Implications of Circular Product Design for Business Model and Supply Chain Management: A Thematic Analysis.

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i) Abstract

The Circular economy (CE) concept has gained much attention in recent years as an alternative economic model to the dominant take-make-dispose linear model. Product waste has been identified as a leading contributor to the unsustainability of this model. Therefore, the aim of this study was to investigate how circular product design can be integrated with supply chain design for the circular economy.

Semi-structured interviews were conducted with 15 participants in Auckland that had knowledge in circular product design. The interview audio recordings were transcribed for thematic analysis in NVivo 12. From the analysis three main themes were uncovered. They were: *End-of-life thinking in product design, Sustainable and innovative business models and Circular supply chain management.*

The findings from the study suggest products need to be designed with the end-of-life considered during the design stage. This ensures products have sustainable options at the end of their life cycle rather than being sent to landfill. In addition, supply chains need to be redesigned to achieve circularity of materials by reverse logistics, powered by renewable energies, and innovative business models need to be developed to support the commercialisation of circular product design.

Limitations encountered during this study included limited participants that were knowledgeable with circular principles. Given the relatively nascent stage of CE, participants were difficult to find. Secondly, the tight timeline for completing the dissertation put time pressure on finding participants, interviews and transcribing. Thirdly, conducting this research in other countries where CE is more popular and has been supported with legislation would possibly yield different results.

This study was able to draw several general propositions that included incorporating end-of-life thinking into product design, circular principles integrated into supply chain design and innovative business model design. In addition, managerial implications that were drawn from the analysis include cost implications, shortening supply chains, incorporating circular thinking into supply chain design and utilisation of renewable energy. Policy implications include development of new sustainable policy to transition the linear economy towards CE, the need for infrastructure development and the need for the price of circular products to be brought in line with linear economy base products for market competitiveness.

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Abbreviation	**Full term**
B2B	Business to business
B2C	Business to consumer
C2C	Cradle-to-cradle
CE	Circular economy
CSCM	Circular supply chain management
CSR	Corporate social responsibility
DfS	Design for sustainability
EU	European Union
IaaS	Infrastructure as a service
IoT	Internet of Things
LCA	Life cycle assessment
PSS	Product as a service
P2P	Peer-to-Peer
SaaS	Software as a service
SCM	Supply chain management

v) Attestation of Authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

Haydn Burke 16/09/2019

Signature…………………………….

vi) Acknowledgements

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Chapter 1: Introduction

1.1 Research background

The global business community has operated on a linear economic model for more than a century. In the linear economy, resources and products move in a unidirectional flow also referred to as take-make-dispose. In this model, manufacturers take virgin resource to make products and sell them to consumers who in turn dispose them into landfills. This model emerged from industrialisation in developed nations and was driven by capitalism. The linear economy was not intentionally designed, but rather resulted from key measures in industrialisation that place higher importance on profit (Michelini et al., 2017). Value in this model is generated from maximising production and sales volume. The externalities associated with doing business in the linear economy have been largely disregarded which has had disastrous effects on society and the environment. Global trends show production and consumption levels continue to increase, which places stress on the global resource supply. Since the earth's resources are finite, this model is unsustainable and has already reached its physical limits (MacArthur, 2013).

Products are a key aspect of any economy, but their design has been the catalyst for the unsustainability of the linear model. Since World War II, producers have designed products with planned obsolescence as a design strategy for stimulating repeat business and reducing the time between product purchases for consumers. Decades have passed since the introduction of this linear design strategy and obsolescent product designs have become widely accepted within society (Bridgens et al., 2019). This design strategy ensures producers continue to make profit each year while fulfilling consumers' intrinsic want to have the latest products. In addition to planned obsolescence, products are not being designed with end-of-life options, so many of them end up in landfills where their embedded resources are lost to the waste stream indefinitely. This creates an issue of waste, while increasing the need for virgin resources for new products (Eichner & Pethig, 2001).

Since the 1970s, global population has more than doubled from 3.7 billion to 7.7 billion. Global consumption has continued to increase alongside population growth. In the same period, resource extraction has increased 3.5 times to 92 billion tonnes per annum (Oberle et al., 2019). In the past 50 years, there has never been a period of stabilisation or decline in the demand for resources. There are serious environmental sustainability problems that come with excessive resource extraction such as climate change, pollution (air, water, soil), depletion of resources (finite and renewables), loss of biodiversity and ecosystems (Murray, Skene & Haynes, 2017). In order to combat these problems, there needs to be a change to the economic model used to drive society forward.

The circular economy (CE) model is an alternative to the traditional linear model and is believed to be the best option to combat the problems facing society in the modern era (Geisendorf & Pietrulla, 2018; Gregson, Crang, Fuller, & Holmes, 2015). The CE philosophy aims to design waste out of the system and keep resource in use for as long as possible. Resource inputs, waste and energy are minimised by closing resource loops to ensure materials already in circulation are used to their maximum value. Resources and products flow in circular patterns which optimises their yield and value. This is a regenerative and restorative system by design which ensures the preservation of natural capital, reduces environmental impacts and improves societal wellbeing. CE aims to redefine economic growth by decoupling economic activities from consumption of virgin resources while utilising renewable energy sources (Ellen MacArthur, 2018).

The CE model is most notable for its cyclical flow patterns that allow resources to move in a continuous loop. It is this cyclic approach that allows resource value to be optimised while waste is minimised (Bocken, De Pauw, Bakker, & van der Grinten, 2016). The CE model differentiates two types of resources: biological and technical materials. In a regenerative cycle, biological materials (e.g., food waste) are safely returned to nature to enhance natural capital after being consumed in the process of fulfilling their purpose. This is a biomimicry process that emulates nature’s process for utilising resources and returning them after use. A restorative cycle deals with technical materials (e.g., plastic and metal) that don’t breakdown in nature. This cycle requires functions like repurpose and remanufacture to recover the materials at the end of the products’ life cycle (McDonough, 2002).

Design strategies that enable materials to circulate through the CE include design for disassembly, designing for long-life products, design for product-life extension and design for performance (Bocken et al., 2016). Integrating CE principles with product design allows products to be the solution rather than the problem. Ensuring products and resources stay in circulation as long as possible creates economic opportunities and generates employment in both high and low skilled areas (Wijkman & Skånberg, 2015).

1.2 Research motivation

There are several sustainability problems caused by the linear economy. Many natural resources are consumed at a pace faster than they can regenerate. Aggressive mining techniques such as fracking and deep-sea drilling are causing environmental degradation while extracting resources in unsustainable volumes. Depleting the earth’s nature resource bank puts stress on global resource levels, and global demand is still increasing. Depleting resources that are finite or found in low volumes creates resource scarcity problems. When resource become scarce it creates uncertainty in supply and demand (Hoornweg & Bhada-Tata, 2012). This creates volatility in commodities and prices can hyperinflate. There are associated economic and political problems with volatile resource prices, but generally the price of goods and services increases along with inflation.

In addition to resource scarcity, resource depletion is another by-product of the linear economy. Resource depletion contributes to the deterioration of the environment and causes environmental degradation. Environmental degradation is the decline in the quality of the natural environment such as pollution of fresh air, clean water and food supply; it also includes destruction of ecosystems and habitats. Environmental degradation is rooted in human advancements such as industrialisation, war, overconsumption, overfishing and deforestation (Stern, Common, & Barbier, 1996). The effects of environmental degradation are having disastrous consequences for humanity such as increased poverty, famine and disease. It is estimated that 11% of species were extinct as of 2010, while a further 50% could become extinct by 2050 due to global demand for land use and fresh water (Oberle et al., 2019).

1.3 Knowledge gaps and research question

The CE is an emerging concept (Andersen, 2007; Geissdoerfer, Savaget, Bocken, & Hultink, 2017; Ghisellini, Cialani, & Ulgiati, 2016), although the philosophy behind it isn't entirely new (Stahel, 2016). Academics have researched the relationship between CE and sustainability (Geissdoerfer et al., 2017) and developed frameworks to guide CE adoption (MacArthur, 2013). Policymakers in the European Union have enacted the European Circular Economy Package (European Commission, 2015), aiming to close the loop on resource waste. Organisations such as TerraCycle have put circular principles to work in industry. Moreover, circular supply chain management (Batista, Bourlakis, Smart, & Maull, 2018; Farooque, Zhang, Thurer, Qu, & Huisingh, 2019) has gained much attention in the same light as CE, because of the integral relationship between supply chain management (SCM) and economic growth. CSCM aims to integrate CE principles into SCM to achieve the circularity of materials (Ying & Li-jun, 2012). The most significant CE principles outlined by the Ellen MacArthur Foundation (2020) include design waste and pollution out of the system; keep products and resources in use for as long as possible; regenerate natural systems . Design for sustainability (DfS) (Bhamra & Lofthouse, 2016; Clark, Kosoris, Hong, & Crul, 2009) has helped further the sustainability aspect of products that move through supply chains, but there is limited works on circular product design that would help the transition to the CE.

Studies conducted on DfS have provided a good base framework for circular product design. DfS strategy on its own is insufficient for the CE because it follows the old "cradle-to-grave" approach from the linear economy. There are limited studies on circular product design embracing the "cradle-to-cradle" approach for the CE. Moreno, De los Rios, Rowe, and Charnley (2016) developed a conceptual framework for circular product design by revising the taxonomy of DfS. They identified business models that would be suitable for the CE and then synthesised the concepts to create their conceptual framework. Similarly, Den Hollander, Bakker, and Hultink (2017) undertook a comprehensive literature review of 400 articles on industrial ecology, eco-design and sustainable product design to set out new concepts and definitions/redefinitions while using Walter Stahel’s Interia Principle as the guiding philosophy for a circular product design concept. These conceptual papers provide a good conceptual understanding of the CE, but further empirical research is required to develop circular product design for the CE.

Previous studies on sustainable product design (Jastorff et al., 2005; Manzini & Vezzoli, 2003) focused on utilizing product design to improve social and environment capital. Spangenberg et al, (2010) advocated the concept of Design for Sustainability which includes but goes beyond what Design for the Environment or eco-design provides. Recently, researchers applied these schools of thoughts towards conceptual frameworks for circular product design (Den Hollander et al., 2017). However, research is lacking on how to operationalize circular product design and integrate it with supply chain management and business model design for the CE.

The purpose of this research is to investigate how circular product design requires changes in the business model and in the supply chain processes. It aims to bridge the knowledge gap by addressing the following research question:

> *What are the implications of circular product design for business model and supply chain management for a transition to the CE?*

The research will guide and support organisations that aim to develop circular products and make the transition to the CE. This research will also support policy makers by highlighting the unsustainability of linear economy-based products and discuss the regulations required to support circular product design. In addition, this research will add to the body of knowledge for circular product design which will assist in supporting researchers who investigate the CE concept in the future.

This research adopted a qualitative approach to data collection. Interviews were used to collect the data and thematic analysis analysed patterns in the participants’ transcripts. Fifteen participants took part in this research. They were interviewed for approximately one hour each and were asked a series of open-ended questions that prompted a discussion around circular product design. The interviews were transcribed and NVivo 12 was used to support the thematic analysis. The results of this research will derive a set of managerial and policy implications for circular product design.

The remainder of the dissertation is organized as follows. Chapter 2 conducts a comprehensive literature review on CE to identify the knowledge gaps on circular product design. Chapter 3 outlines the research methodology. Chapter 4 presents the results, analysis and findings. Chapter 5 summarizes general propositions from the research findings and discusses managerial and policy implications. Chapter 6 conclude the research and suggests future works.

Chapter 2: Literature review

2.1 Circular economy

The CE concept is an alternative to the dominant linear industrial model (take-make-dispose) (W. R. Stahel, 2016). The CE aims to decouple economic growth from consumption of finite resources and design waste out of the system (Geissdoerfer et al., 2017). This model is designed to be regenerative and restorative and is underpinned with the use of renewable energy sources (MacArthur, 2013). CE promotes continuous resource cycles that preserves and enhances natural capital while optimising resource yields (Moreno et al, 2016). The cyclical flow of materials is also known as the cradle-to-cradle (C2C) approach allowing for resources to be used to their maximum potential. In essence CE aims to improve resource productivity by ensuring products and resources are kept in use for as long as possible (Yuan, Bi, & Moriguichi, 2006).

The issue of resource depletion has led researchers to study this problem for many decades (Georgescu-Roegen, 1986; Ghisellini et al., 2016; Miller, 1977), but governments and business leaders have been slow to react and change their business models and enact legislation that would preserve resources for future generations. Some governments are now starting to impose legislation and regulation. European Union (EU) countries such as Germany, United Kingdom, France, Denmark, Netherlands, Sweden, Norway and Finland have made great progress towards CE with the EU Action Plan for the Circular Economy (Maxwell & Reuveny, 2000). Countries outside the EU such as Japan, USA and China have also been pioneering their own movements towards CE principles with legislative and regulatory changes, and eco-industrial parks (Kunz, Mayers, & Van Wassenhove, 2018). While these countries have started the transition from the linear economy to the CE, there needs to be a global movement towards circular business activities because of the ease in which products and resources move between countries in the globalised economy. Manufacturing countries that enact product and environmental legislation and regulations will find controlling the end-of-life management of their exported products difficult to manage (Chen, 2009).

The CE implementation has been accelerated by The Ellen MacArthur Foundation which has spearheaded the movement through education to the public and developing frameworks for businesses and governments to uptake circular processes (Ellen MacArthur Foundation, 2013). Prior to the CE concept, there have been a plethora of environmental buzz words for businesses to attach themselves to. Terms such as sustainability, green procurement or green supply chain management, eco-design and triple bottom line have been commonly used by organisations to illustrate their attempt at environmental consideration. However, these concepts mainly follow a cradle-to-grave approach where products still end up in landfill, albeit at a delayed pace (Jain, Jain, & Metri, 2018). The Ellen MacArthur Foundation has amalgamated these different terms to bring a cohesive circular framework to the forefront of society and give organisations a framework to work towards (Pomponi & Moncaster, 2017).

The CE model is a synthesis of different schools of thought but most closely emulates the work of Michael Braungart and Bill McDonough in *Cradle to Cradle: Rethinking the way we make things* (McDonough & Braungart, 2002). The term C2C was coined by Walter Stahel in the 1970s (Geisendorf & Pietrulla, 2018). C2C focuses on reducing the environmental impact of products through regenerative and biomimetic approaches to product design. C2C is a holistic, economic, industrial and social framework designed to eliminate waste from product life cycles while powered by renewable energies with a focus on natural system design (McDonough, Braungart, Anastas, & Zimmerman, 2003). C2C can be distinguished by two cycles, biological nutrient metabolism and technical nutrient metabolism. The biological nutrient metabolism cycle is concerned with consumable products, these are materials and products that are consumed in the process of fulfilling their purpose such as food. These are consumable products that cannot be recovered and enter the environment in various pathways such as air, water or soil. Once there it should act as nutrients for the environment which in turn allows for renewable resources, and new products can be derived. They are designed to move back into the system through processes like composting, anaerobic digestion or cascading processes (McDonough, 2002). Technical materials are concerned with recovery of components that are not able to be composted such as metals and other ridged materials. These materials are recovered through processes such as reuse, repair, remanufacture and recycling (MacArthur, 2013). C2C concept is closely linked with the CE concept with many parallels synonymous with each other (Esposito, Tse, & Soufani, 2017).

In addition to C2C, the CE model is a synthesise of various other environmental and industrial ecology philosophies which include performance economy, biomimicry, industrial ecology, natural capitalism, and the blue economy. The Performance Economy was developed by Walter Stahel (Stahel, 2010). The concept relates to functional service or product as a service (PSS). It focuses on utilisation of resources and product life extension which has benefits for the environmental and creating job opportunities. Performance Economy is concerned with maximising the value of products in use while resource inputs and energy are minimised. Organisations need to change their business model in order to implement a Performance Economy strategy and consumers will have to change their notion from owning products to purchasing products as services.

Biomimicry concept is a product and process design concept developed by Janine Benyus (Benyus, 1997). Biomimicry looks to emulate nature’s ecosystem because nature has already solved the sustainability issues humankind is facing. If the mechanisms that drive the ecosystem can be copied into product design and process design, then the whole value chain can eliminate negative environmental impacts.

Industrial ecology focuses on the flow of energy and material through industrial systems to reduce their environmental impact. Industrial ecology is a framework with the aim of creating closed loop processes that allow for industrial processes to continue without the harmful environmental impacts by using waste as part of their process. The closed loop approach allows for industrial processes to eliminate waste from their manufacturing processes (Haas, Krausmann, Wiedenhofer, & Heinz, 2015).

Natural Capitalism concept was developed by Paul Hawken, Amory Lovins and Hunter Lovins with a focus on the world's stock of natural assets. Natural capitalism is based on using all resources more productively, which allows time for resources to regenerate. Secondly, natural capitalism looks to redesign products and production to increase the productivity of natural resources. Thirdly, to move to a service and flow business model rather than the traditional sale of goods model. Hawken, Lovins, and Lovins (2013) agree the global economy and business have overlapping common interest in resource utilisation, however, the two are not aligned in the maximisation and optimisation of resources.

The Blue Economy model was designed by Gunter Pauli (Pauli, 2010) and encourages better stewardship of ocean resources in activities such as commercial fishing, oil and gas extraction, and commercial shipping. The blue economy promotes sustainable business growth from the preservation of marine activities, rather than plundering them for short term gain.

The salient difference between the CE model and the linear model is the CE model has no beginning and no end to the material flow loops. This notion is where value is maintained through optimization of the materials and goods, quality and performance are maintained indefinitely. In contrast, the linear model starts with resource extraction and finishes with resource extinction. This process is known as cradle-to-grave, in which resources end in landfill and their value is lost (Bocken et al., 2016). A major factor in the CE model is resource loops. Resource loops govern the flow of materials throughout the process and stimulate the optimal use of products at the end of their life.

2.2 Supply chain management for a circular economy

Where the CE is concerned with the utilisation of resources, supply chains provide the process for which products move through. Supply chain management (SCM) encompasses all procuring and sourcing of raw materials and components, manufacturing and assembly of products and delivery of the final goods to customers through distribution channels (Mentzer et al., 2001). Traditional supply chains are modelled on the linear economy which means supply chains are also designed to be linear, as represented by name and in nature as being a chain. This model is based on the linear flow of materials and fails to consider the environmental impacts of products such as end-of-life management (Jain et al., 2018). Traditional supply chains facilitate and perpetuate the linear economy through their unidirectional flow of materials and utilisation of fossil fuels. In recent years research has been conducted into supply chain design that does consider the environment with the development of green supply chain management (GSCM) (Srivastava, 2007), environmental supply chain management (Seuring & Müller, 2008) and closed loop supply chain management (Savaskan, Bhattacharya, & Van Wassenhove, 2004). Further developments in sustainability have advanced sustainable supply chain management (Seuring & Müller, 2008) that incorporate economic, social and environmental considerations. Sustainable supply chains aim to minimise the material flows in the production process, along with reducing pollution and waste generated throughout the process. However, the criticisms of these supply chain designs is that they all follow the cradle-to-grave approach (Genovese, Acquaye, Figueroa, & Koh, 2017).

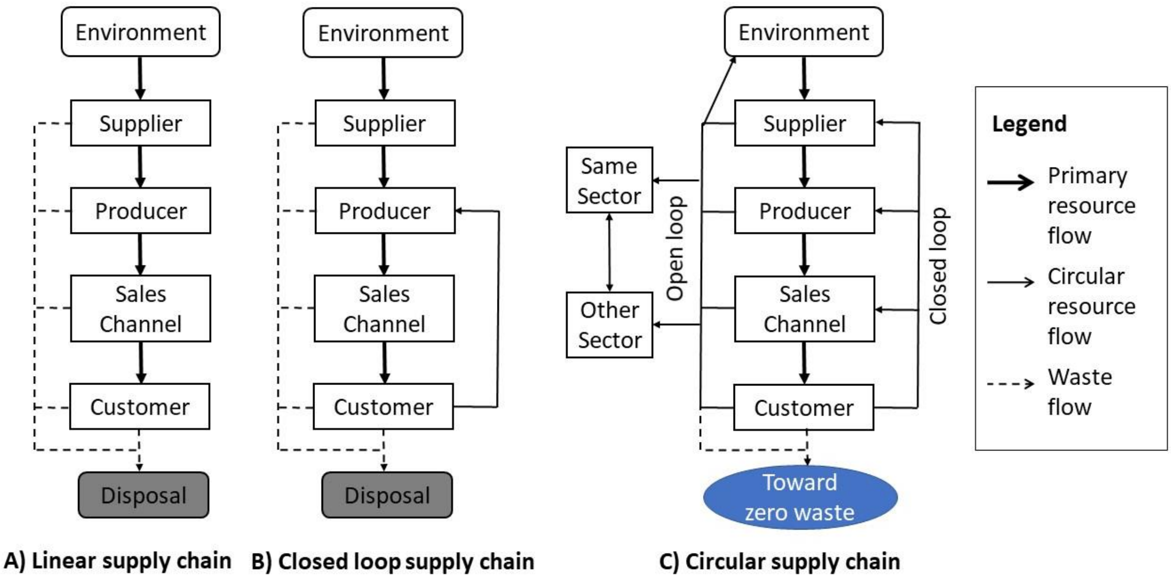
Circular supply chain management (CSCM) is based on the C2C approach which follows the philosophy of CE and ensures resources flow in circles and waste is minimised (Weetman, 2016). This research adopts the CSCM definition from Farooque, Zhang, Thurer, et al. (2019):

"Circular supply chain management is the integration of circular thinking into the management of the supply chain and its surrounding industrial and natural ecosystems. It systematically restores technical materials and regenerates biological materials toward a zero-waste vision through system-wide innovation in business models and supply chain functions from product/service design to end-of-life and waste management, involving all stakeholders in a product/service life cycle including parts/product manufacturers, service providers, consumers, and users".

CSCM ensures biological resources that follow the regenerative cycle are managed correctly at the end of its life cycle and returned to the biosphere. Technical materials such as metals are designed to go through material recovery processes so the resources can be restored to be used again. These processes include remanufacturing, refurbishing, repurposing and reuse (Jain et al., 2018). A key aspect of CSCM is the reverse logistics activities that ensure products are able to be returned at the end of their life cycle to a remanufacturer (Larsen, Knudby, van Wonterghem, & Jacobsen, 2017). This process gives the CSCM the ability to be circular which is paramount to the facilitation and function of the CE because it allows resources to move between manufacturers and consumers in a continuous loop. Reverse supply chains can be either open-loop or closed-loop as illustrated in Figure 1. Closed loop supply chains return products to the producer so they can recover the value (Guide Jr & Van Wassenhove, 2009). However, the issue with closed loop supply chains is they can still produce a substantial amount of waste because rarely does the returned materials fit back into the same supply chain loop (Moula, Sorvari, & Oinas, 2017). A circular supply chain recovers the waste value from products by coordinating and collaborating with businesses within the same industry sector (open-loop same sector) or with businesses from different sectors (open-loop other sector). This process allows for the waste from one supply chain to become the inputs in another supply chain (Genovese et al., 2017).

Measuring the environmental impact of the supply chain is important for ensuring the efficiency and effectiveness of the processes. Life cycle assessment (LCA) is an environmental analysis tool used to support the cleaner production, distribution, consumption and end-of-life management of products (Finnveden et al., 2009). The LCA framework can assess the environmental impacts of products, processes or activities, and can analyse the collaborative impacts of supply chain partners in upstream and downstream supply chain activities. Measuring the supply chain impacts is an important factor in being able to reduce the environmental impacts (Genovese et al., 2017).

Figure 1: Linear, closed loop and circular supply chains.



Source: Farooque, Zhang, Thurer, et al. (2019)

2.3 Product design for a circular economy

Poor product design has been identified as a major contributor to the overuse of virgin resources. Redesigning products with greater consideration for environmental factors and end-of-life management is prudent to preserve life on earth and the resources within it (Moreno et al., 2016). The issue with most products is they are designed for low cost and high profit, but their end-of-life options are not considered in the design phase (Vinodh & Rathod, 2010). This leads to most products going to landfill at the end of their life cycle and the materials lost to the waste stream. Since the 1930s great depression, product designers have been designing products that incorporate planned obsolescence. This plan was formulated by business leaders to stimulate sales by designing products that have a limited lifespan and forces consumers to purchase new products often. This model perpetuates the linear economy but has been widely accepted by consumers to date (Brondoni, 2018). In 1971, Victor Papanek identified industrial design as a harmful profession and since then not much has changed, although social pressure has forced some manufacturers to look for design strategies that look beyond the notion of profits and incorporate social and environmental elements into their product designs.

Papanek and Lazarus (2005) further noted that product designers have a powerful technical ability that allows them to shape the environment in which we live and work.

To be able to keep products out of landfill they need to be designed so their environmental impact is minimised and mitigated throughout their life cycle (Sakao, 2007). This needs to be applied at the earliest stage of the product development phase in order to meet environmental considerations throughout the product life cycle (Gehin, Zwolinski, & Brissaud, 2008). This should effect all diagrams, drawings, dimensions, cost, quality, safety and product description sheets, along with the environmental, ergonomic and aesthetic factors comprising the product (Romli, Prickett, Setchi, & Soe, 2015). From a manufactures and designers perspective, adding in environmental considerations usually means an increase in costs because of the specialised materials and additional design considerations required to make a product sustainable.

2.3.1 Eco-design

Eco-design concept was developed in the 1980s to mitigate the environmental impacts organisations were encountering within their operations. Eco-design is a design concept aimed at integrating environmental considerations with sustainable design solutions that solve environmental problems (Karlsson & Luttropp, 2006). Eco-design can apply to products, services or systems with the objective of minimizing negative effects while maximising positive impacts on the environment. While eco-design has its core objectives embedded in the environment, it also considers the economic, social and ethical impacts throughout the life cycle (Charter & Tischner, 2017). This systematic integration of product and processes with environmental considerations helps manufacturers mitigate risks in their supply chain by maintaining and enhancing competitive advantage, reducing production costs, opening new sales channels and improving regulatory relationships (Knight & Jenkins, 2009). Eco-design is able to inspire and promote the wider field of design through environmentally friendly products, effective system solutions, new design tools and attractive designs (Karlsson & Luttropp, 2006). Eco-design is a synthesis of different fields of research which include ecology, design and sustainability.

For eco-design to be effective, the product must be measured throughout its life cycle which is where LCA tools can be utilised as a method for assessing the environmental impact. For a product or process to be truly environmentally sustainable then its impacts must be measured from the design and conception phase, right through to its end-of-life (Kobayashi, 2006). Eco-design considers a four level model which includes product improvement, product redesign, function innovation and system innovation (Brezet, 2000). The first two levels of product improvement and product redesign are focused on products, either redesigning products or improving products to be environmentally sustainable. While function innovation aims to dematerialise services from products and system innovation considers new products and services to arise from innovation (Kobayashi, 2006).

2.3.2 Design for sustainability (DfS)

Design for sustainability (DfS) is a design strategy developed in the 1990s as an evolution to the eco-design concept and builds on previous design concepts such as green and ecological designs. DfS places a higher importance on the social, economic and ethical dimensions than eco-design while maintaining and enhancing the environmental aspects of design (Spangenberg, 2013). DfS aims to apply elements of life cycle thinking to the design stage and should be used as a tool for designers to express their designs in a sustainable manner. Spangenberg (2013) argues that DfS doesn't provide limitations on design but rather asks designers to solve their problems by providing better alternatives. This concept builds on the methodology of sustainable consumption and sustainable production but still remains on the boundaries of design education and practice (Bhamra & Lofthouse, 2016). DfS is considered a design strategy for closed loop supply chains so that resources are utilised continuously within the same supply chain.

2.3.3 Circular product design

Circular product design is seen as the ideal process to move forward the CE roadmap (Gregson et al., 2015). Circular product design focuses on designing products so their resources can be repurposed at the end of its life cycle (Den Hollander et al., 2017). The concept of circular product design has been derived from other sustainable product designs concepts such as DfS, eco-design, green design, and design for the environment (Dfe) (Moreno et al, 2016) with the aim of closing resource loops. However, unlike its succeeding design strategies that have a cradle-to-grave approach, circular product design involves rethinking the utilisation of resources and waste minimisation in a C2C approach and places a higher emphasis on product design to ensure resources circulate through the supply chain indefinitely (Andrews, 2015). Integrating circular thinking early into the design phase is important because once a product has been designed, then it is difficult to make changes to the design, resource allocation and infrastructure (Bocken et al., 2016). Product design phase is critical to the development of products because it sets the criteria that determine the products life cycle. At this stage product designers have a huge responsibility to shape the direction the product will move in (Moreno et al., 2016).

In circular product design, there are a multitude of design strategies and materials that can be utilised to realise the cyclical approach. Biological and technical materials are used exclusively in circular product design because they can be repurposed at the end of the life cycle. Closing resource loops is important to maintaining resource value and design plays a major part in this process. Design for product-life extension and design for long-life products ensures the usable lifespan of a product is prolonged through reuse, maintenance, repair and technical upgrading. These strategies are usually used in the performance economy where products need to be durable (Bocken et al., 2016).

Circular product design is an important aspect of the CE and has led to many researchers to study this concept in recent times (Bocken et al., 2016; Den Hollander et al., 2017; Moreno et al., 2016). Circular supply chain research (Genovese et al., 2017; Zhu, Geng, & Lai, 2010) has also spiked in recent years as the development of the CE concept begins to gather pace. However, there are limited studies conducted on integrating circular product design with circular supply chain design. Moreno et al. (2016) has developed a conceptual framework for circular product design but this framework is only conceptual and further research needs to be conducted on operationalising circular product design. Therefore, the research gap this study will be addressing is what are the implications of circular product design for business model and supply chain management for a transition to the CE?

2.4 Business models for a circular economy

Business models are an important aspect in the conception of a business venture as they support and facilitate the three key features for commercialising (going to market). These key features include the value proposition which is defined as the product or service being offered, value creation and delivery which encompasses how value will be provided and which stakeholders will be involved in, and finally value capture which outlines how the firm will make money, capture other forms of value and develop revenue streams (Bocken et al, 2016). A business model is the architecture of a firm, and in addition to their 'going to market' strategy it outlines the structure for management, communication, performance assessment, innovation and expansion paths (Bocken, Short, Rana & Evans, 2013).

Traditional business models follow a linear paradigm ideology and are generally focused on making profits with very limited regard for the negative impacts they produce on the environment and society. Given their underlying linear thinking, traditional business models are not suitable to govern business activities in a CE. New business models are needed for innovation, technological advancements and to support sustainable business strategies (Witjes & Lozano, 2016). From a firm's perspective there are huge benefits for switching from a linear business model to a circular business model. Circular business models can narrow, close and slow resource and energy loops far better than their linear counterparts (Lewandowski, 2016). Circular business models support and foster sustainable business strategies which include enhancing and developing social and environmental capital, utilising renewable energies and developing sustainable supply chains. In addition, they provide direct cost savings towards a firm's bottom line by reducing waste and associated costs. They also improve the wider society and environmental capital (Geissdoerfer et al, 2017).

There are multiple business models that have proven to be in synergy with a CE. Product as a service, or product-service system (PSS), has emerged as a very successful model where products are sold as services through business models that are based on renting, leasing or subscriptions. In this model a firm offers access to products but retains ownership. It is an alternative to the traditional linear business model of “buy and own”. In a PSS model the firm will bear the responsibility of maintaining and repairing the products to ensure high performance to the user. An example of this PSS model is Philips pay-per-lux where Philips Lighting sell the service of light bulbs and users only pay for the number of lumens they use (Kjaer et al, 2019). Similar to PSS, sharing platforms and services have also become popular in recent times. The sharing economy has made ways for new business models to be formed based on sharing of products between customers and providers. Sharing platforms use cloud-based technology to connect individuals with underutilised assets wanting to rent or lease these products. This is a peer-to-peer (P2P) based system. Examples of this model in operation include Airbnb, Uber and Lyft (Apte & Davis, 2019).

Business models that aim to extend a product’s life through durable design, repair and maintenance have begun to flourish with environmentally conscious consumers looking to repair rather than to replace their products. In addition, firms that design products for long life such as vehicles and whiteware goods can slow resource loops (Geissdoerfer et al., 2017). Finally, industrial symbiosis may develop into a lucrative business model with mutual benefits for all firms involved in. Industrial symbiosis is concerned with using the waste output from one firm as the resource input of another, thus removing waste from the system while simultaneously adding value to it and allowing firms to profit from waste (Bocken et al, 2016).

Chapter 3: Methodology

3.1 Ontology and epistemology

The philosophical view concerning this research will adopt a realism ontology and an objectivism epistemology. This research will view knowledge as obtained through reason and understanding of the social world and an objective truth that is able to be discovered. Objectivism views reality as one single external reality that exists independent from the human conscience. The knowledge relationship with research should obtain objective knowledge and focus on generalisation and abstraction (Gray, 2013).

Underpinning the ontological and epistemological position is a positivism theoretical perspective to guide the social science of enquiry. The positivism paradigm takes the theoretical stance that reality consists of the senses and what can be seen and touched. The social world can be measured through scientific observation, rather than speculation. The role of the researcher in this paradigm is detached as an external observer. The researcher will be removed from personal feelings with the subjects, however, the researcher will never be fully removed and must have some interaction, no matter how small. Taking an external observation approach allows the researcher to distinguish between reason and feelings while using rational and logical approach to the social inquiry. The aim of the researcher is to discover knowledge from the external world to formulate concepts (Comte, 2015).

This philosophical position differs from an interpretivism paradigm and constructivism epistemology in that they are associated with constructing knowledge through people's perception and social situations, allowing multiple realities and answers to exist within the same world. Knowledge, while independent of human minds, is always created by human and social construction, through social experiences, perception and convention (Crotty, 1998). Constructivism views the role of the researcher as an internal observer who aims to create meaning from what is studied. Identifying the philosophical position of the research is important because it helps clarify the research design and develop the overarching structure of the research. This includes the type of data being collected and the method for analysing that data (Gray, 2013).

Given the exploratory nature of the research it is important for this line of research inquiry to adopt a qualitative approach, aligned with a realism ontology and objectivism epistemology to answer the research question. Understanding the CE concept through qualitative data provides rich knowledge that cannot be expressed through quantitative data. Furthermore, this theoretical position allows the researcher to be independent from the participants during the data collection process. This allows the researcher to gather empirical evidence, and the participants' responses during the interview process will form the facts of the enquiry.

While there are many approaches to qualitative data analysis, the two most common approaches are inductive and deductive reasoning. When using deductive reasoning, theory guides the researcher towards testing the hypothesis to be confirmed or refuted. This allows concepts to be formed and theory to be developed. Ideas can be tested through empirical observation and experimentation, tools are created to measure and confirm the hypothesis (Gray, 2013). When applied to grounded theory or thematic analysis, deductive reasoning uses predefined codes and themes which have already been developed by current theory and concepts. This means the codes and themes are not derived from the process but have already been previously chosen before the analysis and the content is coded to those codes. In contrast, inductive reasoning has no predefined codes, data is collected and analysed so themes, patterns and theory emerge from the analyses. While theory may already exist for the topic, it doesn’t drive the analysis because of the exploratory and discovery nature of this approach. No preconceived notions about the concept influence the researcher which mitigates bias from the analysis (Arthur, 1994). The researcher must be careful not to jump to conclusions without rigorously analysing the data. This could take multiple instances of thoroughly checking the data and becoming familiar with the dataset, but this ensures reliability. The inductive approach doesn’t look to corroborate or refute a theory but rather gather information to establish patterns, themes, consistencies and meaning within the data (Gray, 2013).

This research on CE adopted an inductive reasoning approach to analysing the data because of the relatively new concept of CE and theories are still emerging so the inductive approach allowed the research to gather data without any preconceived notion about the outcome. This approach meant researcher bias was mitigated and empirical data could be gathered independent of pre-existing theories. This process gives the analysis reliability and validity.

3.2 Data collection

Interviews are defined as a verbal exchange where the interviewer attempts to extract information from another person by asking them questions (Braun & Clarke, 2013). There are three types of interviews: structured, semi-structured and unstructured (Longhurst, 2003). Semi-structured interviews provide the structure to guide the conversation for answering research questions and at the same time allows flexibility in the interview process so interesting discourse can be further questioned and deeper knowledge can be obtained. This is opposed to structured interviews that don’t deviate from the script (Whiting, 2008). The method used in this research to collect data was semi-structured interviews. Semi-structured interviews were chosen as the data collection method so participants wouldn’t be limited in their answers, and ideas or concepts could be explored further during the interview process. Structured interviews were not considered for this research because it would limit the participants to answering only the questions put forward by the researcher. This would restrict the type of empirical data required to answer the research question.

The unit of analysis for this research was industry experts who are either researchers or practitioners who have expertise in product design, supply chain management, or CE. Industry experts were chosen as the units of analysis because they are in the best position to provide in-depth knowledge about the research topic. Industry experts are preferred over firms because firms can impose their company ideologies and process which limit the amount of information that can be obtained. Industry experts on the other hand, can converse freely about their experiences and opinions and provide information that is not restricted by organisational policy on circular product design (Yin, 2017).

This study used opportunity sampling (Langdridge & Hagger-Johnson, 2009), where participants were obtained that were available at the time of the study and fitted the criteria for the study. The recruitment process started off by identifying businesses that embraced the CE vision and operated in the Auckland region. These businesses were identified using the Sustainable Business Network's member directory. Once a relevant business had been identified, a Participant Information Sheet was emailed to the business, requesting an interview with a senior business manager that has knowledge of supply chain management and product design. The reason the Participant Information Sheet was emailed to businesses and not to individuals directly is because CE implementation in the industry is still in its infancy stage so finding individuals that meet the criteria is difficult. Engaging organisations that operate with circular product design was used as the starting point for the participant recruitment.

In total, 15 participants agreed to participate in an interview. Their anonymised profiles are presented in Table 2 below. Eleven participants were active within circular product design and four participants were active academic researchers in CE. It was necessary to include academics and practitioners in the research design because they provide differing perspectives. Academics are well versed in theories that govern the CE, however, practitioners that work in the industry can provide practical knowledge on the process. These differing points of view allow for a board range of knowledge which allows the researcher to gain rich in-depth knowledge on the topic of inquiry. Participants were emailed the interview questions ahead of the interview time so they could formulate and structure responses to each question. The participants were asked to state a time and date that would be suitable to them so there would be little disruption to their daily activities. Interviews were conducted at the place of employment for the participants to ensure they were comfortable and relaxed, to mitigate disruption in their daily lives and to ensure the safety of the participant and the interviewer. Each interview took approximately 60 minutes.

Table 1: Participant profile

Participant Number	**Job description**	**Business type**	**Years of experience in sustainability and/or CE**
01	Director of Marketing and Digital	Producer - Personal care products	17
02	Managing Director	Retail - Building supplies	20
03	Business Manager	Producer - Commercial laundry	7
04	Managing Director	Producer - Packaging	10
05	Business Manager	Producer - Logistics equipment	18
06	Marketing Manager	Producer - Logistics equipment	3
07	General Manager	Recycling	9
08	R&D Manager	Producer - Personal care products	25
09	Managing Director	Producer - Personal care products	2
10	General Manager	Producer - Personal care products	2
11	Operations Manager	Producer - Personal care products	2
12	Senior Lecturer in supply chain management	Academia	6
13	PhD student (formerly a university lecturer in supply chain management)	Academia	9
14	Senior Lecturer in Environmental Engineering	Academia	20
15	Senior Lecturer in product design and sustainability	Academia	18

Thematic saturation means collecting data until no more patterns or themes emerge from the dataset (O'reilly & Parker, 2013). Reaching saturation point is important to the validity in the data collection method (Ando, Cousins, & Young, 2014). Once thematic exhaustion and variability within the data set has been achieved, there is no requirement to obtain further data through interviews (Gray, 2009). Guest, Bunce, and Johnson (2006) suggest thematic saturation should occur after 12 interviews, although basic themes should be evident after six interviews. This study did observe thematic saturation by the 12th interview, although a further three interviews were conducted to ensure no further themes or topics would emerge.

3.3 Data analysis

Following each interview, the audio recordings were transcribed by the researcher. Transcripts were anonymised by removing any potentially identifying information such as names of people and place of employment. The researcher transcribed each interview audio recording by listening to the recordings and typing each interview verbatim. This process allowed the researcher to become familiarised with the transcriptions while generating transcriptions that served as the source for the analysis.

The methodology used in this research to analyse the data is thematic analysis. Thematic analysis is a commonly used methodology in qualitative research and is used in many different disciplines and fields, for different datasets such as transcripts, video and audio data (Braun & Clarke, 2006). Thematic analysis focuses on identifying patterns and themes within data. It moves beyond just counting words and phrases but looks for implicit and explicit meaning in the data (Aronson, 1995). A theme is a conceptualised idea that captures shared meaning around an organised core concept. Themes capture the essence of meaning and unite data that would otherwise be disparate or in cases where the meaning could differ in multiple contexts (Braun, Clarke, Hayfield, & Terry, 2019).

NVivo 12 was used to support the thematic analysis. Computer assisted qualitative data analysis software (CAQDAS) allows all data to be consolidated into an integrated database that provides speed and efficiency in processing large volumes of data. It assists with managing, organising and coding the data which in turn provides transparency of the data analysis process (Saillard, 2011).

The thematic analysis used in this research followed the six phase framework as outlined in Table 1 (Braun & Clarke, 2006; Willig & Rogers, 2017). The coding process is an important part of the thematic analysis process. Codes relate to concepts that are central to the research question and are linked to the transcribed text. In the coding process, labels are assigned to portions of the transcribed text. If a participant had expressed an opinion, then a code was assigned to that text identifying and describing it. The main goal of coding was to organise and catalogue the transcribed text so thematic analysis could take place. The codes were developed by the research in an inductive approach. The thematic analysis started with the researcher reading and re-reading the transcripts to become familiar with the data. Secondly, the researcher started to developed codes that identified specific passages of text. In this step, the researcher initially identified 143 different codes after reviewing all the transcripts. The researcher then went through a refining process to reduce the amount of codes because some codes were similar in description. After refining the codes from 143 to 42, the researcher began searching for themes that closely related to the research question. From this phase the researcher was able to identify 10 themes. These themes were then reviewed against the data and research question to ensure they would answer the research question. A process of refining, upgrading, downgrading, merging and deleting took place which resulted in three main themes emerging. Phase five required the researcher to define and name the themes to ensure clear definitions were developed and attached to the themes. The final phase saw the researcher writing the themes into results which are presented in the results section.

Table 2: Phases of thematic analysis

Phase	Description of the process
1. Familiarisation with the data	This step involves the researcher immersing themselves in the data. Transcribing data, reading and re-reading, while noting initial patterns and ideas provides data familiarity.
2. Coding	This step involves creating codes that distinguish important aspects from the data. Appling codes to the whole dataset allows patterns to emerge.
3. Searching for themes	Identifying and examining codes that can become broader themes.
4. Reviewing themes	Checking the themes against the data in step 1 and step 2 to ensure they tell a convincing story of the data and that it can answer the research questions. In this step, themes can be refined, upgraded or downgraded, merged or deleted.
5. Defining and naming themes	This step moves beyond the coding phases and looks to develop deeper themes from the data. It requires the researcher to work out the scope and focus of each theme and ensure clear definitions and names for each theme.
6. Writing the report	The final step involves selecting the themes relevant to the research and writing up an analytic narrative and contextualising the analysis to answer the research question and produce a scholarly report of the analysis.

Source: Braun and Clarke (2006)

3.4 Ethical concerns

All participants involved in this study were provided with a Participant Information Sheet that explained the purpose and aim of the research. The Participant Information Sheet illustrated that the participant's involvement was voluntary and would neither advantage nor disadvantage them. It was noted their right to withdraw from the study at any time, or not answer any question they didn't feel comfortable with. Participants were encouraged to ask questions about the research and their role within it. Consent forms were signed by the participants after they were given ample time to decide on their involvement. Ethics approval for the interview process was approved by Auckland University of Technology Ethics Committee on the 1st February 2019, Reference number 01022019.

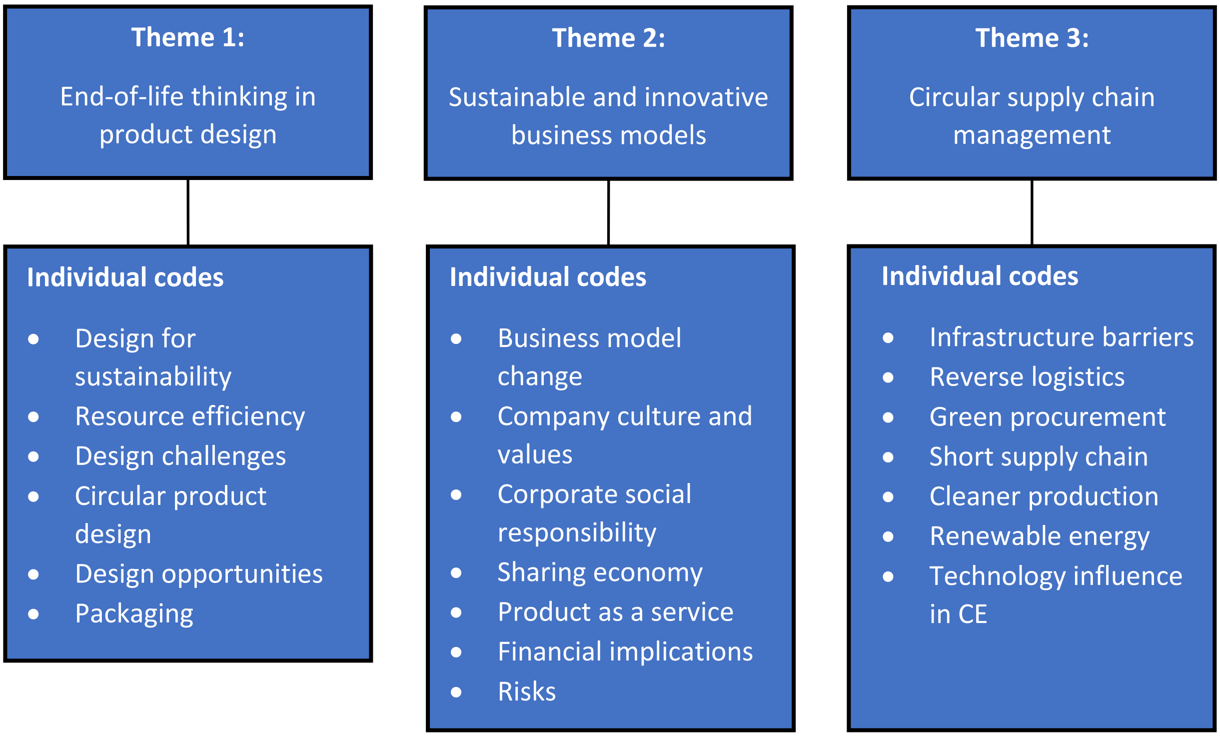
Chapter 4: Results

The analysis of the responses from the participants resulted in three themes being developed. These themes were: *End-of-life thinking in product design*, *Innovative business archetype* and *Circular supply chain management*. The participants discussed a wide range of concepts surrounding the circular product design. All concepts discussed in the transcripts were individually coded using NVivo12. The researcher paid closer attention to codes that relate to the research question. These codes were further analysed to create the three themes. Figure 2 shows the thematic map of the three themes and their associated codes. Further analysis of the most common words used by participants yielded the following results in Table 3. This table illustrates the frequency of key words used by participants. Stop words such as ‘A’, ‘and’, ‘so’ etc were removed from the analysis.

Table 3: Word frequency

Word	**Frequency**	**Weighted Percentage (%)**	**Similar Words**
product	438	1.39	product, product', product’s, products
thinking	397	1.26	think, thinking
circular	365	1.16	circular, circularity
people	358	1.14	people, peoples
change	309	0.98	change, change', changed, changes, changing
business	293	0.93	business, businesses
economy	271	0.86	economies, economy
design	253	0.80	design, designed, designer, designer', designers, designing, designs
recycling	168	0.53	recyclability, recyclable, recycle, recycled, recyclers, recycles, recycling

Figure 2: Thematic map of the main themes and codes



4.1 Theme 1: End-of-life thinking in product design

Theme 1 is called *End-of-life thinking in product design*. This theme encapsulates the participants' responses for the requirement to have sustainable options for every product at the end of its life cycle. Thinking about a product's end-of-life options begins at the product design phase. Product inventors assume considerable responsibility because their products can have unintended consequences if they don't consider the environmental and social impact during this step. Intentionally designing products with options at the end of its life cycle ensures product waste is reduced and resources can be repurposed which maximises their value. Product design is fundamental to the CE and to fixing the waste issues in the linear economy. This theme is presented as a main theme because all participants categorically stated products were the main waste generator in the linear economy. The participants were asked the question "what opportunities does product design offer to businesses, consumers and the environment?" The participants demonstrated good understanding of product design principles and how they contribute to waste and resource utilisation. This question yielded 108 participant responses that were categized into six different codes. The six codes used to form the theme *End-of-life thinking in product design* are presented below with the explanation of the code, summary of the participants discourse and verbatim from the transcripts:

Design for sustainability code relates to product design strategy that incorporates environmental and social benefits while ensuring products are designed to have extended lives. While this is a sustainable product design strategy, it still follows the cradle-to-grave approach from the linear economy (Mayyas, Qattawi, Omar, & Shan, 2012). In some cases, participants would describe sustainable products but label them as circular products. The interchangeability of these two words (sustainable and circular) made coding a difficult task. Having said that, most participants were aware of the difference of the two terms which is the reason C*ircular product design* code was used to distinguish the two concepts. One participant stated, “So, product design is an important part of the CE and we incorporate it into our business model. We partner with other organizations that work on good responsible sustainable product design.”

Resource efficiency code refers to a firm’s ability to use resources to their maximum efficiency. Resource efficiency has been an important topic in government policy which is why the European Union (EU) has marked it as an important aspect of its Europe 2020 strategy (Tukker, 2015). All participants demonstrated good knowledge on resource efficiency and expressed the need for fewer virgin resources to be used in manufacturing. The participants felt the global economy should be using less resources but using them more efficiently. One participant stated, “using less and using it better has to be done.”

Design challenges code captures the issues firms need to overcome when designing innovative products. These challenges can range from design constraints, resource availability, regulatory barriers and design costs (Bocken et al., 2016). All the participants had experienced some form of design challenge within their own organisation which meant they were well versed in overcoming challenges with product design. Product design for the CE has its challenges because of the added pressure of developing products that are environmentally and socially considerate and the costs associated with that process. Most participants felt circular products aren’t supported with the infrastructure required to repurpose products at the end of their life cycle. Some participants built their own infrastructure while others operated with biological products that meant they didn’t have to worry about the returning of goods. One participant stated, “It's just the costs. I mean the practical challenge for businesses is the costs. The costs of changing the way you do business. The cost of changing those supply chains or the cost of redesigning products is a fundamental challenge that will stop some businesses”.

Circular product design code encapsulates designing products that are socially and environmentally sustainable while ensuring the materials can be retrieved at the end of its life cycle (Den Hollander et al., 2017). The participants were very enthusiastic about circular product design and the benefits it has on the environment and society. Moving towards circular product design is seen as very important in reducing waste and using resource more efficiently. The participants saw the linear economy based products as the cause of most pollution and circular products could be the answer to minimising the effects of waste and pollution. The participants saw the value in products moving in cycles. One participant stated, “The reuse of products multiple times over means waste costs reduce because we aren’t throwing out so much stuff now.”

Design opportunities code relates to opportunities firms can leverage from innovative designs. Firms that offer innovative designs to market can gain competitive advantage. This gives a firm the opportunity to gain market share over competitors (Swink & Song, 2007). Most of the participants are new entrants in the market of circular products and have obtained a competitive advantage from being the first entrants. Although the market for circular and sustainable goods is limited in New Zealand, participants had stated their business activities were growing as consumer awareness and demand increases. Moreover, participants felt designing circular products improved a firm’s image and reputation with the public and that brought added value and opportunities to the firm. One participant stated, “The opportunities for businesses is they can build a good reputation and good brand image in the long term…preservation of resources and open new avenues for revenue.”

Packaging code refers to the outer and inner packaging used to contain products. Packaging materials follows a similar life cycle to products where it is used once and then discarded into landfill (Svanes et al., 2010). The participants were very vocal about how firms package their products with many stating the excessive use of packaging is as environmentally harmful as the products they contain. Most packaging is produced with complex materials making it difficult to recycle. Simplifying and standardising packaging would allow infrastructure to be built to increase the ability to recycle packaging after use. One participant stated, “I think standardisation in packaging would help with this issue. If there were global standards for packaging, then recycling could happen more easily.”

4.2 Theme 2: Sustainable and innovative business models

Theme 2 is called *Sustainable and innovative business models.* This theme was drawn from the data because participants noted there needed to be dramatic changes in business strategy for companies to evolve into the CE. Changing business strategies is not an easily achieved task. There are a myriad of challenges business owners face. *Sustainable and innovative business models* holistic sustainable changes to a firm’s business strategy. This includes business model, culture and values, vison and mission statements and changing their responsibility to the environment and society. *Sustainable and innovative business models* provides opportunities for organisations to move beyond the problems facing linear economy-based firms and become a source of sustainable competitive advantage. This theme is presented as a main theme because all participants noted the requirement for firms to adopt business strategies that are conducive to circular principles. The participants were not asked a specific question about business model or value, but there were still 103 participant responses drawn from several different questions. These responses were split over seven different codes that will be outlined below.

Business model change code relates to organisations adopting business models that suit their type of business and encapsulates circular principles (Planing, 2015). Traditional business models are geared towards the linear economy. Changing business models that allow a firm to place equal importance on the environment, society and profitability is paramount to achieving sustainable business growth. One participant expressed frustration at the current linear economy-based business models by stating, "I think the reality is that we can all do better. We must do better. We must completely change. I think the issue is that it's not about incremental change. It is not about doing less bad. It is that we need to fundamentally redesign our systems, our processes, our products, our services such that we are actually doing something circular."

Company culture and values code refers to a firm's ability to create, implement and maintain culture and values that are in line with their company strategy (Flamholtz, 2001). The participants felt very strongly about creating good culture and values within their organisations. Some participants felt their company culture and values were what made their company unique and gave them competitive advantage. This was because top management championed culture and values and they were able to employ staff that held similar values. One participant was very enthusiastic about their company culture and values by stating, "We are lucky because our business is owned by a family, and a decent family, and they do have concerns, and they want to do the right thing. So, management and the people in higher positions in the company are quite important in driving the vision and the culture."

Corporate social responsibility (CSR) code relates to corporate policy that governs ethical decision making around social and environmental factors (Dahlsrud, 2008). The participants felt being a corporate citizen was very important in transiting towards the CE. Corporations contribute to the global waste problem but hold little responsibility when it comes to the clean-up. The participants understood the value CSR creates for them through improved brand image and reputation. They also felt obligated to be good corporate citizens because they needed to provide a sustainable future for their business and society. One participant stated, "Corporate social responsibility is driven by organizations. The leaders of these companies understand the impact they have and don't want to destroy their company image."

Sharing economy code refers to sharing of resources and assets between organisations in a business to business (B2B) context or business to consumer (B2C). In a B2B example it can also be referred to as co-opetition where competitors collaborate and share for mutually beneficial results (Luo, 2007). Sharing of resources and assets between competitors in the linear economy is not generally acceptable because firms try to protect their secrets. The participants felt the CE was more open to sharing. In fact, several participants actively shared their resources and assets with competitors. These participants saw sharing as a prudent way of gaining access to resources and assets that they wouldn't otherwise have access to. One participant stated, "Sharing is a big part of our industry. We can't handle this by ourselves. We must be realistic. We don't have the infrastructure or the capital to make changes happen rapidly enough. We intend to be in the future but, that might be 15 years away."

Product as a service code captures firms that offer products to rent or lease as opposed to selling. This means firms retain ownership of the products and ensure they are maintained to the highest operational level which prolongs the life of the asset (Mont, 2002). Many of the participants felt PSS model was important in decoupling private ownership of products. When a firm retains ownership of a product, they have an invested interest in that asset to ensure its longevity. Two participants were currently working with PSS model. They felt this service worked very well for their products although there were issues with customers treating the products poorly. They stated, "Now we've got the whole situation where the business will take responsibility for the product and you pay for the service…The business takes back and reuse the materials because the materials are really valuable."

Financial implications code relates to costs associated with business activities (Mizik & Jacobson, 2003). All the participants noted financial health as being very important. Some participants were concerned about being financially viable because they have staff and their families to look after. Moreover, the participants were wanting to make sustainable long-term changes within society and stated they couldn't do this if they were not financially viable. The participants noted the connection between finance, technology and staff. If an organisation has the financial capabilities, they can invest in new technologies and employee good staff. One participant stated, "To challenge the bottom line. You're still focused on making money because you need to make money in order to make change… we never downplay financial sustainability because if we're not financially sustainable, then we've got three staff members who are no longer sustainable for their family. So, we have to be financially sustainable."

Risks code refers to business risks associated with changing business activities such as new products, business model or supply chains (Kale, Noe, & Ramirez, 1991). Changing an organisation's supply chain or business model to support new products can leave an organisation exposed to financial risks or hinder their ability to service their customers' needs. Many participants noted the inherent risk associated with changes in business model and supply chains with increased costs and uncertainty around market share. One participant stated, "Because in changing from one system to another, there is a significant cost to business. Therefore, if they don't make that workable, there is no incentive to businesses to change or there is disincentive even if the intention is there."

4.3 Theme 3: Circular supply chain management

Theme 3 is called *Circular supply chain management*. It emerged from the data because participants were noting supply chains needed to be redesigned to incorporate circular principles. Developing a supply chain network that is conducive to the philosophy of the CE requires changes in every aspect of supply chain management. Green procurement strategies should be adopted for sourcing goods and services. Cleaner production practices are required to reduce pollution and reliance on fossil fuels. Decentralising manufacturing will shorten the supply chain, which will reduce the distance goods and resources need to move between processes. Infrastructure needs to be developed to facilitate reverse logistics and renewable energies should be used throughout the entire supply chain. This theme is presented as a main theme because participants felt traditional supply chains were linear in scope and couldn't facilitate the reverse flow of resources and products. It is important to increase the scope of the supply chain to include reverse logistics and to change the linear nature of a supply chain to evolve into a circular supply chain.

The participants were asked the interview question "How does moving towards circular product design require changes in supply chain processes including sourcing and procuring materials, logistics, production, end-of-life product management, etc?" This question yielded the majority of the 170 participant responses. These responses were split over seven codes that will be outlined below.

Infrastructure barriers code refers to all structures required for processing and facilitating the flow of goods and resources throughout the supply chain. These can include, but are not limited to: transport, energy, factories and systems (Ness, 2008). Infrastructure is important in facilitating the cyclical flow of products and resources because they provide the structures that enable the products to move between value added processes. The participants felt there was a lack of infrastructure that could provide reverse logistics support. The lack of infrastructure is a barrier to reverse logistics because there are no facilities that can process the returned goods. One participant stated, "Now one of the other things is reverse supply chain, so when something goes out, how does it get back?! And so that was one of the infrastructure barriers that we've got is we don't have the infrastructure to return goods."

Reverse Logistics code encapsulates activities that occur at the end of a product's life cycle to recapture value from the resources used within the product (Dekker, Fleischmann, Inderfurth, & van Wassenhove, 2013). The participants felt reverse logistics was an important aspect in the CE and would be instrumental in retrieving resources from products at the end of their life cycle. However, they believed reverse logistics was currently not being utilised by many organisations because firms don't see value in returned goods. The participants sighted return costs, lack of infrastructure and a misconception of the value that can be retrieved from products as the main purposes for reverse logistics not being utilised by organisations. One participant stated, "Reverse logistics has always been an issue because generally freight costs more for sending goods in the other direction and it requires a change in the infrastructure and in the processes. The problem with returning goods is businesses don't see the value in the waste and so they don't invest in getting their products back at the end of its life cycle but a significant margin can be made on return trips because of the need for trucks to back fill on their return route. Businesses only see the cost of the transport and not the value in the returning of the material."

Green procurement code involves purchasing goods and services with strict criteria that ensures minimal environmental and social impact (Blome, Hollos, & Paulraj, 2014). The participants felt firms can change their own purchasing behaviours and force change on their suppliers by purchasing with green procurement strategies. This ensures products are being sourced with the utmost concern for the environment and society. Currently, many firms implement procurement strategies that focus on cost reduction. If firms placed the same weight on the environment and society as they do for cost, then this would force change throughout the entire supply chain as suppliers would have to source sustainably also. One participant stated, "businesses have the power to force change throughout the supply chain by using their purchasing power and enact change on suppliers."

Short supply chain code relates to a regional network that connects producers with consumers (Marsden, Banks, & Bristow, 2000). Short supply chains differ from traditional supply chains because they short circuit the long and complex supply chain network and remove intermediators from the process. A short supply chain is where goods are produced in a geographical area and then sold in the same region, removing the need to send goods over long distances. The participants felt shortening the supply chain and decentralising manufacturing would reduce pollution and fossil fuel usage because products wouldn't have to travel so far and would reduce the number of intermediators in the supply chain. One participant stated, "You've really got to have your manufacturing facilities everywhere. Small manufacturing facilities. Local. Then just use the Hub and Spoke shipping models. Businesses need to change to local and bring manufacturing back to New Zealand."

Cleaner production code refers to an organisation's ability to minimise or mitigate environmental impacts from the process of manufacturing products. Through preventative environmental protection initiatives and LCA, an organisation can analyse their use of resources and energy to minimise waste and emission outputs (Kjaerheim, 2005). The participants felt manufacturing was the main cause of waste and pollution. They believed manufacturers should fundamentally change the way they consume resources and manufacture products by utilising cleaner energy and purchasing repurposed resources rather than virgin resources. One participant stated, "It's the manufacturers who really need to understand the design side to make their products circular. The production processes that manufactures are using is harmful to the environment. Products aren't being designed to be circular but rather for single use and ease to throw away."

Renewable energy code refers to energy that is obtained from renewable sources. Renewable energy sources include solar, wind, hydro and geothermal heat. Renewable energies can be used to power supply chain and logistics activities (Boyle, 2004). The participants felt traditional supply chains are inherently unsustainable, partly because they are driven by fossil fuels. Fossil fuels are used throughout the supply chain for manufacturing and transportation of products and resources. Changing the energy used to power the supply chain would decrease the environmental impact. One participant stated, “Energy is a very important factor to the CE because for products and transport they need to be driven by renewable energies. Moving from fossil fuels to solar or wind power is very important to keep the CE operating in a circular manner.”

Technology influence in CE code relates to the utilisation of technology that can drive or enhance the capabilities of an organisation within their supply chain functions (Tjahjono, Esplugues, Ares, & Pelaez, 2017). The global community is in the fourth industrial revolution (industry 4.0) which sees the emergence of technologies such as cyber physical systems, the internet of things (IoT), cloud computing and artificial intelligence. The participants felt these technologies were very important in facilitating the movement of products and resources throughout the supply chain. Most participants felt the cost of some emerging technologies was out of reach for most firms. All the participants did state some form of technology was integrated into their business and was essential in their operations. One participant stated, “Technology is essential for any business activities. We cannot isolate business activities from technology. Now it is integrated. Whatever firms want to do, they have to use technology, but what and how makes a big difference.”

Chapter 5: Discussion

There are several general propositions that can be drawn from the results section. The first is that end-of-life thinking is required in re-engineering product design activities in order to design circular products. Incorporating end-of-life options into product design is paramount in designing waste out of the system and utilising resources to their maximum value (Den Hollander et al., 2017). Product designers should be encouraged to think creatively and offer innovative sustainable solutions to solve end-of-life challenges (Li, Wang, Li, & Zhao, 2007). Furthermore, LCA should be implemented during the design stage to measure the environmental impacts related to all stages of a product's life (Lake, Acquaye, Genovese, Kumar, & Koh, 2015). Having sustainable options at the end of product life cycle allows firms to recover materials and use them as secondary resources in another product.

The second proposition is that circular thinking is required in redesigning supply chain processes in order to recover value from circular products to achieve resource circularity. Supply chains are traditionally linear in scope and redesigning them to incorporate circular thinking requires changes in a diverse network of stakeholders (Nasir, Genovese, Acquaye, Koh, & Yamoah, 2017). Embedding circular principles into supply chain management allows products and resources to circulate in loops. Reverse logistics is an important process in circular supply chains because it enables resources to be recovered at the end-of-life cycle (Genovese et al., 2017). Circular supply chain thinking coupled with sustainable end-of-life product options ensures resources yields are optimised through their life span. Furthermore, by including process such as green procurement for purchasing and cleaner production practices for manufacturing, supply chains can optimise economic and environmental performance.

The third proposition is that innovative thinking is required in creating sustainable business models in order to be economically viable to unlock the potential of circular products. Business models define the architecture of the business and paths for expansion, they support the commercialisation of products and services which is important for firms to create, deliver and capture value (Bocken et al., 2016). Chesbrough (2010) believes linear business model logic can cause firms to miss opportunities within the market if they are not adaptable. New product designs should be coupled with developments in the business model to support strategies for going to market and capturing value (Teece, 2010). The CE is an example of radical change which will require innovative changes in business model design. PSS is an example of an innovative business model that has been adapted to capture value from providing products as services. Other industries have adapted this model to include infrastructure as a service (IaaS) and software as a service (SaaS).

5.1 Managerial implications

From these propositions, we can derive several managerial implications on circular product design. First, there are serious cost implications for circular products that firms need to consider. Circular product design requires large investment to bring products to market and involvement from many different stakeholders which yields much higher costs than linear product design (De los Rios & Charnley, 2017). In some cases, new infrastructure will need to be developed to handle circular products at the end of their life. Furthermore, firms need to consider what materials they will be using in their product. Sustainably sourced materials can be expensive because of the ethical consideration required in obtaining them (Mohanty, Misra, & Drzal, 2002). Manufacturing processes need to be modified to ensure cleaner production practices are implemented and supply chain operations need to be altered to ensure reverse logistics are included and renewable energies are used to power supply chain activities (Witjes & Lozano, 2016). The additional costs can cause firms to avoid developing circular products.

However, there are direct and indirect cost benefits for firms that implement circular product design. Secondary resources should be used in manufacturing of new products and it should be possible to procure secondary resources at a lower cost than virgin resources (Gren, Folke, Turner, & Batemen, 1994). With sustainable taxation policy, tax would have already been paid on the original virgin resource so secondary resources can be traded at a lower commodity price than its virgin equivalent. Given the prevalence of secondary resources to circular products, a secondary resource market will operate to facilitate the trading of secondary resources. This ensures firms that have secondary resources from product disassembly can trade resources to recover costs. A secondary market will ensure secondary resources maintain value, commodity prices stabilise, and resource supply is constant. Circular product design follows an intentional design process that aims to reduce material and energy waste throughout the manufacturing process. By maximising resource yields and reducing energy consumption, firms can reduce the amount of material input for each product and save on material costs (Bocken et al., 2016). Furthermore, waste disposal costs will be lower due to efficient material utilisation. Indirectly, circular product design allows firms to improve their brand image and reputation within society. Developing a sustainable brand image can be a source of competitive advantage which has an indirect cost benefit to the organisation.

Second, shortening supply chains to operate within regions rather than on a global scale can reduce environmental impacts and supply chain costs. For example, short supply chains would only operate within the region of Australasia, North America, Asia, or Europe. By regionalisation of supply chains, firms can reduce the distance between suppliers and reduce the number of intermediators within the supply chain. Shortening the supply chain minimises the distance resources and products need to move between sourcing, production and customer (Renting, Marsden, & Banks, 2003). Furthermore, by removing intermediators from the supply chain, less firms need to handle the products. A pragmatic approach must be taken to regionalisation of supply chain management because supply chains are globalised to leverage cost effective supply of resources, labour, production and transport.

Regionalisation of supply chain management must only be undertaken if the environmental, social, operation and resource costs will be reduced or offset by the reduced logistics costs.

Third, supply chain processes need to incorporate circular thinking to improve sustainability performance. By combining the circular principles of the CE with supply chain management, supply chains can be designed to facilitate the circular flow of resources and remove waste. The notion of waste occurs when resources are not able to be used and must be disposed. Through closed-loop and open-loop supply chain design, resources can be utilised to their maximum potential. In closed-loop supply chains, resources that have been recovered from dissembled products are then reused within the same supply chain process. The issue with closed-loop supply chains is rarely can all resources be used within the same supply chain loop and waste is inevitable. Open-loop supply chains provide an alternative avenue for these resources. Open-loop supply chains allow resources to be used either within the supply chain process of the same industry or within different industry supply chains (Farooque et al., 2019). By collaborating with other organisations, firms are more likely to find valuable uses for their waste.

Fourth, renewable energy should be utilised throughout all supply chain activities. Developments in renewable energy technology have advanced to the point where renewable energies can be used to power supply chain activities. Utilising renewable energy decouples the reliance on fossil fuels and reduces carbon emissions and environmental pollution. Harnessing renewable energy allows firms to reduce their energy costs because they are using renewable energies such as solar or hydropower. The disadvantage of renewable energy is the cost involved in purchasing and installing the technology to harness renewable energy. Renewable energy technology is still nascent, and the costs are high. For many organisations the cost of harvesting renewable energy by themselves is unattainable but they can purchase the energy from providers. Government support and policy can help facilitate the implementation and attainability of renewable energy for organisations (Cullen, 2017). In addition, organisations could collaborate with each other to purchase renewable energy technology that will provide mutual benefits to both parties.

Last but not least, the role of technologies needs to be considered in facilitating circular products and circular supply chain activities. Smart enabling technologies have developed considerably to improve efficiency and productivity of supply chains while reducing environmental impacts. Through cyber-physical interconnection and sensors that collect big data, smart technology has allowed supply chains to gather real time information that allows management to make informed decisions. The use of robotics, IoT and artificial intelligence allows processes to be automated which reduces inventory shortages and human errors while optimising production and logistics activities (Pan et al., 2015). Smart technology connects a diverse network of suppliers, manufacturers, retailers, and logistics providers to communicate important information that optimises supply chain performance. There are barriers and risks associated with smart technologies that firms must consider before investing. The cost of some smart technologies can be unattainable for many organisations. Government funding and co-opetition can help bridge the financial gap but the inherent nature of obsolescence and limited interoperability with technology can cause more problems than it solves.

5.2 Policy implications

There are several policy implications that can be drawn from the propositions that will support policymakers in decision making. First, there are economic, social and environmental benefits from making a transition to CE. Policy needs to be developed to encourage firms to transition their global supply chain towards regional operations. Developing short supply chains and incorporating reverse logistics can increase local employment rates which has social and economic benefits, while the environment benefits from reduction in international logistics and reduction in waste. In addition to policy that supports regional supply chains and reverse logistics, government policy should aim to develop sustainable industrial eco-systems. Eco-industrial parks have had great success in China and Europe in facilitating the mutual benefits of industrial symbiosis (Liu & Côté, 2017). Through sharing of resources, energy infrastructure and information, eco-industrial parks are able to achieve sustainable development and increase economic gains while improving environmental quality (Lambert & Boons, 2002).

Underpinning the CE transition should be investment in public education on CE (Zhang et al., 2019). When making the transition to CE, it is important the public buy into the concept and support the transition period to ensure its success. Investment in public education and embedding the CE principles into school curriculum are important steps in ensuring the general public are educated on CE (Farooque, Zhang, & Liu, 2019). These steps have already started with many schools teaching sustainability courses, but sustainability doesn’t solve the problems inherent with the linear economy. Government funding in education and radical changes to schooling curriculum are important steps towards CE (Andrews, 2015).

Second, Policy makers need to support the CE transition with new policy that aims to develop infrastructure such as affordable technology, improved rail services, additional seaports and eco-industrial parks. Developing this infrastructure allows business operations to reduce their reliance on fossil fuelled transportation and production and move towards sustainable systems (Ness, 2008).

Third, closing the product price gap between circular products and linear products is essential in developing CE. Circular products cannot be produced at the same cost as linear products at present because of the additional costs associated with circular products. A new taxation system should also be considered to support sustainable organisations and circular products (Stahel, 2013). A tax shift would accelerate the transition to the CE by encouraging organisations to adopt circular business models and develop circular products. Providing tax breaks and incentives would allow circular products to become comparable in price to linear products and allow sustainable businesses to be competitive with linear business models (Andersen, 2007). Tax on circular products should be reduced compared to linear products because they are using secondary resources and tax would have already been paid on the virgin resources used.

Chapter 6: Conclusion

This study investigated the implications of circular product design on business model and supply chain management to enable a transition to the CE. This study used semi-structured interviews with 15 participants to gather empirical evidence on the practice and implementation of circular product design and supply chain design in Auckland, New Zealand. By interviewing individuals that had knowledge in circular product design, this study developed themes that will support product design, business models and supply chain design for the CE.

This research makes several contributions to the literature. First, it narrows the knowledge gap in circular product design as little empirical research has been conducted on the topic. The topic is of fundamental importance as a transition to the CE must start with circular product design. Second, as a result from these findings, there are several key research contributions that can be drawn. For product waste to be minimised in the CE, product design needs to include end-of-life options. Developing products with end-of-life options ensures products have options at the end of their life cycle rather than going direct to landfill. When products are designed with end-of-life options it ensures resources yields can be optimised and product waste is minimised. In addition to product end-of-life options, supply chains need to be redesigned with circular principles to facilitate and support circular product design. Supply chains need to be shortened (where possible) from globalised supply chains to regionalised supply chain networks to reduce the distance resources need to travel between supply chain partners and consumers. Redesigning supply chains can provide environmental and social benefits through reductions in carbon emissions and by creating local jobs. Innovative business models need to be designed to support circular product design and supply chain design. Linear business models are not suitable for the CE because they have embedded principles that support short term profits over long term sustainability. Developing business models that incorporate circular principles ensures a sustainable value chain is created that supports the preservation of the environment, social wellbeing and sustainable profit and business growth. Last but not least, managerial and policy implications were derived to guide organisations and government legislation in facilitating CE practices that provide benefits to society and preserve the natural environment.

There were several research limitations experienced during this study. Firstly, participant recruitment was a challenge because there are limited firms operating with circular product design in the Auckland region. This meant there are limited individuals with knowledge about the CE concept. The second limitation was the tight timeline for completing the dissertation. Finding participants, interviewing them and transcribing the interviews took much more time than anticipated. Thirdly, this study was limited to participants in Auckland, New Zealand where CE hasn’t grown in popularity or with legislation as it has in other countries. If the study was conducted in another country such as Norway or Sweden where they have progressed CE, then the results could be different.

Future studies should be aimed towards developing design frameworks to operationalised circular product design. Much attention has been paid to the concept of circular product design, but little research provides guidance on ‘how’ to design circular products. Further research needs to be conducted on understanding how the price of circular products can become comparable to linear products. Finally, tools need to be developed for enabling circular product design.

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Appendices

Appendix A: Participant Information Sheet

TE WĀNANGA ARONUI O TĀMAKI MAKAU RAU

Participant Information Sheet

This information sheet is for individuals who operate within the supply chain and product design areas, and actively promote environmental practices within their business. This could include but is not limited to: Supply chain managers; Sustainability managers; Product development managers; Technical managers.

Date Information Sheet Produced:

25th February 2019

Project Title

Integrating circular product design and supply chain process design.

An Invitation

Kia ora, my name is Haydn Burke and I would like to invite you to take part in a research project. I am a Master of Business Student at Auckland University of Technology (AUT). I am conducting research into circular economies, more specifically on the topic of integrating product design and supply chain design to create a circular supply chain framework. As part of my research, I am looking for product design and supply chain professionals who would be interested in being interviewed as part of the data collection process for my research.

Before you decide whether to take part it is important that you understand why the research is being done and what it will involve. Please take time to read this carefully and ask me if you have any questions. Talk to others about the study if you wish. You will have at least 2 weeks to decide if you want to take part. Your participation and support for this study would be greatly appreciated and is highly valuable.

What is the purpose of this research?

The purpose of this study is to understand how product design and supply chain process design can be integrated to create a circular supply chain framework which can be utilised for industry uptake. I hope to interview supply chain and product design professionals from various organisations and in different sectors to collate their collective knowledge and experiences to help develop the circular supply chain framework.

How was I identified and why am I being invited to participate in this research?

You have received this invitation because of your experience and knowledge of being a professional in supply chain and/or product design. You were found either through an internet search of circular organisations operating in the Auckland region or via the Sustainable Business Network (SBN).

How do I agree to participate in this research?

To agree to participate in this research you will need to email Haydn Burke at circulareconomystudy@gmail.com.

Your participation in this research is voluntary and participate will neither advantage nor disadvantage you. You can withdraw from the study at any time. If you choose to withdraw from the study, then you will be offered the choice between having any data that is identifiable as belonging to you removed or allowing it to continue to be used. However, once the findings have been produced, removal of your data may not be possible.

What will happen in this research?

This research involves a face-to-face interview which will last for 30 minutes, the interview will take place at the participant's place of employment. The interview questions will cover various topics surrounding supply chain and product design practices. If necessary, follow-up email/telephone communications or face-to-face meetings will be initiated by the researcher for clarifying his understanding of your inputs, or for obtaining further information from you for completing the research project.

How will my privacy be protected?

Your privacy is the upmost importance. We will ensure the information provided in this process is kept confidential and will not be released to any organisation. The information you provide in this process will solely be used for this research.

The interview process will require a face-to-face interview however this study does not collect any personal information about the participants. It is ensured to participants that all the obtained information/data will remain confidential both during and proceeding the project.

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What are the costs of participating in this research?

There is no monetary cost to the participants who are involved in this study. Participation in this study will however require an investment of around 30 minutes of your valuable time and will be reimbursed with a free cup of coffee.

Will I receive feedback on the results of this research?

If you choose, a summary of findings can be emailed to you on completion of the study.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Abraham Zhang, E-mail: abraham.zhang@aut.ac.nz; Tel: 09 921 9999 Extension # 5327

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, Kate O'Connor, *ethics@aut.ac.nz*, 921 9999 ext 6038.

Researcher Contact Details:

Haydn Burke
Masters student Supply Chain Management
Auckland University of Technology (AUT), New Zealand
E-mail: circulareconomystudy@gmail.com

Project Supervisor Contact Details:

Dr Abraham Zhang
Senior Lecturer in Supply Chain Management,
Auckland University of Technology (AUT), New Zealand
E-mail: abraham.zhang@aut.ac.nz

Approved by the Auckland University of Technology Ethics Committee on 1st February 2019, AUTEC Reference number 01022019.

Appendix B: Consent form

AUT

TE WĀNANGA ARONUI O TĀMAKI MAKAU RAU

Consent Form

Project title: ***Integrating circular product design and supply chain process design.***

Project Supervisor: ***Dr Abraham Zhang***

Researcher: ***Haydn Burke***

- ○ I have read and understood the information provided about this research project in the Information Sheet.
- ○ I have had an opportunity to ask questions and to have them answered.
- ○ I understand that notes will be taken during the interviews and that they will also be audio-taped and transcribed.
- ○ I understand that taking part in this study is voluntary (my choice) and that I may withdraw from the study at any time without being disadvantaged in any way.
- ○ I understand that if I withdraw from the study then I will be offered the choice between having any data that is identifiable as belonging to me removed or allowing it to continue to be used. However, once the findings have been produced, removal of my data may not be possible.
- ○ I agree to take part in this research.
- ○ I wish to receive a summary of the research findings (please tick one): Yes○ No○

Date:

Participant's name : ....

Participant's contact details (if appropriate):

....

....

....

....

Participant's signature: ....

Approved by the Auckland University of Technology Ethics Committee on 1st February 2019, AUTEC Reference number 01022019

Note: The Participant should retain a copy of this form.

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Appendix C: Participant interview questions

AUT Circular Economy Study

Interview questions

1. What is your understanding of the circular economy and how can it change society, organisations and the environment?

2. How do you see product design contributing to the success of the circular economy?

3. What opportunities does circular product design offer to businesses, consumers and the environment?

4. What technologies have you used or aware of for supporting circular product design and circular supply chains? Can you give examples to explain how the technologies help?

5. What are the implications for the wider business? finance, IT and technology, labour and skills?

6. How does moving towards circular product design require changes in supply chain processes including sourcing and procuring materials, logistics, production, end-of-life product management, etc?

7. What additional factors would help in develop a framework for organisations to adopt or uptake circular product design and circular supply chain design? This could include radical/incremental innovations, new systems of thinking or systems of flow, 'pearls of wisdom' not covered in pervious discussed.

Appendix D: Ethics approval form

TE WĀNANGA ARONUI O TĀMAKI MAKAU RAU

Auckland University of Technology Ethics Committee (AUTEC)

Auckland University of Technology
D-88, Private Bag 92006, Auckland 1142, NZ
T: +64 9 921 9999 ext. 8316
E: ethics@aut.ac.nz
www.aut.ac.nz/researchethics

1 February 2019

Abraham Zhang
Faculty of Business Economics and Law

Dear Abraham

Ethics Application: 19/18 **Integrating circular product design and supply chain process design**

I wish to advise you that a subcommittee of the Auckland University of Technology Ethics Committee (AUTEC) has **approved** your ethics application.

This approval is for three years, expiring 31 January 2022.

Non-Standard Conditions of Approval

1. Remove the consent and release form from the study documentation as this study does not appear to involve photographs;
2. Amendment of the Information Sheet as follows:
   a. The committee suggests that the consent form is signed just before the face to face interview commences, eliminating the need for participants to email it back;
   b. Remove the offer of counselling;
   c. Advice that limited confidentiality only can be offered given the inter interviews will occur in the workplace;
   d. Remove help text left over from the exemplar;

Non-standard conditions must be completed before commencing your study. Non-standard conditions do not need to be submitted to or reviewed by AUTEC before commencing your study.

Standard Conditions of Approval

1. A progress report is due annually on the anniversary of the approval date, using form EA2, which is available online through http://www.aut.ac.nz/research/researchethics.
2. A final report is due at the expiration of the approval period, or, upon completion of project, using form EA3, which is available online through http://www.aut.ac.nz/research/researchethics.
3. Any amendments to the project must be approved by AUTEC prior to being implemented. Amendments can be requested using the EA2 form: http://www.aut.ac.nz/research/researchethics.
4. Any serious or unexpected adverse events must be reported to AUTEC Secretariat as a matter of priority.
5. Any unforeseen events that might affect continued ethical acceptability of the project should also be reported to the AUTEC Secretariat as a matter of priority.

Please quote the application number and title on all future correspondence related to this project.

AUTEC grants ethical approval only. If you require management approval for access for your research from another institution or organisation then you are responsible for obtaining it. You are reminded that it is your responsibility to ensure that the spelling and grammar of documents being provided to participants or external organisations is of a high standard.

For any enquiries please contact ethics@aut.ac.nz

Yours sincerely,

Kate O'Connor
Executive Manager
Auckland University of Technology Ethics Committee

Cc: haydn.burke85@gmail.com