to capture a broader range of technologies. They also noted that *sustainable* can refer to "sustaining the status quo" rather than regenerating natural systems. Sustainable operation was, therefore, replaced by regenerative operation for all business types. All other strategies were considered relevant by the interviewees.

5.2.1.3 Circular Strategies for Construction Companies. One expert representing construction companies and general contractors was interviewed (Interviewee 5). They considered upskilling, education, and collaboration the most important strategy as people need to understand the problem and the implications on future generations to buy into the solutions. Interviewee 5 explained that “without education, you really have no leg to stand on. People aren't going to get on board with it… It starts with education; it starts with making people aware of what's happening”. They considered education on selecting circular materials particularly important to promote within the company and with other sub-contractors. They argued that collaboration is also essential to create buy-in from sub-contractors and suppliers, some of whom may take back materials for reuse or recycling.

Interviewee 5 also explained the relevance of other strategies. They identified minimising waste onsite as particularly relevant for construction companies, including ordering fewer materials, providing enough allocated bins to segregate waste, and ensuring subcontractors take responsibility for their waste. Sharing platforms, reuse, and the different types of recycling were also highlighted as sending materials to landfills is becoming increasingly unacceptable. On the other hand, Interviewee 5 pointed out that circular contract specifications and certifications are driven by the client and the architect, as opposed to the contractor. These two strategies were, therefore, excluded from the survey for construction companies. All other strategies were considered relevant by Interviewee 5.

5.2.1.4 Circular Strategies for Design-Build Companies. One expert representing design-build companies was interviewed (Interviewee 6). Interviewee 6 argued that all the strategies were important and that none needed to be excluded. They considered the design phase highly important, “with 80% of the waste baked-in at design phase”. Therefore, effectively implementing each strategy at the design phase can maximise progress towards circularity: “You have to do all of them [circular strategies at the design phase] well to be able to get the most value out of the circularity aspect, in my opinion”. Interviewee 6 explained that design-builders often work at scale. Therefore, design for standardisation is “quite critical” for successfully reducing waste. In addition, Interviewee 6 considered circular materials critical for circularity and carbon reduction.

Interviewee 6 also mentioned the importance of other strategies outside of the design and planning stage. They argued that offsite modular construction is important as it can deliver “a huge amount of win on the waste front before you've even started”. Interviewee 6 noted they are “a strong believer in regeneration” and acknowledged indigenous knowledge of materials and regenerating nature regarding ecology and biodiversity. Other strategies they considered necessary included minimising waste onsite, including employees' waste and the development of site waste minimisation plans; BIM-aided design or digital design tools; education, upskilling, and collaboration; and service-based models, such as lighting-as-a-service. They suggested that adaptive reuse may not be as relevant for certain housing types but did not suggest that it should be excluded.

5.2.1.5 Circular Strategies for Fit-out Companies. One expert representing fit-out companies was interviewed (Interviewee 7). Interviewee 7 identified circular materials as the most important strategy, closely followed by designing for disassembly and deconstruction. They explained that products with longer life expectancies in good condition should not be recycled too early in their life: “If I’ve got a really good product, it doesn't need to go back to be recycled because it's perfect”. Therefore, while closed and open-loop recycling may be necessary, they argued that reuse and sharing platforms are more important, suggesting a materials passport would help plan deconstruction or demolition and find reuse and recycling opportunities for materials. Other strategies they considered particularly relevant included efficient processes and social and cultural equity.

On the other hand, Interviewee 7 explained that interiors, such as those in retail, hospitality, offices, and aged care, are updated every five to ten years. As such, they argued that sustainable or regenerative operation is not a key strategy for fit-out companies as the benefits often outlast the short lifespan of interiors, and thus, is more relevant to new construction. Interviewee 7 also noted that around 70% of fit-out projects will have some level of demolition and that selecting a contractor that offers deconstruction should be considered. They pointed out that deconstruction and selective deconstruction “could be somewhat the same”. Interviewee 7 also argued that design for adaptability and flexibility is similar to design for longevity, explaining: "If you make something adaptable and flexible, you are giving it life, or you're making it able to be used for longer". Therefore, sustainable/regenerative operation, selective deconstruction, and design for longevity were excluded from the survey for fit-out companies.

5.2.1.6 Circular Strategies for Demolition Companies. One expert representing demolition companies was interviewed (Interviewee 8). Interviewee 8 explained that manual deconstruction, collaboration, and reusing materials were "very important" for circularity. They suggested that regenerating nature, such as mimicking nature and implementing systems to manage water, is more applicable to the design stage. However, they argued that regenerating nature should not be excluded as "in a circular process, you're not degrading the environment at all, you're building it up… you can't not do that in a circular system". Interviewee 8 confirmed that recording waste data was important. They argued that material passports should be developed earlier in the lifecycle, and in their absence, pre-demolition audits allow the company to make "the best of a bad situation", providing time to identify reuse and recycling solutions. Interviewee 8 also suggested that efficient processes are similar to careful segregation. Therefore, material passports and efficient processes were excluded from the survey for demolition companies.

5.2.1.7 Circular Strategies for Waste Management Companies. One CE expert from a waste management company was interviewed (Interviewee 9). Interviewee 9 argued that all presented strategies are required and that "none of them would sit outside of the remit; it's just dependent on which ones to target first". As such, no strategies were excluded from the survey for waste management companies. They suggested that education, upskilling, and collaboration is "the number one thing to do initially" as recognising and understanding the problem is crucial to developing successful circular solutions, such as reuse or closed-loop recycling services. They considered collaboration essential as customers willing to invest in niche solutions must collaborate with others, including service providers and logistics companies, to implement them.

Interviewee 9 emphasised the importance of optimising the use of resources. After a customer has minimised its waste and a specific material has been generated, reuse is “the best option”, particularly for unused excess materials from over-ordering. They argued that reuse is more advantageous than open-loop, closed-loop, or organic recycling from an energy and carbon perspective as it maintains the value of an existing product, allowing it to be used for its “innate purpose”. After reuse, “you start moving down the waste hierarchy in terms of terms of value”. Interviewee 9 considered open-loop recycling less relevant as it does not promote a CE; we cannot “recycle our way out of the issue”. They noted that where recycling is required, infrastructure investment is necessary.

5.2.2 Experts’ Perceptions of CE Implementation

The nine experts interviewed were asked how they would describe CE implementation among their business type in New Zealand. This section outlines the themes identified in the responses provided by interviewees.

5.2.2.1 CE Implementation is Unsatisfactory. Several interviewees noted little consideration for a CE among their business types in New Zealand. For example, Interviewee 3 (representing architecture and engineering companies) explained that CE implementation is still in its early stages and not yet considered a priority:

> New Zealand is really behind in that space... and it is still very new, very much deer in the headlights. ... The sector is coming off a low base, particularly in Australia and New Zealand... I wouldn't say circular is top of the list. It's still mostly sustainability; it's mostly sustainable materials. Circular hasn't really landed on a large scale. (Interviewee 3)

Interviewee 3 also explained that architects and engineers are limited by client ambition: “There's probably only a handful of clients who are open and willing to step into that newer space”. Interviewee 3 observed that implementation is hindered by siloed budgets and focusing solely on financial cost as the key metric. Sustainability initiatives are often rejected to meet capital budgets for constructing assets despite the more significant financial burden of operating a less efficient asset over its lifetime. As such, architects and engineers “can give [clients] great ideas, but if they cost more than the average build business-as-usual solution, it's harder to get that over the line”.

Interviewee 7 (representing fit-out companies) described CE implementation as very poor: “We consider the circular practices in the short-term construction space to be almost non-existent... I think the fit-out sector is fraught with poor practices”. Achieving CE is “a bit of a hard ask” for fit-out companies due to cost barriers and tight timeframes in the planning stage. They noted that many consider fit-out projects too small-scale to contribute “any big impact”. However, they disagreed with this notion and cited an example of a fit-out company that has “put the equivalent to 5000 homes into landfill” over its lifetime. Interviewee 7 expressed concern about the lack of emphasis on honouring our relationship with the land in the context of social and cultural equity and the ongoing practice of landfilling significant volumes of construction materials, questioning New Zealand’s environmental reputation: “We're a ‘clean, green country’, and yet we just bury construction waste constantly”.

Interviewee 8 had also not observed significant activity supporting a CE and reported only one company in New Zealand that consistently practices complete manual deconstruction. They acknowledged that a limited number of demolition companies “are trying to recreate themselves as deconstruction, but what is actually needed is not just a rebranding, it's rethinking about what you're doing.” Due to time and cost pressures, such companies may only recover some materials and effectively demolish the rest of the building (selective demolition). Interviewee 8 explained most demolition contractors fulfil their clients' request of simply getting rid of the building without much regard for materials or a CE:

> There's not a lot happening that I can see… In my experience of being in some of these situations… the whole atmosphere is there's nothing in it to say, let's look after this. It's all a sense of this at the end of the life of this product. … At the moment, what demolition contractors are typically asked for by their clients is ‘get rid of this building for me, just get rid of it. I don't care. I don't want to know’. Demolition contractors need to appreciate that they are actually not at the end of a life of a material, but they're actually at the beginning of a new life of that material. And, it's not just about getting rid of it; we need to be thinking… where can we get it to give it a new life? (Interviewee 8)

Multiple other interviewees indicated that the implementation of specific circular strategies is poor. For example, both manufacturing experts highlighted the implementation of take-back schemes. Interviewee 1 noted regarding take-back schemes: "It's actually evolving. We're a long way behind than other countries". Similarly, Interviewee 2 noted: "There's a requirement for really good take-back schemes, and that's probably what's really missing in New Zealand". They argued that a mature take-back scheme is contingent on deconstruction to recover materials without contamination. However, manufacturers often provide specifications that limit deconstruction. To combat this, they suggested that the government enforce a mandate stipulating that the industry establishes specifications for disassembly. In addition, Interviewee 5 indicated that carefully segregating materials is "something that needs to be drilled into more [construction] contractors out there. They need to put in the work and make allocated waste bins for each material". They also noted that regeneration is "not yet" a consideration. Furthermore, Interviewee 6 observed that not many design-build companies sort waste materials onsite. While critical waste streams can be separated onsite, many types of construction waste do not have solutions, "so we're still trying to find answers".

5.2.2.2 Implementation is Varied. Four interviewees reported that CE implementation is inconsistent and varied. Both experts representing manufacturers agreed that CE implementation is inconsistent, particularly the implementation of take-back schemes. Interviewee 1 explained: "There are some take-back schemes that are already in play. So some people are further down the track, but I don't think they are streets ahead". Interviewee 2 conveyed a similar message and noted that select businesses implement circular strategies "really well". Most notably, take-back schemes are emerging for PET and plastic products. Nonetheless, they considered CE implementation overall "really patchy".

Interviewee 6 (design-build) also argued that the implementation is highly varied:

> I think it's a really big spectrum still and there's some first movers in the space. ... Some companies would have particular contractual obligations around Homestar so that leads to particular diversion from landfill target, which needs to be met. ... So I definitely see some

> playing in that space, but then there's many other operators who haven't got an obligation on them either. ... And some developers haven't even got a fence, which can stop the blowing of polystyrene and plastic waste around the site, and others won't even have a skip bin. So we really are talking about very opposite ends of the spectrum. (Interviewee 6)

In addition, Interviewee 6 highlighted an example of a leading company that has demonstrated "enormous gain in terms of the waste reduction story" through modular offsite construction.

Interviewee 9 also described a spectrum of implementation among waste management companies: "It's a complete mixed bag... You do have that range of businesses, some that really don't care and some that really do care and are leaders in that space... [there are] examples of the good and bad." They explained that some businesses invest considerable time and resources into operating sustainably while others focus solely on financial outcomes with no interest in environmental and social considerations. Between these extremes are companies that are prepared to consider alternative options, but only if they are cost-effective or cheaper than disposal.

5.2.2.3 Ambulance at the Bottom of the Cliff. Four interviewees referred to variations of the 'ambulance at the bottom of the cliff' metaphor to illustrate the ineffectiveness of solutions at the end-of-life and a lack of proactive measures early in the life cycle. For example, Interviewee 3 (architecture and engineering) stated: "What we're dealing with now is that these buildings were not designed for disassembly. They weren't designed for flexibility or adaptability. So now we're the ambulance at the bottom of the cliff." Similarly, Interviewee 9 explained that waste management companies cannot be relied upon to ensure all materials will be recovered for circularity:

> Commercial waste businesses are often just seen as 'we have this material, we're going to give it to you, you need to do what you can with it'. That isn't the way to solve the problem; you can't just outsource it; you're the one generating the waste. We, as a waste company, can't find all the solutions because if you're just that ambulance at the bottom of the cliff, it just isn't going to work to make sure that everything can be recovered. (Interviewee 9)

***5.2.2.3.1 Poor Implementation Early in the Lifecycle*.** A clear theme among interviewees was poor CE implementation at the design and planning phase or the 'top of the cliff'. Interviewee 2 (manufacturing) noted that design strategies are poorly implemented by architects:

> Architects do not want to use certain types of materials that would be more recyclable or fit better in a circular economy... I'd also say that design for disassembly and deconstruction is

> generally extremely poorly considered. That top line [design for disassembly, design for adaptability, design for standardisation, and designing out waste] is probably the worst level of implementation of the circular economy. (Interviewee 2)

Interviewee 4 (architecture and engineering) confirmed that the implementation of design for disassembly/deconstruction is often not considered: “It's not something that's demanded by the industry yet, but I feel that it's something that needs to be put forward… especially as a coastal nation”. It was also acknowledged that “we can do better” at implementing design for adaptability and flexibility.

Interviewees 5 and 6 provided further examples of poor implementation of design strategies. Interviewee 5 stated that “[construction] contractors out there are probably a little bit further behind” regarding circular materials. Interviewee 6 argued that while “there’s probably more acceptance for thinking about designing out waste, I don’t see that translating to other than probably smaller [design-build] companies who have had a particular focus”. They also noted poor implementation of design for standardisation and modularity: “Kiwi buildings have an awful habit of not being particularly standard. Everyone likes to have it slightly bespoke... and more in the same for modularity”. Additionally, there has been “less emphasis” on design for disassembly and deconstruction, and BIM is “an area where we've gotten to as much yet”.

***5.2.2.3.2 Overfocus on Recycling*.** Two experts agreed that there is an overfocus on recycling at the ‘bottom of the cliff’ and insufficient emphasis on reuse. Interviewee 8 (demolition) observed a strong focus on diverting materials from landfills instead of exploring reuse opportunities. Consequently, companies do not change their practices from demolition to deconstruction as they can send smashed materials to a recycling facility and claim high landfill diversion rates: “We've diverted 80% from landfill, and that's kind of the standard people say they're doing, and it sounds really good”. The expert explained that while it is better than landfill, materials are often downcycled: “It's not reuse. It’s not a circular economy. It's downcycling.” However, shifting behaviours towards deconstruction and reuse is challenging: “They've got a model that is working for them. Clients are paying it, they can do it with a digger, and the manual labour isn't high.”

Moreover, Interviewee 8 noted there is a need to develop the downstream network with adequate infrastructure and resources to establish clear and efficient pathways for reuse.

Interviewee 9 (waste management companies) also highlighted that most of the sector is satisfied with the outcome of organic and open-loop recycling despite it not being necessarily circular:

> The majority of the B&C sector goes, is this material being sent to landfill? No. Is it being recycled? Yes, okay, great. I've done my job. Whereas if we're promoting a true circular economy, that is not the pathway to success. ... Let's use timber as a perfect example... At present, if that goes into a wood skip and goes to be chipped, or composted, or whatever it may be, that's seen as a win because it hasn't gone to landfill. (Interviewee 9)

They emphasised that reuse should be considered first, and customers must undertake sustainable procurement.

5.2.2.4 Greenwashing Concerns. Three experts expressed concerns about greenwashing. Interviewee 2 (manufacturing) noted that a lack of CE implementation is “disguised in a little bit of greenwashing”. While implementation is “poor” and their messaging is not “landing as it should”, businesses are beginning to display positive efforts to implement sustainable initiatives. However, Interviewee 9 explained that greenwashing is concerning as it is a deliberate strategy that waste management companies use to gain a competitive advantage:

> Those that tout circular or sustainable services and solutions that aren't necessarily sustainable. Some say it's a closed loop, but it isn't... in a lot of cases, it's just smoke and mirrors by a lot of people. ... As long as they can share a pretty-looking report that says that they're doing good, they're happy, even though they may know that, in reality, it's not the right thing or the data may not be accurate. (Interviewee 9)

Interviewee 3 (architecture and engineering) noted that measuring circularity and certifications are “increasingly important” due to greenwashing and misleading claims.

5.2.2.5 Siloed Innovation. Several interviewees indicated that where implementation is more advanced, advancements are happening independently, requiring systems thinking and greater collaboration. Interviewee 3 identified siloed thinking as a concern: “When you're talking to a building company or an engineering company. They know what they know, they know what they do, it's generally in a silo”. They emphasised the importance of systems thinking for a coordinated CE shift:

> Circular economy work often happens at the boundaries between organisations, in the sense that if one organisation moves, it's hard for one more organisation to move when the system doesn't move. ... So even if you find a client who's super ambitious and embracing circular economy principles, now the building code is in the way. ... When you're looking at transitioning a whole paradigm shift, it's circular procurement, it's the building code, it's how we finance. ... It needs coordination of the system to shift. It’s not the responsibility or a value proposition for one organisation. That's why they need support. (Interviewee 3)

Interviewee 3 also suggested that transition brokers have an important role in coordinating a CE shift, as demonstrated in the Netherlands.

Other interviewees made similar observations. Interviewee 7 (fit-outs) understood that there are “bits of innovation” occurring in “little lanes” that need to be connected for the industry to work together cohesively. Interviewee 8 (demolition) concluded that “there's quite a lot of people trying to deal with the same problems individually” and that working together is crucial for a CE transition. Interviewee 1 (manufacturing) acknowledged that changing business models and behaviours to accommodate take-back schemes is challenging and requires greater collaboration. It was explained that while there are ‘pockets’ of advancements and some groups are already working together and practising industrial symbiosis, “we need to understand as a country, how do we all work together to be more circular?”. Several interviewees briefly identified barriers preventing an economy-wide transition, including transport costs resulting from New Zealand’s unique geography and the lack of economies of scale outside city centres.

5.2.2.6 Lack of Education. Several interviewees mentioned a lack of education to build knowledge and support CE implementation. Interviewee 1 (manufacturing) noted that more education and information would help increase awareness. In addition, both interviewees representing architecture and engineering firms agreed that CE knowledge is lacking, arguing: “There's an education and familiarisation need” (Interviewee 3) and “There's a huge knowledge gap in that space, and we need to get a lot better very fast” (Interviewee 4). Interviewee 7 (fit-outs) also observed that individuals lacking expertise in sustainability face difficulties in accessing readily available information that promotes informed decision-making:

> A lot of this information resides with people who are either passionate about sustainability or know a lot. We need to make sustainability easy for the people that aren't particularly knowledgeable. ... We are not able to make good decisions, because we're not given the right information to be able to make the decision to start with. (Interviewee 7)

A lack of knowledge of what can be recycled was also discussed: “Most people will know that GIB is recyclable, but you wouldn't necessarily know whether the ceiling tile in that space is recyclable, or whether the carpet is recyclable, or whether various other elements are recyclable.” Interviewee 5 raised a similar point: “There's subcontractors and merchants that will take back their products to recycle, reuse again… it's just knowing that”.

5.2.2.7 Increasing Awareness and Interest. On the other hand, several interviewees identified increasing awareness and interest in the CE concept. Interviewee 3 (architecture and engineering) noted that in the private sector, which is held accountable for their social responsibility, “we are seeing some appetite in some of those leading edge thinkers”. A couple of public sector organisations have also shown interest in CE opportunities. Interviewee 7 (fit-outs) also indicated a “desire to be circular”. Furthermore, Interviewee 6 (design-build) observed that: “Increasingly, the focus is shifting from a linear model through to a more circular economy model.” They noted that there is interest in circular materials among companies focused on climate-related targets and constructing low-carbon buildings:

> I think there's a very strong push to find materials which are lower carbon, which can be more reusable, recyclable, and more durable... and increasingly more so as we get into the Building for Climate Change programme and the introduction of carbon caps. (Interviewee 6)

Interviewee 5 (construction) similarly noted that circular materials, modular construction, and BIM are becoming increasingly popular.

Interviewee 1 (manufacturing) noted “a general raising of awareness” for C&D waste, with an increasing number of pilots and sustainability projects. They argued that a CE is “the next step” in this regard. Interviewee 5 also observed an increasing focus on sustainability and a shift in attitude:

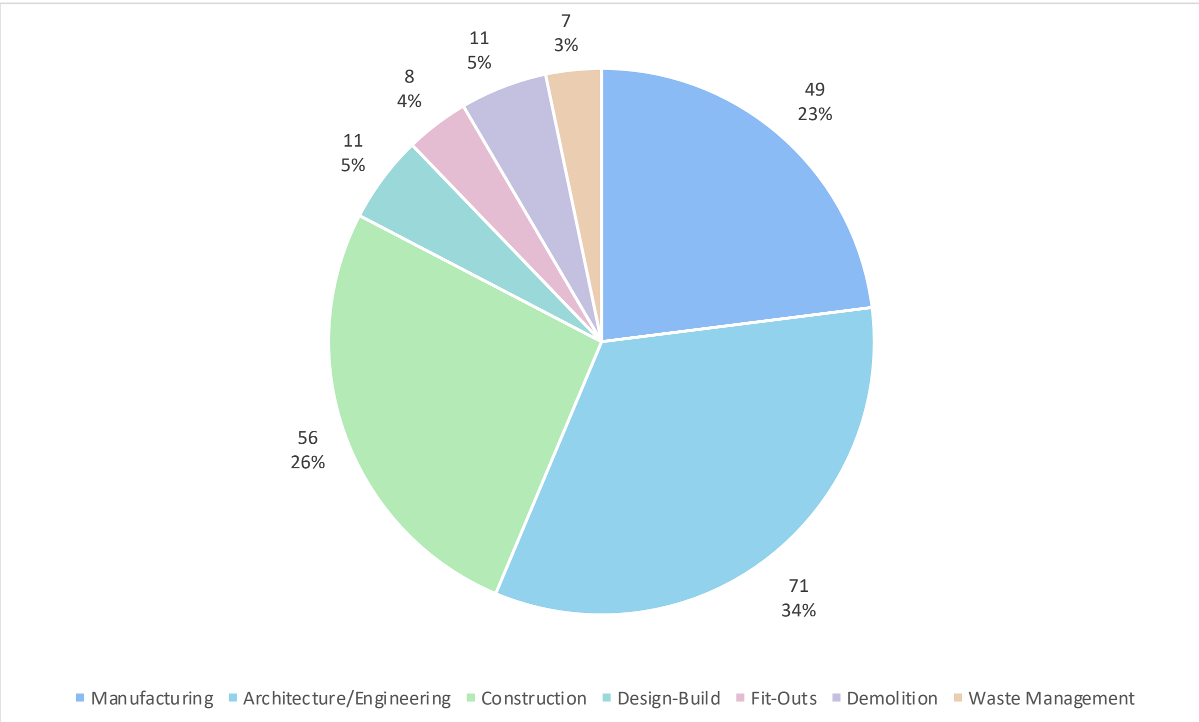
You see more and more these days on the focus on sustainability, and clients want to push on that… people don't like to spend money, but some people are wanting to spend more money these days in respect of sustainability. … More people want to get on board with this. It's actually kind of the cool thing to do now, to start thinking about our future… There are a lot of things that people don't understand, but they're getting there with it. It's a slow process. (Interviewee 5)

5.3 Survey Results

5.3.1 Profile of Businesses

As mentioned in Chapter 4, a 19% response rate was obtained, with 213 complete responses included in the analysis. Most respondents were from manufacturing companies (23%), architecture and engineering firms (33%), and construction companies (26%). Other respondents were from design-build companies (5%), fit-out companies (4%), demolition companies (5%), and waste management companies (3%) (as illustrated in Figure 15).

Figure 15: *The Number of Respondents from each Business Type*



Respondents were asked to select all sub-sectors that their business or place of employment contributes to. Overall, 73% of respondents selected residential building construction, and 64%

selected non-residential building construction (see Table 2). Heavy and civil engineering construction was less common and was selected by 28% of respondents. All business types contribute to each sub-sector, except design-build and fit-out companies, which do not undertake heavy and civil engineering construction.

Table 2: *Sub-Sectors Business Types Contribute To*

Business Types	Residential	Non-Residential	Heavy and Civil Engineering
Manufacturing	76%	88%	47%
Architecture/Engineering	83%	75%	21%
Construction	61%	36%	21%
Design-Build	73%	46%	0%
Fit-Outs	38%	100%	0%
Demolition	73%	27%	46%
Waste management	86%	71%	71%
All Business Types	73%	64%	28%

Respondents were also asked to indicate the age and size of their business. As shown in Table 3 and Table 4, respondents included representatives from businesses of a variety of ages and sizes. Most businesses were 21–50 years old (37%) and small or medium-sized (44% and 38%, respectively). Manufacturing, design-build, and demolition companies were mostly medium-sized, and the remaining business types were mostly small businesses. There were no respondents from large businesses representing design-build, fit-out, or demolition business types, and manufacturing and waste management companies showed a higher percentage of large businesses comparatively.

Table 3: *Age of Businesses*

Business Types	0–5 years	6–10 years	11–20 years	21–50 years	51+ years
Manufacturing	3 (6%)	2 (4%)	7 (14%)	23 (47%)	14 (29%)
Architecture/Engineering	10 (14%)	10 (14%)	20 (28%)	26 (37%)	5 (7%)
Construction	7(13%)	13 (23%)	12 (21%)	16 (29%)	8 (14%)
Design-Build	1 (9%)	2 (18%)	4 (36%)	3 (27%)	1 (9%)
Fit-Outs	2 (25%)	1 (13%)	1 (13%)	3 (38%)	1 (13%)
Demolition	2 (18%)	2 (18%)	4 (36%)	3 (27%)	0 (0%)
Waste Management	1 (14%)	1 (14%)	0 (0%)	4 (57%)	1 (14%)
All Business Types	26 (12%)	31 (15%)	48 (23%)	78 (37%)	30 (15%)

Table 4: *Size of Businesses*

Business Types	Small <20 employees	Medium 20–100 employees	Large 100+ employees
Manufacturing	10 (20%)	24 (49%)	15 (31%)
Architecture/Engineering	44 (62%)	21 (30%)	6 (9%)
Construction	22 (39%)	18 (32%)	16 (29%)
Design-Build	5 (46%)	6 (54%)	0 (0%)
Fit-Outs	6 (75%)	2 (25%)	0 (0%)
Demolition	3 (27%)	8 (73%)	0 (0%)
Waste Management	3 (43%)	1 (14%)	3 (43%)
All Business Types	93 (44%)	80 (38%)	40 (19%)

5.3.2 Perceptions on the Maturity of CE Implementation

Respondents were asked how they would describe the maturity of CE implementation in their business or place of employment based on the five stages of CE maturity (ISO, 2023a, 4.5). On average, most respondents (40%) considered their business at a beginner level of CE implementation, followed by novice (25%) and established player categories (21%) (see Table 5). Only 10% of respondents characterised their business as well-engaged, and 4% as mature. When quantified on a scale of one to five, the average score across all respondents was 2.6 (SD = 1.1), positioning businesses between the beginner and established player stages of CE maturity.

Respondents from demolition and waste management companies had the highest perception of CE maturity in their business, with an average of 3.6 and 3.4, respectively, positioning their businesses among the established player and well-engaged categories. The average perception of maturity for other business types ranged between 2.0 and 2.5, aligning more closely with the beginner category.

Table 5: *Perceptions of the Maturity of CE Implementation Per Business Type*

Business Type	1 Novice	2 Beginner	3 Established Player	4 Well Engaged	5 Mature	Mean	SD
Demolition	0 (0%)	1 (9%)	5 (45%)	2 (18%)	3 (27%)	3.6	1.0
Waste Management	0 (0%)	2 (29%)	2 (29%)	1 (14%)	2 (29%)	3.4	1.3
Manufacturing	10 (20%)	16 (33%)	15 (31%)	6 (12%)	2 (4%)	2.5	1.1
Design-Build	3 (27%)	5 (45%)	1 (9%)	1 (9%)	1 (9%)	2.3	1.3
Fit-Outs	3 (38%)	3 (38%)	0 (0%)	2 (25%)	0 (0%)	2.1	1.2
Construction	16 (29%)	24 (43%)	11 (20%)	5 (9%)	0 (0%)	2.1	1.0
Architecture/ Engineering	21 (30%)	34 (48%)	11 (15%)	4 (6%)	1 (1%)	2.0	0.9
Total	53 (25%)	85 (40%)	45 (21%)	21 (10%)	9 (4%)	2.6	1.1

Note. Light blue cells = averages between 3 and 3.99. Medium blue cells = averages between 2 and 2.99.

5.3.3 Implementation of Circular Strategies

As explained in Chapter 4, survey respondents from different business types were presented with different circular strategies. Respondents were asked to indicate the extent to which their business implements the presented circular strategies in its operations, based on a Likert scale of 0–4 (not at all to completely/always), as well as the categories ‘not applicable’ or ‘unsure’. Table 6 shows the average responses on the implementation of circular strategies across each business type. On average, businesses implement circular strategies at a moderate level of 1.9 out of 4 (SD = 0.5). Respondents from demolition and waste management companies rated the implementation of circular strategies higher than other types of businesses, with averages of 2.8 and 2.2, respectively (i.e. between ‘Moderately/Sometimes’ and ‘Significantly/ Frequently’). The averages for other business types ranged between 1.4 and 1.8 (i.e. between ‘Minimally/Rarely’ and ‘Moderately/Sometimes’). When excluding demolition and waste management companies, the average score is 1.7 out of 4.

The highest-ranking strategies and the only strategies averaging between 3.0 and 4.0 (i.e. Significantly/Frequently and Completely/Always) were pre-demolition audits (M = 3.5, SD = 0.0), selective deconstruction (M = 3.5, SD = 0.0), and careful segregation (M = 3.1, SD = 0.7). In contrast, the lowest-ranking strategy is service-based models (M = 0.5, SD = 0.1), with a score between no to minimal levels of implementation. Other low-ranking strategies include sharing platforms (M = 1.0, SD = 0.8), material passports (M = 1.0, SD = 0.3), and remanufacturing (M = 1.2, SD = 0.0). The following sections describe the implementation of circular strategies per business type. Tables are provided in Appendix F, showing the percentage of respondents that chose each category for each type of business.

Table 6: *Mean Responses from each Business Type on the Implementation of Circular Strategies Within their Business (0–4 Likert Scale)*

Circular Strategies	Manufacturers	Architecture/ Engineering	Construction	Design-Build	Fit-Outs	Demolition	Waste Management	Mean	SD	Rank
Pre-demolition audits						3.5		3.5	0.0	1
Selective deconstruction						3.5		3.5	0.0	2
Careful segregation						3.5	2.6	3.1	0.7	3
Minimise waste on-site			2.5	3.0	2.3	3.6		2.9	0.6	4
Infrastructure investment							2.7	2.7	0.0	5
Preconstruction consulting						2.6		2.6	0.0	6
Regenerative operation		2.3		2.4				2.3	0.0	7
Waste as a resource/industrial symbiosis	2.2							2.2	0.0	8
Efficient processes	2.4		2.0	2.5	2.1		2.3	2.3	0.2	9
Recording waste data			1.5	2.1	0.9	3.5	3.1	2.2	1.1	10
Deconstruction					1.7	2.7		2.2	0.7	11
Circular materials	2.4	2.1	1.7	2.4	2.5			2.2	0.3	12
Design for standardisation	2.7	2.1		2.4	1.6			2.2	0.5	13
Education, upskilling & collaboration	1.8	1.7	1.6	2.4	2.1	2.8	2.6	2.2	0.4	14
Relocation						2.1		2.1	0.0	15
Reuse	1.6		1.8	1.5	2.1	3.4	2.1	2.1	0.7	16
Dematerialisation	2.3	2.0	1.7	2.2	2.3			2.1	0.2	17
Design for adaptability/flexibility	2.3	2.1		1.7	2.1			2.1	0.2	18
Circular contract specifications		1.6		2.4	2.1			2.0	0.4	19
Digital design tools		1.8	1.5	2.5	1.7			1.9	0.4	20
Adaptive reuse		2.3		1.4				1.8	0.6	21
Open-loop recycling	1.2		1.5	1.4	1.8	3.0	2.1	1.8	0.7	22

Circular Strategies	Manufacturers	Architecture/ Engineering	Construction	Design-Build	Fit-Outs	Demolition	Waste Management	Mean	SD	Rank
Offsite & modular construction		2.0	1.6	1.5				1.7	0.3	23
Certifications	1.3	1.4		1.9	1.6			1.6	0.2	24
Design for disassembly/deconstruction	1.9	1.3		1.0	2.1			1.6	0.5	25
Closed-loop recycling	1.5		1.4	1.9	0.8	2.2	1.3	1.5	0.5	26
Social & cultural equity	1.2	1.7		1.5	1.6			1.5	0.2	27
Measuring circularity	1.2	1.2		1.7				1.4	0.3	28
Regenerating nature	1.1	1.7	0.9	1.4	1.2	1.7	1.5	1.3	0.3	29
Organic recycling	0.8		1.0	1.4	1.2	1.9	1.7	1.3	0.4	30
Take-back schemes	1.3							1.3	0.0	21
Remanufacturing	1.2							1.2	0.0	32
Material passports	1.5	1.0	0.8	1.4	0.9			1.1	0.3	33
Sharing platforms			0.8	0.8	0.3	2.2		1.0	0.8	34
Service-based models	0.3	0.4	0.5	0.7	0.4			0.5	0.1	35
Average	**1.6**	**1.7**	**1.4**	**1.8**	**1.6**	**2.8**	**2.2**	**1.9**	**0.5**	

Note. Values are mean responses based on a 0–4 Likert scale (where 0 = not at all, 1 = minimally/rarely, 2 = moderately/sometimes, 3 = significantly/frequently, and 4 = completely/always) and exclude ‘not applicable’ and ‘unsure’ categories. Darkest blue cells = averages between 3 and 4. Medium blue cells = averages between 2 and 2.99. Light blue cells = averages between 1 and 1.99. Pale blue cells = averages between 0 and 0.99. Strategies not included in the survey for specific business types are shown as blank cells.

5.3.3.1 Manufacturing Companies. The average response for the implementation of all circular strategies by manufacturing companies was 1.6 out of 4. Respondents indicated that the least implemented strategies were service-based models (*M* = 0.3, *SD* = 0.9), organic recycling (*M* = 0.8, *SD* = 1.2), and regeneration (*M* = 1.1, *SD* = 1.4). The most implemented strategies included design for standardisation (*M* = 2.7, *SD* = 1.1), circular materials (*M* = 2.4, *SD* = 1.3), and efficient processes (*M* = 2.4, *SD* = 0.9). However, the 'not applicable' category was more frequently selected, particularly for organic recycling (35%), service-based models (20%), regenerating nature (18%), social and cultural equity (12%), remanufacturing (12%), open-loop recycling (12%), and dematerialisation (10%) (for further details, please see Table F1).

5.3.3.2 Architecture/Engineering Firms. The average response for the implementation of circular strategies was 1.7 for architecture and engineering firms. The least implemented strategies were service-based models (*M* = 0.4, *SD* = 0.8), material passports (*M* = 1.0, *SD* = 1.1), and measuring circularity (*M* = 1.2, *SD* = 1.1), and the most implemented strategies were regenerative operation (*M* = 2.3, *SD* = 1.1) and adaptive reuse (*M* = 2.3, *SD* = 0.8). The 'not applicable' category was selected by several respondents, particularly for offsite construction (7%), service-based models (7%), regenerating nature (6%) and social and cultural equity (6%) (for further details, please see Table F2).

5.3.3.3 Construction Companies. The average response for the implementation of circular strategies was 1.4 out of 4 for construction companies, which was the lowest among all business types. Respondents from construction companies indicated that service-based models (*M* = 0.5, *SD* = 0.7), sharing platforms (*M* = 0.8, *SD* = 1.0), material passports (*M* = 0.8, *SD* = 1.1), regenerating nature (*M* = 0.9, *SD* = 1.2), and organic recycling (*M* = 1.0, *SD* = 1.2) were the least implemented strategies. On the other hand, minimising waste on-site was the most implemented strategy (*M* = 2.5, *SD* = 1.0), followed by efficient processes (*M* = 2.0, *SD* = 1.1). 'Not applicable' was selected for organic recycling (7%), service-based models (4%), offsite and modular construction (4%), regenerating nature (3%), digital design tools (3%), and material passports (1%) (for further details, please see Table F3).

5.3.3.4 Design-Build Companies. The average response for the implementation of circular strategies was 1.8 out of 4 for design-build companies. Service-based models (*M* = 0.7, *SD* = 0.7) and sharing platforms (*M* = 0.8, *SD* = 0.8) were the least implemented strategies, while minimising waste onsite (*M* = 3.0, *SD* = 0.8), efficient processes (*M* = 2.5, *SD* = 1.0), and digital design tools (*M* = 2.5, *SD* = 1.2) were the most implemented. The 'Unsure' category was not selected by any respondents, and measuring circularity, offsite and modular construction, adaptive reuse, sharing platforms, and service-based models were selected by one respondent each (9%) for the 'not applicable' category (for further details, please see Table F4).

5.3.3.5 Fit-out Companies. The average response for the implementation of all circular strategies by respondents from fit-out companies was 1.6 out of 4. Sharing platforms (*M* = 0.3, *SD* = 0.5), service-based models (*M* = 0.4, *SD* = 0.5) and closed-loop recycling (*M* = 0.8, *SD* = 0.8) were the least implemented strategies. Circular materials (*M* = 2.5, *SD* = 1.2) and dematerialisation (*M* = 2.3, *SD* = 1.1) were the most implemented. One respondent (13%) selected 'Unsure' for open-loop recycling, social and cultural equity, and closed-loop recycling. For the 'not applicable' category, several circular strategies were selected by a single respondent. However, two respondents (25%) selected 'not applicable' for regenerating nature and sharing platforms, and three respondents (38%) selected organic recycling (for further details, please see Table F5).

5.3.3.6. Demolition Companies. For demolition companies, the average response for the implementation of circular strategies was 2.8 out of 4, which was the highest response among all business types. Respondents from demolition companies indicated that minimising waste on-site (*M* = 3.6, *SD* = 0.5), careful segregation (*M* = 3.5, *SD* = 0.7), pre-demolition audits (*M* = 3.5, *SD* = 0.5), recording waste data (*M* = 3.5, *SD* = 0.7), and selective deconstruction (*M* = 3.5, *SD* = 0.7) were the most implemented strategies. Regenerating nature (*M* = 1.7, *SD* = 1.0), organic recycling (*M* = 1.9, *SD* = 1.2), and relocation (*M* = 2.1, *SD* = 1.1) were considered the least implemented. Two respondents

(18%) selected ‘not applicable’ for preconstruction consulting, organic recycling, and regenerating nature (for further details, please see Table F6).

5.3.3.7 Waste Management Companies. The average response for the implementation of circular strategies within waste management companies was 2.2 out of 4. Respondents indicated that recording waste data was the most implemented strategy (*M* = 3.1, *SD* = 0.9), followed by infrastructure investment (*M* = 2.7, *SD* = 1.3), careful segregation (*M* = 2.6, *SD* = 0.8), and education, upskilling, and collaboration (*M* = 2.6, *SD* = 1.1). Closed-loop recycling (*M* = 1.3, *SD* = 1.5), regenerating nature (1.3) (*M* = 1.5, *SD* = 1.8), and organic recycling (*M* = 1.7, *SD* = 1.4) were the least implemented strategies. One respondent selected ‘Unsure’ for regenerating nature, and one respondent selected ‘not applicable’ for organic recycling (for further details, please see Table F7).

5.3.4 Other Circular Strategies

The participants were asked if the industry or their business/place of employment implements any other circular strategies or practices. While numerous respondents provided examples of strategies already described in the survey, several different strategies were also identified. For manufacturers, these strategies included waste-to-energy (biofuel and other waste streams), local processing for minimal truck movements, and capital investment. For architecture and engineering companies, strategies mentioned included office recycling, carbon accounting, natural building techniques, not specifying dwangs, sizing rooms to standard sheet sizes, and specifying products from suppliers practising product stewardship. For construction companies, strategies included adaptive reuse, returning offcuts to manufacturers, using efficient equipment, careful design to reduce earthworks, embodied carbon calculation, and compiling a list of material handling facilities. For design-build companies, a respondent noted the reuse of furniture through organisations such as All Heart and Junkrun. Strategies identified by respondents from fit-out companies included optimising material use in the design stage, memberships with environmental organisations, and being mindful of the specifications they make. For demolition companies, reporting on the destination of recovered materials, salvage yards, undertaking C&D waste recovery and recycling were noted. Strategies for waste management companies included waste audits, encouraging product stewardship, and recycling used oils from plant equipment.

5.3.5 Other Insights from Survey Respondents

Respondents were asked if they would like to share anything else regarding CE implementation. Several respondents acknowledged that the B&C sector is far from achieving a CE, describing the sector as "extremely wasteful" and "slow to uptake circularity" with "lots of room for improvement". Two respondents stressed sector-wide implementation, while many believed a CE must be driven by specific groups, including regulatory bodies, clients, manufacturers and suppliers, or architects. Moreover, two respondents mentioned the expression "lip service" to describe a lack of support from local government and suppliers. One of these respondents also noted that "the industry talks a big talk", and waste companies fail to uphold their promise to recycle materials.

Cost-related barriers were frequently cited. For example, a respondent noted: "Clients can't afford the basics, let alone the cost of sustainable initiatives". Respondents identified numerous other barriers, such as a lack of demand for used materials, risk-averse insurers, local regulations that prevent crushing concrete on-site, standards that prevent manufacturers from using recycled materials, and exporting wood products whilst there is an unreliable and unaffordable supply of green building materials locally. Respondents also noted the need for more recycling options, plastic waste solutions, education and resources, and the implementation of CBMs to demonstrate benefits to clients. On the other hand, several responses indicated that positive steps are occurring. They included remarks about implementing circular or sustainable practices, waste considerations in corporate strategy, steel recycling opportunities, and the environmental and financial benefits of a CE. One manufacturing respondent believed: "It's the future, and the sooner we align our practices with the circular economy, the better".

5.3.6 Significant Relationships

Chi-squared tests were performed to evaluate the relationship between the perceived maturity of CE implementation and sub-sector, business age, or business size. No significant associations were found between these variables (α = 0.05). Chi-squared tests of independence were also conducted to evaluate the relationship between the implementation of circular strategies and sub-sectors, business age, and business size. The results showed that the implementation of most circular strategies is not associated with sub-sectors, business age, or business size. However, a limited number of significant relationships between these variables were found. These relationships generally revealed a slightly higher level of implementation among larger and newer businesses. Please see Appendix G for more details.

5.4 Conclusion

This chapter has outlined the main findings of this research. The nine experts interviewed discussed the importance of circular strategies, and a few circular strategies were excluded from the survey based on their recommendations. The interviewees also discussed CE implementation, revealing that the CE concept is just emerging in New Zealand, and there is limited consideration for implementing circular practices. They also indicated the prevalence of greenwashing and noted that CE implementation is highly varied across a broad spectrum, concentrated on open-loop recycling or downcycling at the end-of-life stage, lacks consideration of higher value strategies and the design phase, and occurs in isolated siloes. However, interviewees acknowledged that awareness and interest in the CE concept, as well as sustainability and C&D waste, is increasing.

The survey results showed that respondents perceive the maturity of CE implementation in their business or place of employment as between ‘beginner’ and ‘established player’. Respondents indicated that circular strategies receive minimal to moderate levels of implementation on average. The most and least implemented circular strategies were discussed overall and per business type, revealing that most respondents consider the implementation of service-based models as particularly poor. Respondents identified other circular strategies occurring in the sector and shared other concerns, including slow uptake of the CE concept, requirements and barriers, particularly cost-related barriers, and positive steps towards circularity. Chi-squared tests of independence revealed that the maturity of CE implementation and the implementation of circular strategies is generally not associated with sub-sectors, business age, or business size.

6. Discussion

6.1 Introduction

This chapter discusses the key findings highlighted in the previous chapter to answer the research questions. It is divided into eight sections. Sections 6.2 and 6.3 discuss the interview results, including the relevant circular strategies and experts' perceptions of CE implementation. Sections 6.4–6.6 discuss the survey results, including respondents' perceptions of the maturity of CE implementation, the implementation of circular strategies, and the significant relationships between the survey variables. Finally, Section 6.7 concludes the chapter and suggests recommendations.

6.2 Relevant Circular Strategies

This section answers the research question: What circular strategies are relevant in supporting a CE transition among selected business types in the B&C sector in Aotearoa New Zealand?

The insights gathered from the interviews reveal that most circular strategies were considered relevant. The most notable exclusions from the survey were designing out waste and pollution and designing for longevity, as they could be accounted for through other strategies due to their overarching nature. Interviewees highlighted education, upskilling, and collaboration as the foremost priorities to garner support for adopting circular practices. Several other circular strategies were also emphasised for their potential to accelerate a CE transition, including adaptive reuse, dematerialisation, circular materials, design for disassembly/ deconstruction, design for standardisation, minimising waste onsite, offsite and modular construction, deconstruction, take-back schemes, service-based models, and regenerating nature.

The importance of these particular circular strategies is also explicated in the literature. Indeed, collaboration and bridging education and skills gaps are identified as essential levers to a CE transition, as entirely different mindsets, practices, and systems to business-as-usual are required from stakeholders across the value chain (ISO, 2023c, p. 36; WGBC, 2023, p. 73). Adaptive reuse and dematerialisation can deliver enormous material, waste, carbon, and cost savings (Arup & EMF, n.d.;

Zaman et al., 2023). Circular materials are pivotal, as closing loops and eliminating waste hinges on whether materials can safely return to the soil in biological cycles or be kept within continuous technical cycles while their value is retained (EMF, 2013, p. 26). Regenerating nature, a key CE principle (EMF, n.d.-a), is critical for rebuilding ecosystems and improving their health to maintain the provision of ecosystem services we depend upon (ISO, 2023c, p. 35; Mhatre et al., 2021).

Other circular strategies are recognised for their potential to extend and close loops. Deconstruction and designing for disassembly/deconstruction are also pivotal, as they unlock various end-of-life options, including relocation, reuse, and recycling (Eberhardt et al., 2022; Zaman et al., 2023). Design for standardisation fosters a consistent reuse market (Finch et al., 2021; Guerra & Leite, 2021) while streamlining processes, avoiding offcuts, and prolonging product lifespans (Eberhardt et al., 2022). Minimising waste onsite is crucial to recovering waste materials (Zaman et al., 2023), while offsite and modular construction can be prioritised for significant waste reduction (Shooshtarian et al., 2022). Additionally, take-back schemes are a significant opportunity to advance circularity by enabling material recovery (Adams et al., 2017; Bendix et al., 2022). Furthermore, service-based models are central to the CE concept as they decouple revenue generation from resource consumption and reduce dependency on the volume of products supplied (ISO, 2023c, p. 31).

The emphasis on the aforementioned circular strategies underscores their potential to catalyse transformative change towards a CE in Aotearoa New Zealand's B&C sector. Stakeholders can make informed decisions and generate engagement in circular practices by prioritising education, upskilling, and collaboration. The other strategies identified can be adopted to potentially make significant progress towards closing and extending material loops while contributing to nature regeneration. Interviewees also emphasised the importance of the design phase and keeping materials at their highest value by adhering to the waste hierarchy and prioritising reuse before recycling. These observations reflect CE theory, which acknowledges designing out waste and pollution, circulating products and materials at their highest value, and the waste hierarchy/re-principles as important principles (as discussed in Section 2.3.3).

6.3 Experts' Perceptions of CE Implementation

This section answers the research question: What are experts' perceptions on the current state of CE implementation among selected business types in the B&C sector in Aotearoa New Zealand?

6.3.1 CE Implementation is Unsatisfactory

Interviewees indicated that CE implementation is not yet prioritised, lags behind other countries, and is still largely unsatisfactory, novel, and unfamiliar. This suggests CE implementation is at an early stage in Aotearoa New Zealand's B&C sector, reflecting observations in previous research. For example, Jamieson and MacEwan (n.d.) note that the CE transition is 'at the beginning of the curve' in Aotearoa New Zealand, particularly compared to European and other Asia Pacific counterparts. Similarly, Guerra et al. (2021) noted that CE is still gaining recognition in regions such as Australasia. In addition, a Sustainable Business Network (SBN) report found that CE implementation is advancing slowly in Aotearoa New Zealand, despite the pressing urgency posed by sustainability challenges (SBN, 2021, p. 6, 13). Instead of systemic adoption of CE principles, cost, speed, and bespoke builds remain a priority in the B&C sector (Griffin et al., 2018, p. 41).

Interview findings suggested a lack of end-of-life solutions for certain types of C&D waste and pointed to the continual landfilling of C&D waste, contradicting New Zealand's 'clean, green' reputation. This resonates with the findings of Finch et al. (2021), who observed that the dominant construction approach exhibits poor CE performance despite New Zealand's emphasis on its natural environment and status as a pioneer in sustainable practices. This highlights a need for a reassessment of priorities and transformative action to address the prevalent use of linear materials incompatible with a CE.

Interviewees also highlighted a lack of client ambition, capital investment, consideration of non-financial metrics, time and money, manual deconstruction, deconstructable building products, take-back schemes, careful segregation, and regeneration. In addition, survey respondents identified economic barriers as a significant constraint. Therefore, addressing these factors, among the other barriers outlined in Sections 3.2.8 and 3.3.1, could promote circularity in the B&C sector. For example, it is crucial that developers, government agencies, and other architecture and engineering clients require cooperation between capital and operation teams and incorporate non-financial knowledge into capital budgeting decisions to account for a sustainable operational life (Frost & Rooney, 2021). This approach could facilitate the integration of circular and regenerative building features.

While Aotearoa New Zealand's progress may lag behind other countries, CE implementation in the B&C sector is still in its infancy globally (Akhimien et al., 2021), as mentioned in Chapters 1–3. According to Barreiro-Gen and Lozano (2020) and Eberhardt et al. (2022), a significant gap exists between CE theory and the practical implementation of CE principles. Osobajo et al. (2020) argue that existing efforts fall short of supporting a true CE transition. Adoption is slow due to a lack of understanding of the practical application of CE (Benachio et al., 2020), which may stem from poor to moderate levels of awareness (as discussed in Section 3.2.4) and a lack of adequate, comprehensive, and transformational policies (as discussed in Section 3.2.9). Thus, addressing this gap suggests an urgent need for innovative and alternative approaches, more transformative policies, and awareness and education campaigns to align clients' expectations and priorities with circular practices.

6.3.2 Implementation is Varied

Interviewees across several business types agreed that CE implementation across Aotearoa New Zealand's B&C sector is characterised by inconsistency and variability. Inconsistency is particularly evident in take-back schemes; while some businesses are progressing, the overall picture is that implementation is unsatisfactory and uneven, with a broad spectrum of commitment and engagement. Businesses range from those deeply invested in sustainable practices to those that lack basic waste management and environmental considerations, with others falling in between. Studies conducted internationally have also shown that the implementation of CE practices is inconsistent, not widely adopted, and often only limited to specific applications (Adams et al., 2017; Buser et al., 2021; Guerra et al., 2021; Guerra & Leite, 2021; Wijewansha et al., 2021). The variation of CE implementation highlights the challenge of achieving consistent and widespread adoption of CE principles across different businesses in the sector, indicating a need for increased awareness, standardised approaches, and regulatory measures to promote more consistent and widespread adoption of CE strategies.

6.3.3 A Lack of Focus on the Design Stage and Overfocus on Recycling

Several interviewees characterised current efforts to recover materials for a CE as the 'ambulance at the bottom of the cliff', indicating a lack of proactive measures early in the life cycle leading to ineffective solutions at the end-of-life stage. Interviewees reported that circular strategies at the design and planning phase, such as design for disassembly, design for adaptability, design for standardisation, and circular materials, are generally not considered and are poorly implemented. At the end-of-life stage, there is an overfocus on demolition and recycling and a lack of emphasis on manual deconstruction and reuse. Stakeholders perceive landfill diversion and open-loop recycling or downcycling outcomes as a success, although they tend not to be genuinely circular solutions. Moreover, businesses tend to rely on waste management companies to find solutions after the waste has already been generated instead of proactively addressing the issue.

An SBN report corroborates these findings, arguing that New Zealand businesses must focus on engaging with progressive strategies and designing out waste instead of waste diversion and recycling, particularly in the B&C sector (SBN, 2021, p. 6, 13). These findings are also aligned with international research, which shows that recycling is the most implemented strategy worldwide (Morseletto, 2020b; Potting et al., 2017) and that there is a need for greater attention in the design phase (Asante et al., 2022; Bilal et al., 2020; Gerding et al., 2021; Wijewansha et al., 2021). Bertozzi (2022) noted that most circular strategies are adopted during the permit stage, excluding the design phase altogether.

Overemphasis on recycling could also be due to open-loop recycling/downcycling being perceived as the 'low-hanging fruit' (Guerra et al., 2021; Guerra & Leite, 2021). Moreover, Kirchherr et al. (2017) noted that the CE concept is often misinterpreted as merely revolving around recycling when businesses actually need to fundamentally overhaul production and consumption processes per the highest 9R principles and levels of the waste hierarchy. In the context of New Zealand's B&C sector, Gade (2022) also emphasised the need to promote 10R thinking. Overfocus on recycling and the end-of-life stage could result from the significant attention these subjects receive in the literature (as discussed in Section 3.2.1) and the implementation of policies that encourage downcycling while neglecting higher-priority practices (as discussed in Section 3.2.9). This highlights a need for researchers, policymakers, and B&C stakeholders to prioritise more transformative measures, circular design, and higher levels of the waste hierarchy and 9Rs.

6.3.4 Greenwashing Concerns

Greenwashing was a significant concern raised in the interviews, and survey respondents noted superficial or insincere expressions of support from local government, suppliers, and waste companies. In some cases, businesses engaging in greenwashing practices have positive intentions but fail to communicate their message effectively, especially when their initiatives are not yet advanced. This indicates that businesses making positive incremental steps towards circularity must be careful not to overstate their efforts. Gade (2022) also found that greenwashing is a concern in Aotearoa New Zealand's B&C sector. Greenwashing can occur due to a lack of understanding of the CE concept and, subsequently, mislabelling practices (Bertozzi, 2022). Unintended sustainability trade-offs or rebound effects, whereby circular practices encourage increased resource consumption, can also lead to greenwashing (Opferkuch et al., 2021; Zerbino, 2022). Businesses can avoid greenwashing and mispresenting overall sustainability performance by undertaking regular sustainability reporting, providing transparent and third-party verified information, and practising open dialogue with stakeholders (Lopes et al., 2023; Opferkuch et al., 2021).

However, interview findings revealed that greenwashing can also manifest as an intentional and calculated strategy to gain a competitive advantage. For instance, recycling solutions have been falsely promoted as closed-loop recycling, and businesses have also shown that they are content with sharing attractive reports despite being aware of inaccuracies. This suggests that New Zealand businesses have consciously created distorted superficial appearances whilst their alignment with circular principles is questionable or their efforts are not substantial. Addressing greenwashing requires policymakers to introduce education campaigns, more stringent regulations and penalties, and incentives that promote genuine adoption of circular principles and advancements to the CE (Lopes et al., 2023).

6.3.5 Siloed Innovation

Systems thinking and collaboration are key CE principles (as illustrated in Figure 7). However, the issue of siloed innovation emerged as a recurring theme from the interviews. Interviewees observed that CE implementation tends to occur in isolated pockets and called for increased collaboration for a cohesive sector-wide effort, as it is challenging for individual organisations to undertake a CE transition when the wider system remains static. This highlights the interdependence of system elements and the need to transcend organisational and sectoral boundaries to coordinate efforts from various actors and create transformative system-wide change. Additionally, challenges such as transport costs, a lack of economies of scale outside city centres, and economic barriers, as noted by survey respondents, may hinder systemic implementation.

As previously noted, the B&C sector has been known for having fragmented supply chains and an uncollaborative, siloed mindset (Ababio & Lu, 2023; Adams et al., 2017; Hart et al., 2019; Wuni, 2022b). The tendency toward siloed thinking was also recognised in the global scan of CE implementation in B&C companies (Guerra et al., 2021). This lack of collaboration and coordination is extended to how circular strategies are implemented, which can be described as a fragmented and uncoordinated approach (Akhimien et al., 2021; Eberhardt et al., 2022; Giorgi et al., 2022). This concern may be exacerbated by a lack of coherent, coordinated, and integrative policy approaches (as discussed in Section 3.2.9) and fragmented academic discourse that lacks a holistic systems perspective (as discussed in Section 3.2.1). Therefore, accelerating a successful CE transition demands a departure from isolated efforts and necessitates a coordinated, systems-thinking approach from researchers, policy-makers, and businesses to foster collaboration across the sector. Thus, the guiding principle of New Zealand's waste strategy *thinking across systems, places, and generations* is highly relevant (MfE, 2023a, p. 19) and interlinks with increasing social and cultural equity.

Systems thinking for a CE will involve tackling root causes, identifying leverage points for transformative systems change, determining systemic enablers, and shifting incentives (Circle Economy, 2024, p. 35). Moreover, a holistic systems-based transdisciplinary approach can help ensure linear practices are identified, systemic complexity is managed, burden-shifting is avoided, and policy measures are effective (Iacovidou et al., 2021). A grassroots or NGO-led initiative could provide a safe space where multi-partner collaboration can thrive (Diprose et al., 2022, p. 1). Producer Responsibility Organisations (PROs), such as those in Europe, Japan, and Canada, can also facilitate multi-partner collaboration, acting as intermediaries in implementing EPR (OECD, 2016, p. 76). Furthermore, transition brokers can coordinate system-level change by serving as neutral intermediaries that prepare, negotiate, finalise, scale up, and mainstream circular initiatives (Cramer, 2020).

However, where collaboration between economic agents is necessary to avoid the 'first mover disadvantages' of a CE, conflicts inevitably arise with competition law (Gerbrandy, 2019). Fear of legal repercussions or complex exemption processes disincentivises the collaboration necessary for systemic change. As demonstrated in Europe, there is a need to re-evaluate the narrow approach to competition law, which stifles urgent climate action, endorses the continuation of environmental degradation, and limits sustainable development to isolated and ad-hoc efforts (Holmes, 2020; Malinauskaite, 2022). Thus, investigating New Zealand's approach may be essential to ensure that vital collaboration is not hindered. Whether Commerce Commission (2023) guidelines for collaboration and sustainability enable straightforward collaboration for a CE remains to be seen.

6.3.6 Lack of Education

Interviewees observed a lack of education to support further CE implementation. Thus, more education and readily accessible information are required to rapidly address the knowledge gap, increase awareness, and promote informed decision-making. In various countries, researchers have found that stakeholders' awareness and understanding are generally insufficient to support a CE transition (see Section 3.2.4). There is confusion about what a CE involves, its benefits, and how it differs from other sustainability concepts (Adams et al., 2017; Adi & Wibowo, 2020; Bertozzi, 2022; Tomaszewska, 2020). A lack of awareness and understanding is unsurprising as the concept is considered relatively new (Murray et al., 2017; Winans et al., 2017). However, this issue may be compounded by a need for more supportive policies. Bilal et al. (2020) found that a lack of environmental regulations and laws leads to a lack of public awareness and support from public institutions, which, in turn, drives other significant CE barriers.

A lack of education, knowledge, and awareness are frequently cited barriers (Bilal et al., 2020; Charef et al., 2021; Liu et al., 2021; Mahpour, 2018; Mhatre et al., 2023; Wuni, 2022a). This is also echoed in New Zealand literature, which identifies a lack of knowledge, education, and training (Berry et al., 2022; Low et al., 2020; Purchase et al., 2022; Shanks, 2022). On the other hand, training courses and awareness and education campaigns are enablers that can mitigate these concerns (Adams et al., 2017; Bilal et al., 2020; Hart et al., 2019; Wuni, 2022a).

6.3.7 Increasing Awareness and Interest

Despite a general lack of awareness, understanding, and education about the CE concept, interview findings highlighted growing awareness and interest, particularly among leading-edge thinkers. Moreover, those focusing on sustainability and C&D waste may view the CE concept as a logical progression. In this context, CE practices are beginning to be viewed as attractive and cutting-edge, especially among those at the forefront of sustainable innovation and business practices.

These findings align with the global scan of CE adoption, which found that companies are beginning to integrate circular principles into their operations (Guerra et al., 2021). It was suggested that early adopters should persist in exploring untapped opportunities to advance circularity.

Interviewees also highlighted the rising prevalence of specific strategies, such as circular materials, modular and offsite construction, and BIM. This is supported by the *Building and Construction Sector Trends: Annual Report 2022*, which noted trends like retrofitting existing buildings, technologies such as digital twins, and waste-based construction materials (MBIE, 2022a, pp. 29–40). Furthermore, BIM, green buildings, and prefabrication were trends identified in the previous report. Alongside climate change and heightened environmental awareness, the increased awareness and adoption of circular practices could be a reflection of a growing number of publications (as discussed in Section 3.2.1) and the use of CE terminology in the Waste Strategy (MfE, 2023a) and the ERP (MfE, 2022, pp. 155–165).

6.4 Perceived Maturity of CE Implementation

This section answers the research question: How do professionals perceive the maturity of CE implementation in their business/place of employment?

Overall, the results indicate that B&C stakeholders perceived the maturity of CE implementation in their businesses at a moderate level of maturity on average (2.6 out of 5). However, higher average responses among demolition and waste management companies suggest that respondents from these business types perceived the maturity of CE implementation to be between ‘established player’ and ‘well-engaged categories’. This is in contrast to other business types whose average responses were slightly above the ‘beginner’ stage. These results suggest ample room for growth and development in advancing a CE transition across surveyed businesses. Moreover, well-engaged and mature categories were the least selected, indicating a noteworthy absence of advanced and mature CE implementation among surveyed businesses. These findings align with Cohen et al. (2022), which included a similar inquiry regarding how CE is perceived among construction stakeholders in Argentina. Despite 81% of firms indicating efforts to implement CE practices, only 10% integrate them into daily operations.

Higher average responses from demolition and waste management companies may signal more advanced CE implementation and commitment, reaffirming interview findings that suggest an overfocus on the end-of-life stage and reiterating the need for circular practices earlier in the life cycle. However, the operational focus of these business types is on end-of-life activities, occurring at the critical juncture where materials are either recirculated into the economy or follow the linear pathway. Thus, their contribution to circularity can have a more visible and tangible impact than other business types. Additionally, B&C businesses tend to have fragmented and complex supply chains (Charef et al., 2021; Wuni, 2022b). As such, other business types with longer or more complex supply chains may perceive CE practices as more challenging to implement, potentially leading to a slower adoption rate.

Furthermore, awareness of the CE concept among waste management companies may be driven by clients interested in improving the end-of-life outcomes for materials or avoiding costs due to the increasing landfill levy. This may lead waste businesses to highlight their efforts, improve the environmental impact of their operations, invest in technology and infrastructure, and collaborate with other stakeholders. However, as established from the interviews, there appears to be significant emphasis on open-loop recycling or downcycling. Given that the CE concept is often mistaken for recycling, which often does not effectively foster a substantial contribution towards a CE (Kirchherr et al., 2017), this may lead respondents from demolition companies, waste management companies, and other types of businesses that engage in downcycling to perceive their CE performance as higher than reality.

6.5 Implementation of Circular Strategies

This section answers the research question: What is the current level of implementation of identified circular strategies among businesses in the B&C sector in Aotearoa New Zealand, and which circular strategies require greater attention to accelerate the transition?

The results indicated that stakeholders from manufacturing, architecture and engineering, construction, design-build, and fit-out businesses perceive the implementation of circular strategies to be between minimal and moderate levels in their business. However, respondents from demolition and waste management companies perceive the implementation of circular strategies in their business as slightly higher, between moderate and significant levels, reflecting the findings on the maturity of CE implementation. Across all business types, implementation was perceived to be moderate (1.9 out of 4). Therefore, there is significant potential for expansion and progress in implementing circular strategies to accelerate a CE transition among surveyed businesses in Aotearoa New Zealand. As discussed in the previous section, a higher perception of implementation among respondents from demolition and waste management companies could indicate more advanced implementation and confirm interview findings that suggest overemphasis on the end-of-life stage. However, it could also indicate that these business types have a more visible contribution or overestimate the circularity of open-loop recycling/downcycling, among other factors.

The results align with similar studies conducted in other countries that reported unsatisfactory, insignificant, and inadequate implementation, with levels ranging from low to above moderate (as discussed in Section 3.2.5). The findings of this study are also comparable, although slightly lower, than similar studies that calculated averages on implementation. For example, Bilal et al. (2020) reported an average score of 2.9 out of 5.0 or 58% for the implementation of CE indicators in 16 developing countries. Additionally, Amudjie et al. (2022) obtained average scores ranging between 2.5 and 3.3 out of 5.0 for the practice of six CE principles in Ghana. In Indonesia, Adi and Wibowo (2020) documented an average of 3.5 out of 5.0 for the implementation of 12 CE aspects. The slightly lower results observed in this study support previous research findings, which suggest that the CE concept is still gaining recognition in regions such as Australasia (Guerra et al., 2021) and that Aotearoa New Zealand is transitioning slowly, particularly in the B&C sector (SBN, 2021, p. 6, 13), as noted in Section 6.3.1.

However, a limitation of this study, along with similar research, is that an exact measure of circularity is not provided. Given that the circularity of the global economy stood at a modest 7.2% in 2023 (Circle Economy, 2023, p. 8), and that the B&C sector accounts for approximately 50% of raw material consumption (UNEP, 2022, p. xvi) and 35% of landfill waste (Chen et al., 2022), the actual implementation of circular strategies might be lower. This further underlines an urgent need for increased awareness and understanding of mature CE implementation among B&C stakeholders.

6.5.1 Strategies that Require Greater Attention

The results indicate that the vast majority of circular strategies are not widely implemented by the surveyed companies. Arguably, the strategies currently implemented the least overall have the most potential to accelerate a CE transition (i.e., service-based models, sharing platforms, material passports, remanufacturing, take-back schemes, organic recycling, and regenerating nature). In addition to these strategies, the results suggest that architecture and engineering firms need to improve their adoption of measuring circularity, whilst fit-out companies can improve their adoption of closed-loop recycling and recording waste data.

In similar papers, circular strategies and business models that received low adoption included design for disassembly, closed-loop recycling, modular construction, material passports, industrial symbiosis, use of secondary materials, sharing platforms, and Product as a Service (PaaS) (Adi & Wibowo, 2020; Amudjie et al., 2022; Cohen et al., 2022; Guerra & Leite, 2021; Guerra et al., 2021; Lee et al., 2023). Low adoption can be due to perceived complexity; for example, PaaS, sharing platforms, and design for disassembly are associated with more complex barriers than waste as a resource and utilising circular materials (Guerra et al., 2021). Levels of adoption may also be correlated with what may be perceived as profitable. It is increasingly widely recognised that improving efficiency and reducing waste can increase profitability. This may explain why the strategies of selective demolition, minimising waste on-site, waste as a resource, efficient processes, and circular materials receive moderate to significant levels of implementation in this study. The following seven sub-sections discuss the circular strategies that received the lowest overall averages.

6.5.1.1 Service-based models. Service-based models were the least implemented circular strategy in this study. Additionally, 20% of manufacturing respondents selected 'not applicable' for service-based models, which may signify a lack of familiarity with how this strategy can be applied or reluctance to change established business models. The absence of manufacturers offering products as services will, in turn, limit the ability of other business types to specify or procure products as services. A lack of implementation is also observed in Europe, where service-based models for building products are generally not applied in practice or considered in legislative frameworks (Giorgi et al., 2022). Moreover, the global scan of CE implementation by Guerra et al. (2021) found that PaaS was the least implemented business model, potentially due to a lack of understanding, perceived complexity, and disruption to business practices. Nonetheless, 'as-a-service' models have been applied to entire buildings, roads, bridges, the provision of water and energy, solar panels, HVAC and climate systems, drains and plumbing, façades, lifts, lighting, carpet tiles, audio-visual equipment, and furniture (Anastasiades et al., 2020; Circle Economy & ABN AMRO, 2017, pp. 10–11; Circle Economy et al., p. 22; Fischer et al., 2020a, 2020b).

Despite this, financiers remain cautious, given the uncertainties stemming from limited adoption that could demonstrate the long-term performance of a PaaS business model (Fischer et al., 2020b). This is exacerbated by the long life cycles of buildings (Giorgi et al., 2022). Accelerating the implementation of this strategy requires financial regulators to revise policies to accommodate service-based models and financial institutions to challenge risk models and develop appropriate financing structures conducive to CBMs (Fischer et al., 2020a, 2020b; Ramirez Bañales, 2021). A shift in perspective, acceptance, and commitment from stakeholders and the wider society is also required (Illankoon & Vithanage, 2023). This necessitates stakeholder and consumer education to shift mindsets away from ownership of material resources. Furthermore, direct and indirect policy actions and Industry 4.0 technologies such as RFID, IoT, BIM, and big data analytics can be leveraged to increase the implementation of service-based models (Cruz Rios & Grau, 2019; Han et al., 2020).

6.5.1.2 Sharing Platforms. This circular strategy received the second lowest score in this study, with particularly low averages from construction, design-build, and fit-out companies. This implies a need for these business types to consider utilising sharing platforms to maximise product utilisation, thereby reducing raw material consumption (Mhatre et al., 2021). Sharing platforms are also the second least adopted business model in the global scan of CE implementation in the B&C sector (Guerra et al., 2021). In addition, Lee et al. (2023) found that shared material markets and shared furniture or supplies platforms receive low levels of adoption, which was attributed to closed attitudes towards sharing. This highlights the importance of education and awareness campaigns to communicate the advantages of sharing to overcome traditional practices and the stigma of used items. Moreover, focus on overcoming barriers, including a perceived increase in effort, lack of trust, performance or safety concerns, economic or legal risks, market uncertainty, and social and cultural barriers, such as an unwillingness to share, will aid in the promotion of using sharing platforms (Jabbour et al., 2020; Spindeldreher et al., 2019). Civil Share and Mutu are examples of online sharing platforms in Aotearoa New Zealand that businesses can use to ensure the reuse of building products and materials (Low et al., 2020; SBN, 2022, 2023).

6.5.1.3 Material Passports. Material passports were the third-least implemented strategy, with construction and fit-out companies showing particularly low implementation. Material passports also emerged as one of the least implemented strategies among construction stakeholders in Argentina (Cohen et al., 2022), and Lee et al. (2023) found a relatively modest rate of adoption among construction companies in Taiwan (Lee et al., 2023). These results are somewhat expected, considering that material passports are a relatively recent innovation still being explored, with limited literature on the topic (Honic et al., 2019; Munaro & Tavares, 2021).

Nonetheless, it is clear that material passports have the potential to play a crucial role in enhancing the likelihood of reuse and recovery of building materials (Benachio et al., 2020; Giorgi et al., 2022). The development of materials passports has been demonstrated in Europe through Project BAMB, which resulted in the development of 345 product passports from 94 manufacturers, seven building passports, and 47 ‘instances’ or occurrences of products that can be linked to a building (BAMB, 2019, p. 3). Systems thinking, stakeholder collaboration, and government support through supportive laws and tax incentives can be employed to foster the widespread adoption of material passports (Munaro et al., 2019). Moreover, Göswein et al. (2022) highlighted the need for standardised and regulated use of material passports and argued the need for a legal standard, such as the ISO 14025 for EPDs.

6.5.1.4 Remanufacturing. The limited implementation of remanufacturing suggests that surveyed manufacturers could consider increasing engagement with this strategy to promote circularity in New Zealand’s B&C sector as a more progressive strategy than recycling (Potting et al., 2018). The overall average is slightly below the global scan of CE implementation, which showed that remanufacturing was adopted by about a quarter of the companies studied (Guerra et al., 2021). This could be attributed to these companies being concentrated in the USA and Europe, where remanufacturing is becoming an increasingly popular product recovery method (Ohiomah & Sukdeo, 2022). Successful remanufacturing programmes are supported by design for remanufacturing, an effective collection strategy, management commitment, a positive brand image and reputation, modern technologies, and skilled workers, among other critical success factors (Khan, Ali, et al., 2022; Khan, Haleem, et al., 2022; Singhal et al., 2020). Shifting consumer attitudes away from ‘one-time consumption’ and correcting misconceptions about quality and safety highlight a need for stakeholder education (Singhal et al., 2020). Governments can provide stringent take-back and EPR laws and introduce incentives that promote remanufacturing for a CE.

6.5.1.5 Take-back Schemes. Take-back schemes also received a low score on average, indicating minimal take-back activity among surveyed manufacturing companies. These findings are supported by observations from the interviewees representing manufacturing companies, who emphasised the lack of take-back schemes in Aotearoa New Zealand’s B&C sector. Product take-back is associated with serviced-based models and EPR (Charef et al., 2022; Sharma et al., 2022) or, in the case of New Zealand, product stewardship. Envirocon, which utilises waste concrete to produce the

Interbloc Modular Wall System, is the only accredited construction-related product stewardship scheme in New Zealand (MfE, 2020). However, it can be argued that the refrigerant recovery scheme for air conditioning, Resene's PaintWise scheme, and the Interface ReEntry Programme for carpet tiles (MfE, 2022a) also apply to the broader B&C sector.

Manufacturers aiming to develop effective take-back schemes can enhance their efforts by designing for disassembly and recycling, providing product labelling and documentation, developing cost-effective reverse logistics systems, undertaking health and safety risk management, and prioritising reuse, repair, and reconfigurable remanufacturing systems before recycling (Andersen et al., 2023; Bendix et al., 2022; Shooshtarian, Maqsood, et al., 2021). Additionally, EPR policy can be implemented to support take-back schemes. However, the policy stance on EPR must transition from voluntary to mandatory arrangements (Shooshtarian, Maqsood, et al., 2021).

The roll-out of product stewardship/EPR approaches in Aotearoa New Zealand has been slow and, until recently, largely voluntary (Blake et al., 2019; Hannon et al., 2018; Blumhardt, 2021, p. 64). This appears due to both the technical complexity of product stewardship/EPR and the lobbying of vested interest industry groups, which undermined public consensus and political leadership (Espiner, 2023; Hannon, 2018). This is despite guidance from the Parliamentary Commissioner for the Environment (2006), widespread endorsement from the local government and the public, and overwhelming evidence of the ineffectiveness of voluntary approaches (Hannon et al., 2018; Blumhardt, 2021, p. 64).

However, MfE (2019) recognised the low participation levels and product recovery rates under existing voluntary schemes (p. 11) and have declared six priority products for regulatory product stewardship (p. 18), none of which are for building products. Additionally, as announced under the previous government, potential new legislation will aim to strengthen existing powers regarding EPR (MfE, 2023a, p. 29; 2023b). EPR policy should promote prioritisation of the higher levels of the waste hierarchy and integrate circular design requirements (Blumhardt, 2021, p. 68; Campbell-Johnston et al., 2021). Considering the historically limited effectiveness of voluntary schemes and that C&D waste constitutes approximately 50% of total waste generation (BRANZ, 2023), there is a need for mandatory product stewardship/EPR schemes for building products to encourage sector-wide adoption of take-back schemes.

6.5.1.6 Organic Recycling. Long-lived assets, such as buildings and infrastructure, predominantly contain technical nutrients (EMF, 2013, p. 37). Consequently, it is unsurprising that 35% of respondents from manufacturing companies deemed this strategy 'not applicable', and that the average overall score for this strategy was low. This could be attributed to the extensive use of boron-treated radiata pine and gypsum plasterboard in the residential sub-sector (Finch et al., 2021) and the persistence of plasterboard and timber as significant waste streams in terms of mass and GHG emissions (Dixon & Vickers, 2022, p. 5).

Winstone Wallboards, the only manufacturer of gypsum plasterboard in New Zealand, is investigating various solutions, including gypsum for agricultural and horticultural uses (see Dixon & Vickers, 2022, pp. 27–31; Fletcher Building, 2021, p. 2). Boron and Copper Chrome Arsenic (CCA) treatments prevent closed loops for timber (Finch et al., 2021). This is reinforced by the standards *NZS 3602* and *NZS 3640*, which stipulate minimum boron and CCA preservative timber treatment levels and are considered acceptable solutions to comply with *Clause B2—Durability* of the Building Code (MBIE, 2019, p. 17). The utilisation of another timber treatment is separately assessed for compliance with the Building Code. Therefore, while it is possible to use thermal modification instead, promoting a sector-wide CE transition necessitates changes to this process. Deconstructability is also crucial to avoid contamination from fixings and adhesives (Finch et al., 2021). Furthermore, the transition from oil-based plastics to biocomposite materials represents an attractive paradigm shift, if designed to be regenerative (Oberti & Paciello, 2022). Therefore, ensuring sufficient solutions to close bio-loops will become increasingly relevant, particularly if upcoming changes to waste legislation limit or ban organic waste from entering landfills (MfE, 2023a, p. 48).

6.5.1.7 Regenerating Nature. The results indicate that regenerating nature is neglected across all surveyed companies, particularly construction companies, confirming Interviewee 5's observation that regeneration is "not yet" a consideration among construction contractors. This finding indicates that surveyed B&C companies must undertake significant changes to ensure that "regeneration is the norm and part of our circular business models" by 2050, as stated in New Zealand's Waste Strategy (MfE, 2023a, p. 24). This is unfortunate as participation from the B&C sector could reduce its significant contribution to environmental degradation, the breach of planetary boundaries, and the global biodiversity crisis (Circle Economy, 2023, p. 34; WGBC, 2023, p. 57). However, a lack of focus on regeneration is also expected, given that the sector prioritises cost, speed, and bespoke builds (Griffin et al., 2018, p. 41), as previously established. Furthermore, actors in New Zealand that adopt CE language tend to neglect EMF's third principle of regenerating nature (Diprose et al., 2022).

The key challenges of regenerating nature are financing and funding, knowledge gaps, and a need for more conclusive research regarding the effectiveness of nature-based and regenerative solutions (WGBC, 2023, p. 64). Additionally, there is a need for robust measures and standards for scaling up solutions, ensuring that the outcomes minimise unintended social and environmental consequences. B&C businesses aiming to regenerate nature can align their business models with regenerative practices and minimise harmful practices, integrate regenerative building features, employ nature-based solutions and biomimicry, replenish natural resources as they are used, actively rebuild ecosystems, enhance biodiversity, and utilise renewable and regenerative materials (Circle Economy, 2023, p. 58; ISO, 2023c, p. 43; MfE, 2023a, p. 19; WGBC, 2023, pp. 58–63). Regarding regenerative buildings, insights can be gleaned from several Living Building Challenge projects (see Figure 13), providing a basis for scaling up solutions.

Research and policymaking for the built environment tend to narrowly focus on recycling and closing loops while neglecting ecologically regenerative and adaptive actions, necessitating policy revision (Bucci Ancapi et al., 2022). Moreover, CE policies must prioritise renewable resources and dematerialisation to operate within planetary boundaries and ensure that resource extraction rates do not surpass regeneration rates or the absorptive capacity of the Earth (Suárez-Eiroa et al., 2019; Velenturf & Purnell, 2021). For example, policymakers can implement environmental taxation, such as the Ex'tax model, which involves a budget-neutral tax shift that transfers the burden from labour to pollution and resource use, as required by the European Green Deal (Groothuis, 2022). Environmental taxation can be finely tuned based on systematic measurement and monitoring of natural capital (Circle Economy, 2023, p. 58).

6.6 Significant Relationships

This section answers the research question: Are there any associations between business age, size, or sub-sector and the maturity of CE implementation or implementation of circular strategies?

As highlighted in Section 5.3.6, there are no significant associations between business age, size, or sub-sector and the maturity of CE implementation. In instances where significant relationships were identified between these variables and the implementation of circular strategies, larger and more recently established businesses tended to demonstrate a slightly elevated level of implementation. Lee et al. (2023) attained similar results, finding that the implementation of only one strategy (building-scale wastewater treatment and reuse system) correlated with company size, which was more prevalent among medium and large companies in Taiwan. However, a global scan of CE implementation found that the CE transition is primarily driven by newer and smaller companies (Guerra et al., 2021). Smaller companies may perceive innovative approaches as opportunities to attain a competitive edge, although insufficient capital and upfront costs can be significant barriers (Guerra & Leite, 2021; Lee et al., 2023; Rizos et al., 2015). Conversely, larger companies have greater access to resources but tend to be more conservative and cautious, favouring familiar and straightforward strategies (Guerra et al., 2021; Lee et al., 2023).

6.7 Conclusions & Recommendations

This research has found that CE implementation in the B&C sector in Aotearoa New Zealand is still in its early stages. While early adopters are beginning to show interest, progress may be trailing behind global counterparts. Findings suggest that researchers, policymakers, and B&C stakeholders in Aotearoa New Zealand and internationally tend to approach circularity with a focus on the end-of-life stage, particularly open-loop recycling/downcycling, providing limited contributions to a CE and neglecting regeneration. Findings also suggest that greenwashing is a concern and commitment from businesses is highly varied. Where committed businesses are making meaningful advancements, they are likely occurring in siloes. Accelerating a CE transition requires a coordinated effort, as individual and isolated efforts are challenging within a static system. Significant opportunities remain to address knowledge gaps and increase engagement in circular strategies, such as service-based models. In this context, given the current absence of assertive well-designed government interventions to promote a CE and create a level playing field for businesses, the following recommendations, although demanding, are suggested for making substantial advancements toward a CE in Aotearoa New Zealand's B&C sector.

Recommendations for all actors:

1. All actors should consider how to increase engagement in circular strategies and address the highest possible tiers of the waste hierarchy/9Rs in descending order of impact (i.e., refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, and repurpose) before resorting to recycling, particularly open-loop recycling or downcycling.
2. All actors should adopt systems thinking and a holistic, transdisciplinary, and collaborative approach for a coordinated and equitable shift.
3. All actors should consider actively engaging in creating and/or participating in awareness campaigns and educational and training initiatives to promote informed decision-making, increase client ambition, and shift mindsets on deconstruction, ownership, and used items.

Recommendations for businesses:

1. Businesses in the design and planning phase should work towards eliminating waste and pollution from the outset, prioritising strategies such as adaptive reuse, dematerialisation, circular materials, and design for disassembly/deconstruction while avoiding incompatible adhesives, spray foams, sealants, fixings, nails, and wood treatments.
2. Manufacturers should consider transitioning to service-based models, establishing take-back schemes, and, where appropriate, developing remanufacturing programmes.
3. Demolition businesses should shift to deconstruction and identify reuse opportunities.
4. Architecture and engineering clients should facilitate cooperation between capital planning and operational departments and integrate non-financial considerations to promote investment in circular and regenerative features, which may ultimately provide cost savings.
5. Financial institutions should develop appropriate financing structures and challenge risk models to support service-based models.
6. All businesses should exercise caution to avoid greenwashing and ensure that claims are substantiated with transparent and third-party verified information.

Recommendations for policymakers:

Policymakers should aim to develop transformative, coherent, coordinated, and integrative policy approaches that encourage system-wide CE transition and level the playing field. Among policy measures outlined in Section 3.2.9, it is suggested that policymakers consider:

1. Developing supportive policy measures and tax incentives for adopting circular strategies, such as adaptive reuse, service-based models, deconstruction, remanufacturing, material passports, and regenerative practices;
2. Strengthening EPR powers to promote circular design and high-value circular strategies, with the intention of increasing mandatory participation for building products;
3. Reviewing and revising competition law to ensure it does not disincentivise the collaboration needed for a system-wide CE transition;
4. Reviewing and revising financial regulations to accommodate service-based models;

5. Reviewing and revising compliance with NZS 3602 and NZS 3640 to support a phase-out of boron and CCA timber treatments that prevent timber from being recycled or returned safely to biological cycles;
6. Adjusting environmental taxation according to systematic measurement and monitoring of natural resources;
7. Exploring the applicability of the Ex'tax model, or a budget-neutral tax shift transferring the burden from labour to pollution and resource use; and
8. Developing regulations and penalties to address greenwashing.

7. Conclusion

7.1 Introduction

This concluding chapter first summarises the main findings obtained from this exploratory sequential mixed-methods study on the level of CE implementation among businesses in Aotearoa New Zealand's B&C sector. It then discusses the contribution and implications of this research and concludes with future work and research opportunities.

7.2 Summary of the Main Findings

This study aimed to assess the current level of implementation of the CE concept among businesses in the B&C sector in Aotearoa New Zealand. An exploratory sequential mixed-methods design was employed to develop a survey enhanced by insights gained from expert interviews. Most of the circular strategies presented to interviewees were considered relevant, with only a limited number excluded from the survey. Interviewees also identified some strategies as particularly important, most notably education, upskilling, and collaboration. Other important strategies included adaptive reuse, dematerialisation, circular materials, design for disassembly/deconstruction, design for standardisation, minimising waste onsite, offsite and modular construction, deconstruction, take-back schemes, service-based models, and regenerating nature. The importance of the design phase and adhering to the waste hierarchy were also highlighted.

Interview findings also suggest that the current state of CE implementation in the B&C sector is in a nascent stage in Aotearoa New Zealand, lagging behind international advancements. A notable focus on recycling in the end-of-life stage, particularly on open-loop recycling or downcycling, is evident, overshadowing the critical design phase, which tends to be overlooked. Consequently, the current approach to a CE falls short of making substantial advancements and can be described as the 'ambulance at the bottom of the cliff'. There are challenges in addressing particular waste streams, highlighting the widespread use of materials incompatible with a CE. Experts further pointed out that businesses exhibit differing levels of commitment, with some masking their actual efforts through greenwashing. Advancements occur in isolated siloes, highlighting the need for enhanced collaboration and a systemic approach for a coordinated CE transition. Furthermore, CE implementation is hindered by a lack of education. Nevertheless, there was observed growth in awareness and interest, particularly among businesses leading in sustainable innovation and adopting forward-thinking approaches.

The survey results provide a high-level overview of the current state of CE implementation and insight into the state of implementation of key circular strategies. The findings suggest that most professionals perceived the maturity of CE implementation in their businesses or workplaces at a ‘beginner’ stage. However, on average, respondents from demolition and waste management companies indicated higher maturity levels, between the ‘established player’ and ‘well-engaged’ stages. Survey findings also show that the current level of implementation of circular strategies among surveyed businesses in the B&C sector in Aotearoa New Zealand is moderate. Respondents from manufacturing, architecture and engineering, construction, design-build, and fit-out businesses reported minimal to moderate levels of implementation on average. In contrast, respondents from demolition and waste management companies were again recognised for indicating higher levels of circular strategy implementation, averaging at moderate to significant levels. While this could suggest a more mature state of implementation, efforts at the end-of-life stage may be more visible and tangible than other life cycle phases, and the impact of open-loop recycling or downcycling may be overestimated. It was found that larger and more recently established businesses tended to exhibit a slightly higher degree of implementation for some circular strategies.

These results are comparable to similar studies conducted in other countries, which have found low to above moderate levels of CE implementation—inadequate for the scale of transition required. The results of this study indicate that most circular strategies require greater attention to accelerate a CE transition, with most circular strategies yet to be implemented to a significant extent among surveyed companies. However, service-based models, followed by sharing platforms, material passports, remanufacturing, take-back schemes, organic recycling, and regenerating nature, appear to receive the least implementation, thus potentially requiring the greatest attention.

In sum, the findings of this research suggest that the current level of CE implementation among businesses in Aotearoa New Zealand's B&C sector is at an early stage and characterised by independent efforts and limited contributions at the end of material lifecycles. Therefore, there is an urgent need for proactive measures from the design phase, replacement of materials incompatible with a CE, and a more comprehensive, systemic, and collaborative approach. There are significant opportunities for businesses to increase their engagement in circular practices further to accelerate a CE transition.

7.3 Contribution and Implications

As discussed in Chapters 1 and 2, the CE concept can be considered a promising solution to address global sustainability challenges (Murray et al., 2017; Winans et al., 2017). This research contributes to the existing body of knowledge on CE in the B&C sector, recognising that the significant environmental impacts of the B&C sector suggests that the sector must play a significant role in achieving a CE. Despite being the biggest contributor to landfill waste, CE-focused research on this sector is relatively limited in the Aotearoa New Zealand context (e.g., Balador et al., 2020; Berry et al., 2022; Finch et al., 2018, 2021; Finch, 2023; Fitwi, 2023; Gade et al., 2020; Gade, 2022; Low et al., 2020; Purchase et al., 2022; Roy, Dani, et al., 2022; Roy, Su, et al., 2022; Shanks, 2022; Zaman et al., 2018). As such, a research gap was addressed by shedding light on the state of CE implementation among B&C businesses. It provides insight into how experts perceive the state of implementation and how professionals perceive the maturity of CE implementation and the implementation of circular strategies in their business. In addition, this research synthesises current literature into the background and literature review chapters.

The practical implications of this research extend to B&C stakeholders from manufacturing, architecture and engineering, construction, design-build, fit-out, demolition, and waste management companies. Stakeholders can leverage the findings, which highlight the circular strategies that businesses should prioritise according to interviewees and those that require greater attention according to survey results, among other recommendations, to transition towards a CE and avoid the environmental impacts that linear practices inflict. In addition, the findings underscore a need for more transformative and progressive policy, and recommendations for policymakers were suggested.

7.4 Future Directions

A CE transition represents a fundamental paradigm shift in our resource utilisation practices, thereby presenting a plethora of opportunities to challenge entrenched linear systems in the B&C sector, overcome institutional barriers, and embrace circular solutions. Developing robust strategies, targets, and roadmaps founded on international best practices is crucial to bridge the rhetoric-action gap and measure progress. Modelling can demonstrate the benefits and repercussions of enforcing systemic action or choosing inaction and fragmented efforts. However, as discussed in Chapter 2, accelerating a CE implementation is hindered by lobbying efforts from vested interest industry groups (Espiner, 2023; Hannon, 2018). Moreover, if historic patterns reoccur, the recent election of a right-wing coalition government may provide a challenging future environment for CE implementation. The newly established CE policy framing, NZWS:2023, can be considered as environmentally assertive as the past zero waste NZWS:2002, which was subsequently abandoned in a historically similar right-ward swing in political ideology (Hannon, 2018). In addition, recent coalition agreements have been criticised for their 'backward' stance on environmental policies (Prickett & Hales, 2023; Wannan, 2023; White, 2023).

However, there are reasons for optimism and avenues for progress, including awareness and education campaigns, corporate responsibility, engaging stakeholders and network building, academic research, grassroots initiatives, and advocating for legislative reforms, economic incentives, and lobbying transparency. By rethinking and redesigning processes to embrace a CE, exciting R&D opportunities could be unlocked to create innovative, deconstructable solutions that align with technical or biological cycles. Successful projects can be used as a case study for advancing progress. Additionally, opportunities exist for research to explore the design phase, higher-priority solutions than recycling, and the effectiveness of regenerative and adaptive solutions. Stakeholders can be encouraged to think in systems and come together to develop a cohesive approach that aligns with global advancements while also considering local contexts.

Several research endeavours can be identified to build on this study. Future studies could survey companies in a more representative manner or conduct in-depth interviews with a broader range of experts and stakeholders, including developers and clients. Further studies could also consider exploring CE implementation in greater depth by drawing on quantitative data based on CE indicators and metrics or conducting detailed investigations into implementing specific circular strategies. Finally, the study could be replicated in smaller geographical regions, particular industries within the sector, or a different sector to accelerate a CE shift in Aotearoa New Zealand.

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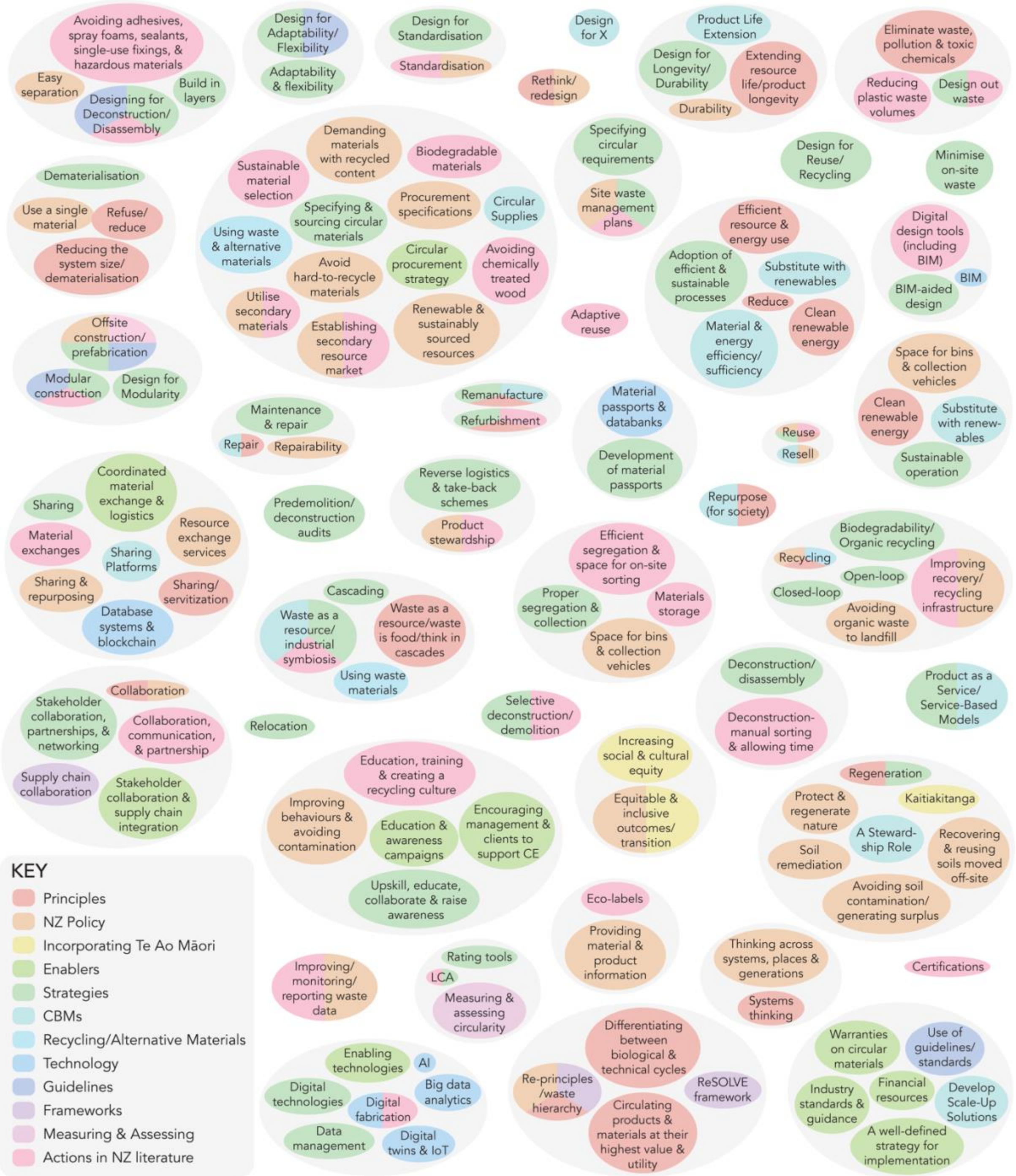
Appendices

Appendix A: Key Points on CE Implementation from the Literature Review and Background Chapters



Appendix B: Interview Participant Information Sheet

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

Implementation of circular economy strategies in the building and construction sector in Aotearoa New Zealand

The transition to a circular economy is gaining traction globally, including in New Zealand. The Emissions Reduction Plan and the Waste Strategy have both outlined 2050 visions for a circular economy. Achieving this vision requires changes in the building and construction sector, which is associated with several sustainability challenges and contributes to construction and demolition waste – the largest waste stream in New Zealand. Therefore, this study aims to identify the circular economy strategies that are and are not being implemented by businesses in New Zealand's building and construction sector. The results will point to the 'gaps' or the strategies requiring greater attention to achieve a more sustainable and circular future in New Zealand.

I have identified strategies from the literature and organised them into different business types within the sector. With your help, I aim to shortlist circular economy strategies and ensure that they are appropriate for [*business type*] in New Zealand before surveying businesses about their implementation. In addition, I will ask for your opinion on the state of circular economy implementation among [*business type*]. Participating in this interview will take around 20-30 minutes.

Confidentiality

With your permission, the interview will be recorded. No information that identifies you will be disclosed in any dissemination of the research findings. Instead, a descriptor will be used (i.e. an expert in …) to provide anonymity. Your contact details and interview transcript will be kept securely and will only be accessible to myself and my supervisors.

Participants' Rights

Participation is completely voluntary. You are under no obligation to accept this invitation. However, I would be grateful for your assistance. At all times, you have the right to:

- decline to answer any particular question;
- withdraw from the study;
- ask any questions about the study;
- be given access to a summary of the research findings when the study is concluded;
- decline to be recorded or ask for the recorder to be turned off.

Project contacts

You are welcome to contact the researcher and/or supervisors if you have questions about the project.

Lucy Cossar (student)	lucyccossar@gmail.com
Jonathon Hannon (supervisor)	J.B.Hannon@massey.ac.nz
Karen Hytten (supervisor)	K.Hytten@massey.ac.nz
Ferran de Miguel Mercader (supervisor)	ferran@fbu.com

This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named in this document are responsible for the ethical conduct of this research. If you have any concerns about the conduct of this research that you want to raise with someone other than the researcher(s), please contact the Research Ethics Office, email humanethics@massey.ac.nz.

Consent

I agree / do not agree to the interview being recorded.

I have read the Information Sheet and agree to participate in this study under the conditions set out above:

Signature: ____

Date: ____

Full Name – printed: ____

Thank you for your time and cooperation.

Appendix C: Survey Cover Letter and Questions

Introduction.

Kia ora,

You are invited to participate in a study concerning the implementation of circular economy strategies in New Zealand's building and construction sector. By participating in this survey, you will help to identify which strategies are/are not being implemented by your business or place of employment to build a picture of circular economy implementation in the sector.

All responses will remain entirely anonymous and confidential. The survey does not ask for information that can directly identify you or the business you are employed at.

There are eight main questions, and the survey should take around 5-10 minutes of your time. You do not need to be knowledgeable on the topic, but some understanding of the practices occurring in your business would be beneficial. Please refer to the Participant Information Sheet for more details.

I appreciate your consideration.

Ngā mihi,

Lucy Cossar

Participant consent.

You are under no obligation to participate. At all times, you have the right to:

- decline to answer any particular question
- withdraw from the study
- ask any questions about the study
- be given access to a summary of the research findings when the study is concluded

If you have any questions about this research, please contact Lucy Cossar (email: lucyccossar@gmail.com) or Jonathon Hannon, School of Agriculture and Environment (main academic supervisor) (email: J.B.Hannon@massey.ac.nz). This project has been evaluated by peer review and judged to be low risk.

Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named in this document are responsible for the ethical conduct of this research. If you have any concerns about the conduct of this research that you want to raise with someone other than the researcher(s), please contact the Research Ethics Office, email humanethics@massey.ac.nz.

- **I agree to participate in this survey and understand the participant rights above**

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1. Which subsector(s) does your business/place of employment contribute to? Select all that apply
   - Residential building construction (e.g. houses and flats)
   - Non-residential building construction (e.g. shops and offices)
   - Heavy and civil engineering construction (e.g. roads, bridges, tunnels, pipes)
2. How old is your business/place of employment? Select one
   - 0-5 years
   - 6-10 years
   - 11-20 years
   - 21-50 years
   - 51+ years
3. What is the size of your business/place of employment? Select one
   - Small (under 20 employees)
   - Medium (20-100 employees)
   - Large (100+ employees)
4. How would you describe the maturity of circular economy implementation in your business/place of employment? Select one
   - Just getting started (e.g. waste minimisation and legal conformity). Novice.
   - Informed choices for a circular economy have been established (e.g. exploring recycling opportunities). A beginner.
   - Adapting and reinforcing engagement (e.g. reviewing processes (CapEx) and overhauling operating procedures for a circular economy). An established player.
   - Expanding the scope to remoter elements (e.g. focusing on value creation for the customer through dematerialisation). Well-engaged.
   - Full implementation of innovative circular economy business models (e.g. product-as-a-service). Mature.
5. Q5. Which category best describes your business/place of employment? Select one

- Building product/material manufacturer
- Architecture or engineering firm
- Construction company
- Design-build company
- Interior and fit-out company
- Demolition or deconstruction company
- Waste management company

6. To what extent does your business or place of employment implement the following circular economy strategies into its operations? Select one per statement and press 'next'

[*Circular strategies and descriptions*]

- Not at all
- Minimally/Rarely
- Moderately/Sometimes
- Significantly/Frequently
- Completely/Always
- Not applicable
- Unsure

7. Are there any other circular economy strategies or practices that your industry or business/place of employment implements?
8. Is there anything else you would like to share regarding the implementation of circular economy in your industry or business/place of employment?

Thank you for your time spent taking this survey.

Your response has been recorded.

Appendix D: Survey Participant Information Sheet

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

Implementation of circular economy strategies in the building and construction sector in Aotearoa New Zealand

In the linear economy, we extract natural resources, manufacture products, and later discard them. This 'take-make-waste' pattern drives consumption beyond what the Earth can sustainably provide, threatening the ecosystem services that current and future economies and societies need to function. The circular economy concept is a promising alternative gaining traction from industry, academia, and policymakers as a solution to numerous sustainability challenges, including resource depletion, waste, climate change, and environmental degradation. It involves systematically maintaining a circular flow of resources within technical and biological cycles by recovering, retaining, or adding to their value while contributing to sustainable development.

However, the Circularity Gap Report 2023 reveals that the global economy is just 7.2% circular. In New Zealand, the building and construction sector has a significant opportunity to contribute to our 2050 visions for a circular economy (as set out in the Waste Strategy and the Emissions Reduction Plan) as the primary contributor to waste. In turn, businesses that adopt circular practices can receive benefits such as material savings, enhanced brand image, supply chain resilience, and future preparedness. Therefore, this study aims to identify which circular economy strategies businesses are implementing in New Zealand's building and construction sector. This is to provide a baseline understanding of what circular economy strategies need greater attention to achieve a circular future in New Zealand.

Participating in this survey will take around five to ten minutes to complete. You do not need to be knowledgeable on the circular economy, but some understanding of the practices occurring in your business would be beneficial. Your contribution is key to developing a comprehensive understanding of what circular economy strategies businesses implement in this sector. I would be very grateful for your participation.

Confidentiality & Anonymity

All participants will be guaranteed confidentiality and anonymity of the information they provide. The survey does collect any information that can identify you or the business you are employed at directly. The information you provide will be used for research purposes; however, no identifying information will be disclosed in any dissemination of the research findings or future publications. The data gathered from the survey will be kept securely and will only be accessible to myself and my supervisors.

Participants' Rights

Participation is completely voluntary. You are under no obligation to accept this invitation. However, I would be grateful for your assistance. At all times, you have the right to:

- decline to answer any particular question;
- withdraw from the study;
- ask any questions about the study; and
- be given access to a summary of the research findings when the study is concluded.

Project contacts

You can contact the researcher or supervisors if you have questions about the project.

Lucy Cossar (student)	lucyccossar@gmail.com
Jonathon Hannon (supervisor)	J.B.Hannon@massey.ac.nz
Karen Hytten (supervisor)	K.Hytten@massey.ac.nz
Ferran de Miguel Mercader (supervisor)	ferran@fbu.com

Participant Consent
The survey will ask you to check a box to indicate whether you agree to participate in the survey and understand the participant's rights.

This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named in this document are responsible for the ethical conduct of this research. If you have any concerns about the conduct of this research that you want to raise with someone other than the researcher(s), please contact the Research Ethics Office, email humanethics@massey.ac.nz.

Thank you for your consideration, and if you participate, thank you in advance for helping make this study possible.

Appendix E: Circular Strategies Included in the Interviews and Survey

Note. • = Excluded from the Survey √= Included in the survey Blank = Not included the interviews or survey

Lifecycle Stage	Circular Strategies	Manufacturers	Architecture & Engineering	Construction	Design-build	Fit-outs	Demolition	Waste Management
Design/ Planning	1. Design for disassembly/deconstruction- Products/buildings/structures can be easily disassembled without damage or contamination. Connections are reversible (i.e. no nails, adhesives, or sealants required).	√	√		√	√		
	2. Design for adaptability/flexibility- The design allows for easy adjustments, modifications, or reconfigurations to adapt to changing user needs or other uncertainties.	√	√		√	√		
	3. Design for standardisation- Products/buildings/structures are designed for uniformity to streamline processes, avoid offcuts, and enable reuse (e.g. avoiding custom sizes and multiple connection types).	√	√		√	√		
	4. Design for longevity- Products are designed with durable materials and are easy to protect, maintain, refurbish, and replace.	•	•		•	•		
	5. Designing out waste & pollution- Avoiding waste generation and negative environmental externalities from the design and planning phase. Pollutants and hazardous materials to humans and natural systems are eliminated.	•	•		•	•		
	6. Dematerialisation- Refusing unnecessary construction, elements, or use of materials.	√	√	√	√	√		
	7. Circular materials- Producing/selecting/specifying materials that are reclaimed, reusable, compostable or infinitely recyclable, renewable, durable, locally sourced, non-toxic, contaminant-free, or contain high recycled content.	√	√	√	√	√		
	8. Circular contract specifications- e.g. site waste minimisation plans, procurement criteria, material passports, or deconstruction.		√	•	√	√		

Lifecycle Stage	Circular Strategies	Manufacturers	Architecture & Engineering	Construction	Design-build	Fit-outs	Demolition	Waste Management
	9. **BIM-aided design/Digital design tools-** e.g. using Building Information Modelling to guide design, model disassembly, and track material locations.		✓	✓	✓	✓		
	10. **Sustainable/Regenerative operation-** The product/structure is designed for a reduced environmental footprint throughout its operation.	•	✓		✓	•		
	11. **Social & cultural equity-** Equitable and inclusive outcomes are achieved by incorporating social considerations and te ao Māori (according to the Treaty of Waitangi principles).	✓	✓		✓	✓		
	12. **Adaptive reuse-** Repurposing existing infrastructure to avoid new construction.		✓		✓			
	13. **Pre-construction consulting-** Consulting on deconstructability in the construction process.						✓	
Construction/ Manufacturing	14. **Minimise waste on-site-** e.g. by implementing a site waste minimisation plan and site environmental controls, avoiding over-ordering, and providing enough bins to segregate materials.			✓	✓	✓	✓	
	15. **Waste as a resource/industrial symbiosis-** Utilising waste or by-products in production. May involve collaborating with other businesses.	✓						
	16. **Offsite & modular construction-** Building components/modules are manufactured offsite and assembled onsite.		✓	✓	✓			
	17. **Efficient processes-** All processes are optimised to minimise waste, emissions, and the consumption of materials, water, and energy.	✓		✓	✓	✓	•	✓
	18. **Careful segregation-** To avoid damage or contamination that prevents reuse or recycling.						✓	✓
Closing/ Extending Loops	19. **Pre-demolition audits-** An audit carried out before demolition/deconstruction to identify material types, locations, volumes, and their reuse/recycling potential.						✓	
	20. **Deconstruction-** Instead of demolition, buildings are disassembled manually to recover materials.					✓	✓	

Lifecycle Stage	Circular Strategies	Manufacturers	Architecture & Engineering	Construction	Design-build	Fit-outs	Demolition	Waste Management
	21. Selective deconstruction- Only recoverable materials are salvaged before demolishing the remaining structure.					•	✓	
	22. Sharing Platforms- Using online marketplaces to exchange reusable items (e.g. Mutu, CivilShare).			✓	✓	✓	✓	
	23. Remanufacture- Used products undergo an industrial process, renewing their expected lifespan based on original or modified product specifications.	✓						
	24. Maintenance & repair- Materials/products/buildings are restored to their original function to extend their lifespan.	•						
	25. Take-back schemes- Producers take their products back and are responsible for reuse/recycling. Associated with product stewardship and service-based models.	✓						
	26. Relocation- Of houses/structures						✓	
	27. Reuse- Recovered products are resold or redistributed for reuse.	✓		✓	✓	✓	✓	✓
	28. Closed-loop recycling- Materials from a product are used to create the *same* product as the original (e.g. PVC pipe into PVC pipe; concrete waste as aggregate in new concrete).	✓		✓	✓	✓	✓	✓
	29. Open-loop recycling- Materials from a product are used to create a *different* product from the original, often with reduced material quality or functionality (e.g. concrete waste into base course).	✓		✓	✓	✓	✓	✓
	30. Organic recycling- Bio-based materials are returned to natural cycles (e.g. through composting).	✓		✓	✓	✓	✓	✓
All Stages	31. Material passports- For products: A detailed, accessible record of product information (such as material composition, durability, and recyclability). For buildings: a detailed, accessible inventory of building materials used in a project with product information (such as material composition, location, and end-of-life options).	✓	✓	✓	✓	✓	•	

Lifecycle Stage	Circular Strategies	Manufacturers	Architecture & Engineering	Construction	Design-build	Fit-outs	Demolition	Waste Management
	32. Service-based models- Products are sold/procured as services and manufacturers/service providers retain ownership (e.g. through leasing, buy-back, and pay-per-use).	✓	✓	✓	✓	✓		
	33. Regenerating nature- By sequestering carbon, building biodiversity, and improving air, soil, and water quality (e.g. incorporating green spaces, soil remediation, native conservation initiatives, or selecting regenerative materials).	✓	✓	✓	✓	✓	✓	✓
	34. Measuring circularity- Using life cycle assessment or circular economy assessment/rating tools or indicators	✓	✓		✓			
	35. Recording waste data- Collecting, documenting, and analysing waste data (e.g. reuse and recycling rates).			✓	✓	✓	✓	✓
	36. Certifications- Improving circularity to obtain certifications (e.g. Cradle to Cradle Certified, the Living Certification, BREEAM, LEED, Green Star).	✓	✓	•	✓	✓		
	37. Education, upskilling & collaboration- To support a circular economy transition.	✓	✓	✓	✓	✓	✓	✓
	38. Infrastructure Investment- To improve reuse and recycling rates.							✓

Appendix F: Tables Showing the Number of Respondents that Selected Each Category

Table F1

Circular Strategies Implemented by Manufacturing Companies

Strategies	NA	Unsure	0 Not at all	1 Minimally/ Rarely	2 Moderately/ Sometimes	3 Significantly/ Frequently	4 Completely/ Always	Mean[a]	SD[a]	Rank
Design for standardisation	1 (2%)	2 (4%)	3 (6%)	4 (8%)	7 (14%)	21 (43%)	11 (22%)	2.7	1.1	1
Circular materials	1 (2%)	0 (0%)	5 (10%)	6 (12%)	10 (20%)	17 (35%)	10 (20%)	2.4	1.3	2
Efficient processes	1 (2%)	1 (2%)	1 (2%)	4 (8%)	23 (47%)	14 (29%)	5 (10%)	2.4	0.9	3
Dematerialisation	5 (10%)	2 (4%)	6 (12%)	2 (4%)	15 (31%)	10 (20%)	9 (18%)	2.3	1.3	4
Design for adaptability/flexibility	3 (6%)	1 (2%)	4 (8%)	11 (22%)	9 (18%)	11 (22%)	10 (20%)	2.3	1.3	5
Waste as a resource/industrial symbiosis	2 (4%)	1 (2%)	5 (10%)	8 (16%)	14 (29%)	10 (20%)	9 (18%)	2.2	1.3	6
Design for disassembly/deconstruction	6 (12%)	1 (2%)	9 (18%)	9 (18%)	9 (18%)	7 (14%)	8 (16%)	1.9	1.4	7
Education, upskilling & collaboration	2 (4%)	1 (2%)	6 (12%)	15 (31%)	13 (27%)	7 (14%)	5 (10%)	1.8	1.2	8
Reuse	4 (8%)	0 (0%)	7 (14%)	16 (33%)	13 (27%)	6 (12%)	3 (6%)	1.6	1.1	9
Closed-loop recycling	4 (8%)	1 (2%)	13 (27%)	11 (22%)	8 (16%)	7 (14%)	5 (10%)	1.5	1.4	10
Material passports	2 (4%)	1 (2%)	14 (29%)	8 (16%)	14 (29%)	7 (14%)	3 (6%)	1.5	1.3	11
Open-loop recycling	6 (12%)	1 (2%)	8 (16%)	18 (37%)	10 (20%)	5 (10%)	1 (2%)	1.4	1.0	12
Certifications	1 (2%)	1 (2%)	18 (37%)	10 (20%)	8 (16%)	8 (16%)	3 (6%)	1.3	1.3	13
Take-back schemes	1 (2%)	0 (0%)	17 (35%)	13 (27%)	9 (18%)	6 (12%)	3 (6%)	1.3	1.3	14
Measuring circularity	1 (2%)	1 (2%)	20 (41%)	10 (20%)	7 (14%)	7 (14%)	3 (6%)	1.2	1.3	15
Remanufacturing	6 (12%)	1 (2%)	10 (20%)	21 (43%)	4 (8%)	5 (10%)	2 (4%)	1.2	1.1	16
Social & cultural equity	6 (12%)	1 (2%)	15 (31%)	12 (24%)	9 (18%)	5 (10%)	1 (2%)	1.2	1.1	17
Regenerating nature	9 (18%)	2 (4%)	19 (39%)	6 (12%)	6 (12%)	3 (6%)	4 (8%)	1.1	1.4	18
Organic recycling	17 (35%)	2 (4%)	18 (37%)	6 (12%)	1 (2%)	4 (8%)	1 (2%)	0.8	1.2	19
Service-based models	10 (20%)	1 (2%)	31 (63%)	4 (8%)	1 (2%)	1 (2%)	1 (2%)	0.3	0.9	20

Average	1.6

Note. n = 49. NA = Not Applicable. SD = Standard Deviation. Medium blue cells = averages between 2 and 2.99. Light blue cells = averages between 1 and 1.99. Pale blue cells = averages between 0 and 0.99.

[a] 'NA' and 'Unsure' categories were excluded from the mean and standard deviation.

Table F2

Circular Strategies Implemented by Architecture and Engineering Companies

Strategies	NA	Unsure	0 Not at all	1 Minimally/ Rarely	2 Moderately/ Sometimes	3 Significantly/ Frequently	4 Completely/ Always	Mean[a]	SD[a]	Rank
Regenerative operation	1 (1%)	0 (0%)	5 (7%)	11 (15%)	20 (28%)	26 (37%)	8 (11%)	2.3	1.1	1
Adaptive reuse	2 (3%)	0 (0%)	0 (0%)	13 (18%)	27 (38%)	25 (35%)	4 (6%)	2.3	0.8	2
Design for adaptability/flexibility	1 (1%)	0 (0%)	2 (3%)	16 (23%)	28 (39%)	19 (27%)	5 (7%)	2.1	0.9	3
Circular materials	0 (0%)	1 (1%)	2 (3%)	19 (27%)	26 (37%)	18 (25%)	5 (7%)	2.1	1.0	4
Design for standardisation	1 (1%)	0 (0%)	2 (3%)	18 (25%)	27 (38%)	20 (28%)	3 (4%)	2.1	0.9	5
Offsite & modular construction	5 (7%)	0 (0%)	4 (6%)	11 (15%)	29 (41%)	22 (31%)	0 (0%)	2.0	0.9	6
Dematerialisation	1 (1%)	0 (0%)	5 (7%)	19 (27%)	24 (34%)	14 (20%)	8 (11%)	2.0	1.1	7
Digital design tools	2 (3%)	0 (0%)	18 (25%)	13 (18%)	12 (17%)	17 (24%)	9 (13%)	1.8	1.4	8
Education, upskilling & collaboration	1 (1%)	0 (0%)	8 (11%)	25 (35%)	15 (21%)	21 (30%)	1 (1%)	1.7	1.1	9
Regenerating nature	4 (6%)	0 (0%)	13 (18%)	17 (24%)	20 (28%)	14 (20%)	3 (4%)	1.7	1.1	10
Social & cultural equity	4 (6%)	1 (1%)	9 (13%)	22 (31%)	22 (31%)	9 (13%)	4 (6%)	1.7	1.1	11
Circular contract specifications	3 (4%)	0 (0%)	14 (20%)	18 (25%)	24 (34%)	8 (11%)	4 (6%)	1.6	1.1	12
Certifications	3 (4%)	0 (0%)	15 (21%)	25 (35%)	16 (23%)	10 (14%)	2 (3%)	1.4	1.1	13
Design for disassembly/deconstruction	0 (0%)	0 (0%)	18 (25%)	23 (32%)	22 (31%)	7 (10%)	1 (1%)	1.3	1.0	14
Measuring circularity	2 (3%)	0 (0%)	23 (32%)	23 (32%)	13 (18%)	8 (11%)	2 (3%)	1.2	1.1	15
Material passports	3 (4%)	0 (0%)	25 (35%)	27 (38%)	7 (10%)	6 (8%)	3 (4%)	1.0	1.1	16
Service-based models	5 (7%)	1 (1%)	44 (62%)	15 (21%)	4 (6%)	2 (3%)	0 (0%)	0.4	0.8	17
Average								1.7		

Note. n = 71. NA = Not Applicable. SD = Standard Deviation. Medium blue cells = averages between 2 and 2.99. Light blue cells = averages between 1 and 1.99. Pale blue cells = averages between 0 and 0.99.

[a] 'NA' and 'Unsure' categories were excluded from the mean and standard deviation.

Table F3

Circular Strategies Implemented by Construction Companies

Strategies	NA	Unsure	0 Not at all	1 Minimally/ Rarely	2 Moderately/ Sometimes	3 Significantly/ Frequently	4 Completely/ Always	Mean[a]	SD[a]	Rank
Minimise waste on-site	0 (0%)	0 (0%)	3 (4%)	6 (8%)	14 (20%)	26 (37%)	7 (10%)	2.5	1.0	1
Efficient processes	1 (1%)	1 (1%)	4 (6%)	14 (20%)	17 (24%)	15 (21%)	4 (6%)	2.0	1.1	2
Reuse	0 (0%)	0 (0%)	9 (13%)	11 (15%)	20 (28%)	14 (20%)	2 (3%)	1.8	1.1	3
Circular materials	0 (0%)	0 (0%)	8 (11%)	14 (20%)	20 (28%)	13 (18%)	1 (1%)	1.7	1.0	4
Dematerialisation	0 (0%)	0 (0%)	10 (14%)	12 (17%)	19 (27%)	14 (20%)	1 (1%)	1.7	1.1	5
Education, upskilling & collaboration	0 (0%)	0 (0%)	8 (11%)	17 (24%)	19 (27%)	11 (15%)	1 (1%)	1.6	1.0	6
Offsite & modular construction	3 (4%)	0 (0%)	11 (15%)	15 (21%)	15 (21%)	10 (14%)	2 (3%)	1.6	1.1	7
Digital design tools	2 (3%)	0 (0%)	15 (21%)	11 (15%)	15 (21%)	10 (14%)	3 (4%)	1.5	1.2	8
Recording waste data	0 (0%)	0 (0%)	16 (23%)	15 (21%)	6 (8%)	17 (24%)	2 (3%)	1.5	1.3	9
Open-loop recycling	0 (0%)	1 (1%)	13 (18%)	15 (21%)	13 (18%)	13 (18%)	1 (1%)	1.5	1.2	10
Closed-loop recycling	0 (0%)	0 (0%)	18 (25%)	8 (11%)	17 (24%)	13 (18%)	0 (0%)	1.4	1.2	11
Organic recycling	5 (7%)	0 (0%)	22 (31%)	16 (23%)	5 (7%)	6 (8%)	2 (3%)	1.0	1.2	12
Regenerating nature	2 (3%)	0 (0%)	31 (44%)	7 (10%)	9 (13%)	6 (8%)	1 (1%)	0.9	1.2	13
Material passports	1 (1%)	0 (0%)	29 (41%)	14 (20%)	6 (8%)	5 (7%)	1 (1%)	0.8	1.1	14
Sharing platforms	0 (0%)	0 (0%)	29 (41%)	15 (21%)	8 (11%)	3 (4%)	1 (1%)	0.8	1.0	15
Service-based models	3 (4%)	0 (0%)	29 (41%)	20 (28%)	3 (4%)	1 (1%)	0 (0%)	0.5	0.7	16
Average								1.4		

Note. n = 56. NA = Not Applicable. SD = Standard Deviation. Medium blue cells = averages between 2 and 2.99. Light blue cells = averages between 1 and 1.99. Pale blue cells = averages between 0 and 0.99.

[a] 'NA' and 'Unsure' categories were excluded from the mean and standard deviation.

Table F4

Circular Strategies Implemented by Design-Build Companies

Strategies	NA	Unsure	0 Not at all	1 Minimally/ Rarely	2 Moderately/ Sometimes	3 Significantly/ Frequently	4 Completely/ Always	Mean[a]	SD[a]	Rank
Minimise waste on-site	0 (0%)	0 (0%)	0 (0%)	0 (0%)	3 (27%)	5 (45%)	3 (27%)	3.0	0.8	1
Efficient processes	0 (0%)	0 (0%)	0 (0%)	2 (18%)	3 (27%)	4 (36%)	2 (18%)	2.5	1.0	2
Digital design tools	0 (0%)	0 (0%)	0 (0%)	3 (27%)	3 (27%)	2 (18%)	3 (27%)	2.5	1.2	3
Design for standardisation	0 (0%)	0 (0%)	1 (9%)	1 (9%)	3 (27%)	5 (45%)	1 (9%)	2.4	1.1	4
Circular materials	0 (0%)	0 (0%)	0 (0%)	2 (18%)	4 (36%)	4 (36%)	1 (9%)	2.4	0.9	4
Circular contract specifications	0 (0%)	0 (0%)	2 (18%)	0 (0%)	2 (18%)	6 (55%)	1 (9%)	2.4	1.3	4
Regenerative operation	0 (0%)	0 (0%)	1 (9%)	2 (18%)	4 (36%)	3 (27%)	1 (9%)	2.4	1.1	4
Education, upskilling & collaboration	0 (0%)	0 (0%)	1 (9%)	2 (18%)	1 (9%)	6 (55%)	1 (9%)	2.4	1.2	4
Dematerialisation	0 (0%)	0 (0%)	1 (9%)	2 (18%)	4 (36%)	2 (18%)	2 (18%)	2.2	1.3	9
Recording waste data	0 (0%)	0 (0%)	3 (27%)	1 (9%)	0 (0%)	6 (55%)	1 (9%)	2.1	1.5	10
Closed-loop recycling	0 (0%)	0 (0%)	2 (18%)	2 (18%)	3 (27%)	3 (27%)	1 (9%)	1.9	1.3	11
Certifications	0 (0%)	0 (0%)	2 (18%)	1 (9%)	4 (36%)	4 (36%)	0 (0%)	1.9	1.1	11
Design for adaptability/flexibility	0 (0%)	0 (0%)	0 (0%)	6 (55%)	3 (27%)	1 (9%)	1 (9%)	1.7	1.0	13
Measuring circularity	1 (9%)	0 (0%)	3 (27%)	2 (18%)	2 (18%)	1 (9%)	2 (18%)	1.7	1.6	14
Reuse	0 (0%)	0 (0%)	3 (27%)	2 (18%)	4 (36%)	1 (9%)	1 (9%)	1.5	1.3	15
Social & cultural equity	0 (0%)	0 (0%)	3 (27%)	3 (27%)	2 (18%)	2 (18%)	1 (9%)	1.5	1.4	15
Offsite & modular construction	1 (9%)	0 (0%)	3 (27%)	2 (18%)	3 (27%)	1 (9%)	1 (9%)	1.5	1.4	17
Adaptive reuse	1 (9%)	0 (0%)	2 (18%)	4 (36%)	2 (18%)	2 (18%)	0 (0%)	1.4	1.1	18
Open-loop recycling	0 (0%)	0 (0%)	2 (18%)	5 (45%)	2 (18%)	2 (18%)	0 (0%)	1.4	1.0	19
Organic recycling	0 (0%)	0 (0%)	4 (36%)	3 (27%)	2 (18%)	0 (0%)	2 (18%)	1.4	1.5	19
Material passports	0 (0%)	0 (0%)	3 (27%)	4 (36%)	2 (18%)	1 (9%)	1 (9%)	1.4	1.3	19
Regenerating nature	0 (0%)	0 (0%)	4 (36%)	2 (18%)	2 (18%)	3 (27%)	0 (0%)	1.4	1.3	19

Design for disassembly/deconstruction	0 (0%)	0 (0%)	4 (36%)	4 (36%)	2 (18%)	1 (9%)	0 (0%)	1.0	1.0	23
Sharing platforms	1 (9%)	0 (0%)	4 (36%)	4 (36%)	2 (18%)	0 (0%)	0 (0%)	0.8	0.8	24
Service-based models	1 (9%)	0 (0%)	4 (36%)	5 (45%)	1 (9%)	0 (0%)	0 (0%)	0.7	0.7	25
Average								1.8		

Note. n = 11. NA = Not Applicable. SD = Standard Deviation. Darkest blue cells = averages between 3 and 4. Medium blue cells = averages between 2 and 2.99. Light blue cells = averages between 1 and 1.99. Pale blue cells = averages between 0 and 0.99.

[a] 'NA' and 'Unsure' categories were excluded from the mean and standard deviation.

Table F5

Circular Strategies Implemented by Fit-Out Companies

Strategies	NA	Unsure	0 Not at all	1 Minimally/ Rarely	2 Moderately/ Sometimes	3 Significantly/ Frequently	4 Completely/ Always	Mean[a]	SD[a]	Rank
Circular materials	0 (0%)	0 (0%)	0 (0%)	2 (25%)	2 (25%)	2 (25%)	2 (25%)	2.5	1.2	1
Minimise waste on-site	1 (13%)	0 (0%)	0 (0%)	2 (25%)	2 (25%)	2 (25%)	1 (13%)	2.3	1.1	2
Dematerialisation	0 (0%)	0 (0%)	0 (0%)	3 (38%)	2 (25%)	1 (13%)	2 (25%)	2.3	1.3	3
Circular contract specifications	1 (13%)	0 (0%)	0 (0%)	2 (25%)	3 (38%)	1 (13%)	1 (13%)	2.1	1.1	4
Efficient processes	1 (13%)	0 (0%)	0 (0%)	2 (25%)	3 (38%)	1 (13%)	1 (13%)	2.1	1.1	4
Design for disassembly/deconstruction	0 (0%)	0 (0%)	0 (0%)	2 (25%)	4 (50%)	1 (13%)	1 (13%)	2.1	1.0	6
Design for adaptability/flexibility	0 (0%)	0 (0%)	0 (0%)	3 (38%)	2 (25%)	2 (25%)	1 (13%)	2.1	1.1	6
Reuse	0 (0%)	0 (0%)	0 (0%)	3 (38%)	3 (38%)	0 (0%)	2 (25%)	2.1	1.2	6
Education, upskilling & collaboration	0 (0%)	0 (0%)	1 (13%)	1 (13%)	4 (50%)	0 (0%)	2 (25%)	2.1	1.4	6
Open-loop recycling	1 (13%)	1 (13%)	0 (0%)	1 (13%)	5 (63%)	0 (0%)	0 (0%)	1.8	0.4	10
Digital design tools	1 (13%)	0 (0%)	1 (13%)	2 (25%)	3 (38%)	0 (0%)	1 (13%)	1.7	1.3	11
Deconstruction	1 (13%)	0 (0%)	1 (13%)	3 (38%)	1 (13%)	1 (13%)	1 (13%)	1.7	1.4	11
Certifications	0 (0%)	0 (0%)	1 (13%)	3 (38%)	3 (38%)	0 (0%)	1 (13%)	1.6	1.2	13
Design for standardisation	1 (13%)	0 (0%)	1 (13%)	2 (25%)	3 (38%)	1 (13%)	0 (0%)	1.6	1.0	14
Social & cultural equity	0 (0%)	1 (13%)	1 (13%)	2 (25%)	3 (38%)	1 (13%)	0 (0%)	1.6	1.0	14
Organic recycling	3 (38%)	0 (0%)	2 (25%)	1 (13%)	1 (13%)	1 (13%)	0 (0%)	1.2	1.3	16
Regenerating nature	2 (25%)	0 (0%)	3 (38%)	1 (13%)	1 (13%)	0 (0%)	1 (13%)	1.2	1.6	17
Material passports	0 (0%)	0 (0%)	5 (63%)	1 (13%)	1 (13%)	0 (0%)	1 (13%)	0.9	1.5	18
Recording waste data	1 (13%)	0 (0%)	4 (50%)	2 (25%)	0 (0%)	0 (0%)	1 (13%)	0.9	1.5	19
Closed-loop recycling	1 (13%)	1 (13%)	2 (25%)	3 (38%)	1 (13%)	0 (0%)	0 (0%)	0.8	0.8	20

Service-based models	1 (13%)	0 (0%)	4 (50%)	3 (38%)	0 (0%)	0 (0%)	0 (0%)	0.4	0.5	21
Sharing platforms	2 (25%)	0 (0%)	4 (50%)	2 (25%)	0 (0%)	0 (0%)	0 (0%)	0.3	0.5	22
Average								1.6		

Note. n = 8. NA = Not Applicable. SD = Standard Deviation. Medium blue cells = averages between 2 and 2.99. Light blue cells = averages between 1 and 1.99. Pale blue cells = averages between 0 and 0.99.

[a] 'NA' and 'Unsure' categories were excluded from the mean and standard deviation.

Table F6

Circular Strategies Implemented by Demolition Companies

Strategies	NA	Unsure	0 Not at all	1 Minimally/ Rarely	2 Moderately/ Sometimes	3 Significantly/ Frequently	4 Completely/ Always	Mean[a]	SD[a]	Rank
Minimise waste on-site	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	4 (36%)	7 (64%)	3.6	0.5	1
Careful segregation	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (9%)	3 (27%)	7 (64%)	3.5	0.7	2
Pre-demolition audits	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	5 (45%)	6 (55%)	3.5	0.5	2
Recording waste data	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (9%)	3 (27%)	7 (64%)	3.5	0.7	2
Selective deconstruction	1 (9%)	0 (0%)	0 (0%)	0 (0%)	1 (9%)	3 (27%)	6 (55%)	3.5	0.7	5
Reuse	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (9%)	5 (45%)	5 (45%)	3.4	0.7	6
Open-loop recycling	1 (9%)	0 (0%)	0 (0%)	0 (0%)	3 (27%)	4 (36%)	3 (27%)	3.0	0.8	7
Education, upskilling & collaboration	1 (9%)	0 (0%)	0 (0%)	0 (0%)	3 (27%)	6 (55%)	1 (9%)	2.8	0.6	8
Deconstruction	0 (0%)	0 (0%)	0 (0%)	1 (9%)	3 (27%)	5 (45%)	2 (18%)	2.7	0.9	9
Preconstruction consulting	2 (18%)	0 (0%)	1 (9%)	1 (9%)	2 (18%)	2 (18%)	3 (27%)	2.6	1.4	10
Sharing platforms	0 (0%)	0 (0%)	2 (18%)	3 (27%)	0 (0%)	3 (27%)	3 (27%)	2.2	1.6	11
Closed-loop recycling	0 (0%)	0 (0%)	1 (9%)	2 (18%)	2 (18%)	6 (55%)	0 (0%)	2.2	1.1	11
Relocation	0 (0%)	0 (0%)	2 (18%)	0 (0%)	4 (36%)	5 (45%)	0 (0%)	2.1	1.1	13
Organic recycling	2 (18%)	0 (0%)	1 (9%)	3 (27%)	1 (9%)	4 (36%)	0 (0%)	1.9	1.2	14
Regenerating nature	2 (18%)	0 (0%)	1 (9%)	3 (27%)	3 (27%)	2 (18%)	0 (0%)	1.7	1.0	15
Average								2.8		

Note. n = 11. NA = Not Applicable. SD = Standard Deviation. Darkest blue cells = averages between 3 and 4. Medium blue cells = averages between 2 and 2.99. Light blue cells = averages between 1 and 1.99.

[a] 'NA' and 'Unsure' categories were excluded from the mean and standard deviation.

Table F7

Circular Strategies Implemented by Waste Management Companies

Strategy	NA	Unsure	0 Not at all	1 Minimally/ Single Material Stream	2 Moderately/ Several Material Streams	3 Significantly/ Most Material Streams	4 Completely/ All Material Streams	Mean[a]	SD[a]	Rank
Recording waste data	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (29%)	2 (29%)	3 (43%)	3.1	0.9	1
Infrastructure investment	0 (0%)	0 (0%)	0 (0%)	1 (14%)	3 (43%)	0 (0%)	3 (43%)	2.7	1.3	2
Careful segregation	0 (0%)	0 (0%)	0 (0%)	0 (0%)	4 (57%)	2 (29%)	1 (14%)	2.6	0.8	3
Education, upskilling & collaboration	0 (0%)	0 (0%)	0 (0%)	1 (14%)	3 (43%)	1 (14%)	2 (29%)	2.6	1.1	3
Efficient processes	0 (0%)	0 (0%)	0 (0%)	1 (14%)	3 (43%)	3 (43%)	0 (0%)	2.3	0.8	5
Reuse	0 (0%)	0 (0%)	0 (0%)	2 (29%)	3 (43%)	1 (14%)	1 (14%)	2.1	1.1	6
Open-loop recycling	0 (0%)	0 (0%)	0 (0%)	0 (0%)	6 (86%)	1 (14%)	0 (0%)	2.1	0.4	6
Organic recycling	1 (14%)	0 (0%)	1 (14%)	2 (29%)	2 (29%)	0 (0%)	1 (14%)	1.7	1.4	8
Regenerating nature	0 (0%)	1 (14%)	3 (43%)	0 (0%)	1 (14%)	1 (14%)	1 (14%)	1.5	1.8	9
Closed-loop recycling	0 (0%)	0 (0%)	3 (43%)	1 (14%)	2 (29%)	0 (0%)	1 (14%)	1.3	1.5	10
Average								2.2		

Note. n = 7. NA = Not Applicable. SD = Standard Deviation. Darkest blue cells = averages between 3 and 4. Medium blue cells = averages between 2 and 2.99. Light blue cells = averages between 1 and 1.99.

[a] 'NA' and 'Unsure' categories were excluded from the mean and standard deviation.

Appendix G: Significant Relationships Identified Through Chi-Squared Tests of Independence

Table G1

Average Responses for Significant Relationships Between Circular Strategies and Sub-Sectors

Business Type	Sub-Sector	Circular Strategy	Mean [a]	p-value
Manufacturing	Non-residential	Regenerating nature	1.1	<.001
	Heavy and civil	Open-loop recycling	1.6	.031
Architecture/Engineering	Residential	Service-based models	0.3	.040
	Heavy and civil	Design for adaptability/flexibility	1.6	.046
Construction	Residential	Recording waste data	1.2	.006
	Heavy and civil	Regenerating nature	1.8	.009
	Heavy and civil	Material passports	1.2	.012
	Heavy and civil	Service-based models	1.0	.041
Design-Build	Residential	Open-loop recycling	1.0	.037
	Non-residential	Regenerating nature	1.8	.040
Fit-Out	Residential	Education, upskilling & collaboration	3.0	.046
	Residential	Design for adaptability/flexibility	3.3	.046
Demolition	Residential	Closed-loop recycling	2.4	.037
Waste Management	Residential	Careful segregation	2.3	.030

Note. α = 0.05. 'Not applicable' and 'unsure' categories were excluded from mean responses.

Table G2

Average Responses for Significant Relationships Between Circular Strategies and Business Age

Business Type	Circular Strategy	0–5	6–10	11–20	21–50	51+	p-value
Manufacturing	Material passports	2.0	4.0	1.7	1.5	1.0	<.001
	Open-loop recycling	2.0	2.0	1.0	1.4	1.2	.029
Design-Build	Design for standardisation	4.0	1.5	2.8	2.3	1.0	.023

Note. α = 0*.05*. 'Not applicable' and 'unsure' categories were excluded from mean responses.

Table G3

Average Responses for Significant Relationships Between Circular Strategies and Business Size

Business Type	Circular Strategy	Small	Medium	Large	p-value
Manufacturing	Design for disassembly/deconstruction	2.1	2.1	1.3	.040
Architecture/Engineering	Design for standardisation	2.2	1.7	2.6	.016
	Service-based models	0.3	0.5	1.3	.017
	Regenerative operation	2.3	2.1	2.6	.026
	Offsite and modular construction	2.1	2.0	2.0	.040
Construction	Recording waste data	1.0	1.6	2.3	.015
Design-Build	Organic recycling	0.2	2.3		.040
Demolition	Regenerating nature	0.0	0.9		.027
	Minimise waste on-site	3.0	3.9		.007
Waste Management	Efficient processes	2.0	1.0	3.0	.007

Note. α = 0.05. 'Not applicable' and 'unsure' categories were excluded from mean responses.