



# Transformational Cloth

*Weaving the Undervalued Threads of Textile  
Waste into a Value Added Change Model*

Donna Cleveland

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Waste into a Value Added Change Model*

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## A b s t r a c t

This thesis identifies some of the issues surrounding an unsustainable manufacturing cycle and the associated problems of pre- and post-consumer textile waste that continue to cause considerable environmental problems when sent to landfill. Existing sustainable fashion theory proposes that one solution to unsustainable practices within the industry relies on building a re-connection between the value of fashion garments and the textile involved in their production. A key outcome of this research is the development of a new approach to textile recycling that considers the materials life cycle within a circular economy. The project engages directly with individual New Zealand companies to re-circuit their manufacturing waste streams by developing a customised design solution that recycles their textile waste locally. It aims to develop a model where the scale of textile waste is matched with the scale

of intervention and style of innovation. New Zealand has limited infrastructure in place for textile recycling; therefore, this offers a unique opportunity for the development of new ways of thinking and new models of engagement. The outcome is a local recycling system that alters the current production model by demonstrating how textile waste can be diverted from landfill and reanimated through the use of textile technologies and design, tangibly maximising the utility of textile waste. The research initiates a model of innovative sustainable practice into New Zealand's fashion manufacturing industry by developing a solution to their textile waste offering relevant contemporary recycled textiles. The experimental design practice recycles the textile waste of several apparel companies, offering a proof of concept for the proposed model, which highlights the future possibility for a localised recycling system. Moreover, the study demonstrates the potential for textile production to reconnect people with the value of the original fibres.

It is envisaged that the outcomes of this research will be used to inform initiatives to enable New Zealand to aim towards zero textile waste in the future. It is intended that this research will make a meaningful measured contribution to the continuum of sustainable development through innovation and design.

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### 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 acknowledgments), 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.”*

Signed

A handwritten signature in cursive script that reads "Donna Cleveland". The signature is written in black ink on a light-colored background.

Date 14th November 2018

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# 1: Introduction to the research

## 1.1 Introduction

This chapter introduces and details the background to the research project and the researcher's position. It outlines the aims and objectives, specifically taking textile waste and transforming it into a new cloth of increased value through reanimation, and the use of textile technologies producing a transformational, value-added model. The approach and role of the researcher are defined within this research context, and the textile waste streams and experimental practice used in this research are outlined. This PhD research builds on the researcher's preceding Bachelor of Design Honours' level research (Cleveland, 2013), that highlighted the possibilities for further research to develop a localised and scalable recycling solution. The findings of this 'Transformational Cloth' PhD project, describe a model for a closed-loop production. Thus a contribution to knowledge is identified and the benefits of the research are determined.

## 1.2 Rationale

For the first time in the history of the earth, we are witness to significant geological changes to our planet caused by a single biological species. Human beings have caused a distinct change to the physical layer of the Earth's geological strata leading to unprecedented climate change. This is arguably the most important, and existential challenge that humans and non-humans currently face. This period has been termed the Anthropocene: "The formal establishment of an Anthropocene Epoch ... mark[s] a fundamental change in the relationship between humans and the Earth system" (Lewis & Maslin, 2015, p. 171). It is by definition a 'wicked', complex, multidisciplinary problem, which raises the question of how design can be best used to sustain ourselves and others on this planet. Sustainability as a concept is complex. It has been defined and deployed in very different and often contradictory ways. Fry (2011) suggests:

The word 'sustainability' has been evacuated of any substantial meaning it may once have had. It's been appropriated by a ragbag of 'green-washing' market interests, opportunists and political hacks. As a result of this we frequently find ourselves 'sustaining the unsustainable'.

(para 1)

In addition, the notion of fashion as "a style of clothing or a way of behaving that is popular at a particular time" (Collins English Dictionary), is the very antithesis of sustainability. There are inherent contradictions in the term sustainable fashion, as fashion is about obsolescence: "its lexicon is new every year, like that of a language which always keeps the same system but suddenly and regularly changes the 'currency' of its words" (Barthes, 1990, p.34). The system of rapid change surrounding the

fashion industry, with frequent new seasonal ranges, means constant renewal and the discarding of clothes; a ‘wear it today throw it out tomorrow’ approach (Blanchard, 2008). Conversely, perceptions of sustainability are associated with preservation and longevity. Herein lies a paradox that has motivated this inquiry. Sustainable fashion design and its associated practices are of current global concern (Fletcher, 2014; Gwilt, 2014; Niinimäki, 2013); the issues are complex, and the possible solutions necessitate continual adjusting and transforming. The principles of sustainable fashion design seem like a moving target that is difficult to work towards. This is due to both a myriad of possible interpretations of the subject and the vastness of the situation, which can seem overwhelming. In this context, the role of the designer as someone who only looks forward in their practice and does not engage with the experience and implications of materials and materialism, requires a recalibration (Fry, 2014).

This research sets out to reconcile design strategies by using sustainable design practices to make change. This project examines the future of textile recycling through several lenses: sustainable strategies, materials future and design innovation. The experimental practice utilises unconsidered textile waste streams and reanimates them through the hands and experience of a practising designer, using textile technologies to enable the recovered fibres to have new scales of value and new narratives.

### 1.3 Aims and objectives of the study

This research aims to re-think and re-value textile waste. It critically assesses the current linear flow of industrial textile waste to landfill in order to identify factors which contribute to undervaluing textile waste and to provide an alternative, design led approach to textile waste re-use.

To achieve these aims the research objectives are to: (1) critically examine specific textile waste streams, including volumes, typology of the materials and the qualities of the fibres (2) evaluate options for mechanical textile recycling and fibre recovery (3) to develop a new model for localised textile waste reuse that reconnects people with the value of their textiles and to maximise recovery opportunities through systems change.

#### 1.4 Outline of the project

This project sets out to identify and collect textile waste from existing industrial waste streams that currently go to landfill. All of the waste is sorted, categorised and mapped so that quantitative and qualitative data about the textiles can be generated and analysed. The textiles are then disassembled in preparation for recycling. The textiles then go through

processes, such as shredding, opening and carding the textile fibres. The carded fibres are then fabricated back into felt or spun into new yarns. The researcher intends to use existing mechanical processes, machinery and expertise to show proof of concept for a local, flexible and scalable model for feasibly recycling New Zealand's industrial textile waste.

##### 1.4.1 Background to the project

This 'Transformational Cloth' project builds on a previous textile recycling process and an analytical framework developed during my Bachelor of Design Honours level research titled 'Sustainable Fashion; Translating awareness into action' (Cleveland, 2013). The project utilised designer textile waste recovered from the fashion design studios at the Auckland University of Technology at the end of year clear out in 2012. The aims of the project were twofold: firstly to profile the gap between the awareness of sustainable design

practices and the action of utilising these practices within an educational environment; secondly to challenge the action of applying these practices resulting in an expected 'sustainable design aesthetic'. The practical outcome was a capsule collection that demonstrated the potential of recycling designer textile waste. There were several significant findings of the study. Firstly, the development of a contemporary capsule collection emphasised the ability for sustainable practice to result in products which had a clear fashion context. Secondly, the statistical data and analysis enabled some understanding of designer textile waste. Thirdly, the project highlighted the possibilities for further research to develop a localised and scalable textile recycling framework. This earlier research also identified some issues surrounding what types of textile fibres can be successfully recycled using a mechanical process, and identified problems with methods of disassembling the textiles and separating the colours for an improved

recycling aesthetic. These unanswered questions were the initial motivation for this PhD research.

#### 1.4.2 Introduction to the textile waste streams

Textile waste is commonly classified as either pre-consumer textile waste or post-consumer textile waste. A widely understood definition of textile waste is that pre-consumer waste is the refuse material generated during the manufacturing process of textile products, while post-consumer waste is thought of as pre-worn garments that are obtained using second-hand clothing merchants and charities (Fletcher, 2008; Fraser, 2009; McQuillan, 2009). For the purpose of this research, pre-consumer textile waste denotes the excess material created at any stage during the process of designing and manufacturing clothing, and post-consumer textile waste refers to any garment that is no longer in use and is destined for landfill. This project

is concerned with recycling pre- and post consumer textile waste.

The textiles used in this project were sourced in various ways from different textile waste streams. The three textile waste streams recovered from industry are introduced here, and will be referred to as A, B and C.

- Waste stream A was from a Charitable Trust that operates a garment rental service based in Newmarket, Auckland. The trust supplied this research project with two years' worth of retired academic regalia as part of their annual stocktake. The recovered apparel was complete, intact garments and trenchers, predominantly black and of mixed fibre origins. The regalia was in a well used condition with some of the garments being worn many times a week through the hireage system for as many as twenty years. The trust has a sustainable

ethos and endeavours to reuse as much textile waste as possible.

- Waste stream B was from a privately owned knitwear manufacturing company located in Pukekohe, Auckland. The company supplied this research project with nearly three years' worth of manufacturing textile waste by collecting it in-house at the site of manufacture, and informing me each time a large 'fadge' had accumulated. In New Zealand, the term fadge refers to a bale of textiles, typically wool, that weighs less than 100 kilograms. The recovered waste was mostly yarn and rejected knitted textiles of varying colours and configuration. Possum merino yarn is very expensive so the companies percentage of waste to landfill is tiny compared to the amount that they produce. The company strive to reduce their wastage and purchase machines and change techniques regularly so that the amount of yarn that is cut and sent to waste is lessened

or eliminated. The fibre content included merino, lambswool merino, possum, kid mohair and nylon.

- Waste stream C was from a university fashion design studio located in central Auckland. The fashion department approved the collection of students' end of year textile waste between 2013-2016. The recovered waste was wide ranging in its composition, structure and colour.

### 1.5 Positioning statement

My personal philosophy on life and my career as a fashion designer and educator often feel as though they are opposing teams fighting for different causes. This disparity drives my research ambitions, influences my design decisions and motivates me to challenge the status quo. This philosophy overarches and frames the research. The position of a researcher is imperative to how they research.

As Crouch and Pearce suggest “our research position, knowingly or unknowingly, underpins all our research” (Crouch & Pearce, 2012, p.57). My position as a researcher is multifaceted; it is reflective of many things including my life experiences, personal values, my knowledge as a designer/maker and role as a design educator. Crouch and Pearce describe this positioning as a lens through which we view our methodology (2012). Acknowledging this lens is imperative as these filters influence and guide the trajectory of the project. My own understanding of the area of sustainable fashion design has influenced the path of this project. In addition, new filters are added and subtracted through the course of research as the researcher engages with different people, projects and ideas. These changes are considered in more detail in the discussion of the project methodology and research process.

## 1.6 Research approach

Due to the aims and complexity of the project, a mixed methods approach to the design of the research was employed. Whilst the overarching approach aligns with a design through practice methodology (Archer, 1966) a philosophical overlay of redirective practice (Fry, 2014) was influential in informing the research. This approach positions the designer as a design researcher, conducting sustainable design practice, with the intent of making change. The position of the researcher drew from different research frameworks to engage a selection of relevant methods, providing a reconnection and redirection of design practice. This mixed method approach to practice accommodated quantitative and qualitative data generation, analysis, reflection, experimentation and sustainable textile design. For the purposes of this research, the term affect is used to qualify the change that happened to the researcher,

when physically and cognitively engaged with the materials; that is how the materials affected the researcher. The quantitative approach describes the data collection and mapping of the measurable data that was generated throughout the research.

The mixed method approach required the researcher to employ different strategies to thinking about and doing the research. These conceptual approaches are defined and discussed, drawing on a cognitive model proposed by Banerjee, whereby a designer uses “the logic of the possible in addition to inductive and deductive thinking” (2008, p.4). Furthermore, the researcher explored Banerjee’s notion of an extended designer modality, whereby the designer operates in a trans-disciplinary way (2008). This enabled the researcher to develop a mixed method mode of enquiry which considered quantitative and qualitative research and allowed engagement with research practice at different

scales and different levels of complexity.

Another layer of the process, where the impact of the research practice on the designer leading to a change in habitual practice, is recognised. This change was a product of an intense and physical engagement with the textile waste when sorting, mapping and disassembling during phases one, two and three. These methodological issues are discussed further in Chapter 3.

### 1.7 Contribution to knowledge

This project collects, processes and reanimates textiles that are destined for landfill. This is achieved in a novel way, in that the emphasis shifts from the usual preoccupation with a homogenised recycling mantra where fibres are devalued and concerns itself with the specific materiality of what is usually considered a raw material that supplies an industrial

process. While the project uses some of the same processing technologies, it explores them using another lens. This focus zooms into a micro level, where the designer explores the qualities and character of the fibres, rather than maintaining an operational distance seated in a logistical enterprise. This investigates ways to revalue the actuality of the materials other than solely analysing their technical properties. It is intended that this will contribute to a continuum of new knowledge by generating a different discourse around sustainable textile waste management. The findings will be of interest to other sustainable designers, educators and commercial operators. It is envisaged that the outcomes of the project could be grafted with or onto existing or emerging textile waste management initiatives and offer a fresh perspective on materials knowledge. This could alter the trajectory of a designer's practice when considering sustainable applications for used textiles. Additionally, this project aspires to provide tangible building blocks, in the

form of tabled data and experimental textile development, including new colour stories informed by aesthetic, as well as sensing and visualisation of materials. This could be fused to existing initiatives, or inform future materials' design practice both in industry and education.

### 1.8 Outline of the thesis

This written thesis accompanies the practical design research, presenting a conceptual framework and analysis that connects with the creative work. It is intended that the exegesis is an extension of the practice, a place to describe and synthesise the research practice with relevant literature and context, and discuss the research methodology. The overall thesis is thought to be holistic, as the exegesis and practice are intrinsically entwined. This written exegesis has been structured in a manner that supports the researcher's practice-based work, where the components

are considered together as fundamental parts of the overall thesis. This first chapter outlines the rationale and situates the research and the researcher within the context of the research strategy. It introduces the project and sets out the aims and objectives of the study. It explains the relevance of the previous research that informed this PhD project (Cleveland, 2013). It introduces the textile waste streams used in the experimental practice and defines the role of the designer within the context of that practice. It describes the contribution to knowledge and identifies who will most benefit from the research findings. The second chapter outlines the research context by: examining current sustainable strategies, evaluating the future of the materials and investigating the role design and innovation play in making a sustainable change. Fundamental to this chapter is a discussion of the literature and critical thinking that create and support this research. The third chapter discusses the design and development of the research. It

comprehensively details the main methods of inquiry, to show the progression of the research and its analysis. It discusses the ways an active multifaceted methodology determines how the research moves through phases of practice. The fourth chapter details the six main phases that describe the processes and actions of the practice. Phase one introduces the waste stream contributors, their generated waste and the logistics of collection and storage procedures over a three year period. Phase two sets out the methods employed for quantitative and qualitative data generation, collection, mapping and analysis. Phase three outlines the processes surrounding the disassembly of the waste. Phase four examines fibre experimentation and its complexities. Phase five explains processing the textile waste through to developing a textile recycling platform. Phase six details the design of the textiles using traditional textile technologies. Chapter five presents a synthesis and discussion of the main research findings and the implications for the future.

## 1.9 Conclusion

This chapter backgrounded the researcher's intentions and purpose in undertaking this research project, namely to address issues raised in previous research that had proposed the development of a scalable, localised recycling solution to contribute towards the global issue of textile waste. Factors influencing the researcher's position are considered, such as the contradiction between design and sustainability with regard to textiles and clothing. The research project, along with its aims and objectives, was introduced and the process undertaken to achieve this outlined. The next chapter presents a review of relevant literature in order to further position, contextualise and justify the goals and approach taken to the research.

A close-up photograph of a sheep's woolly coat, showing the texture of the fibers. A semi-transparent grey rectangular box is overlaid horizontally across the middle of the image, containing the text '2: Literature and contextual review'.

## 2: Literature and contextual review

## 2.1 Introduction

This chapter positions the focus of this research through an examination of relevant literature and contextually backgrounds the project's main aims: re-thinking and revaluing textile waste. As the current global challenges of sustainability that fashion and textiles pose to the world also underpin the key focus of this research, they are discussed through reviewing literature and critical thinking. This supports and contextualises the main aim of this research, to develop a new approach to recycling both pre- and post-consumer textile waste through sustainable design practice and strategies. Factors, such as sustainable strategies and barriers, evaluating the future of textiles and investigating the role of design and innovation in creating a sustainable change, are considered. The connection and differences for the New Zealand context are examined, thereby further illustrating the relativity to and purposing this research and practice.

## 2.2 Sustainable Strategies

Sustainability is a key challenge of our time. The mass production processes of the apparel industry create large volumes of waste posing significant issues of sustainability at all levels. To fully understand the scale of this problem, the fashion and textile industry must be recognised as one of the earliest and most prevalent industrial sectors in the world (Niinimaki, 2013). Recently declared by Eileen Fisher, clothing industry magnate, as the second biggest industry in the world and the second largest industrial polluter (as cited in Szokan, 2016), the fashion industry is also said to be one of the most unsustainable (Quinn, 2010). The fashion and textile industry annually produces more than 1.2 billion tons of bulk, which in turn contributes to a considerable environmental impact (Ellen MacArthur Foundation, 2017). Pre- and post-consumer textile waste continues to cause considerable environmental problems as they are added to landfill (Gordon & Hill, 2015; Fraser,

2009). In addition, manufacturing has moved at breakneck speed, which has seen industry expansion in the 1980s and 90s reaching significant growth rates of 143% (Niinimaki, 2013). International statistics show that with mass production moving offshore in the late 80s, it is estimated that 90-95% of our clothing is now imported (Niinimaki, 2013). It is presumed that New Zealand statistics would be similar, following this global trend. The rise of available cheap clothing and the onset of ‘fast fashion’ dramatically increased consumption rates (Fletcher, 2014); so in turn did the quantities of textiles in our waste stream.

### 2.2.1 Fast-paced fashion

The pace of life is gaining momentum with a sense of constantly running in the fast lane to keep up. “Ideas and language associated with speed today pepper the fashion landscape” (Fletcher, 2010, p.260). The notion of speed appears oppositional to perceptions of longevity associated

with sustainability. Fletcher (2010) posited:

In some circles, 'fast' has become a proxy for a type of fashion that epitomises ideas of unsustainability; yet high speed is not itself a descriptor of unethical and/or environmentally damaging practices but a tool that is used to increase sales and deliver economic growth with attendant ecological and social effects. (p.259)

'Fast' in itself is not responsible for misconceptions that fashion and sustainability do not marry; however, it does to some degree confuse issues. Keeping up to date with the latest fashion and buying bargains is standard consumer practice. "We want new, new, new. We want it before it's even in the shops. We are already shopping for winter the spring before" (Blanchard, 2008, p.2). We as consumers

and producers in the fashion industry actively promote consumerism. "We have become a nation of shopaholics. We love the fact that we can buy armfuls of clothes - several outfits - for the same price we used to pay for a single item" (p.3). This was not always the case, as fashion indicated one's status and was not the domain of the masses. "What was once the preserve of the elite few who could afford it, is now accessible to all - albeit in poor - quality fabrics and badly made, wear today, throw- away - tomorrow designs" (Blanchard, 2008, p.4). In the fashion industry, economy of scale was seen as an answer to profitability. Off the rack, chain stores, 'buy two get one free' budget clothing only serves to perpetuate this throw away, constantly changing image. "Sales and growth are increased by maximising economies of scale and minimising costs in both food and fashion, 'fast' is an economic tool" (Fletcher, 2010, p.260). Blanchard states "we (are) producing more clothes than we could need in ten lifetimes" (Blanchard, 2008, p.4).

One theory is that rising consumption is related to a rising population. However, Chapman explains “over the last fifty years the world’s population has increased by over 50 per cent; but our resource utilization has increased by more than 1000 per cent for the same period (Chapman, 2005, p.4). Over-consumption contradicts ideas of sustaining the earth’s resources. While mass production in some regards is cheaper, there are long term costs to the planet. This research project explores sustainable design strategies that will extend the life cycle of our clothing reducing the environmental costs on our planet and value the resources that initially went into making them.

## 2.2.2 Current Fashion Manufacturing cycle

With regard to the precept of our fashion system, Niinimäki (2013) maintains that our present-day fashion design, apparel manufacturing systems and economic models have directed us towards an unsustainable level of fashion consumption and its resultant waste stream. The current linear system, commonly referred to as the “take, make and waste model” (The World Economic Forum, n.d.) means “high volumes of non-renewable resources are extracted to produce clothes that are often used for only a short period, after which the materials are largely lost to landfill or incineration” (Ellen MacArthur Foundation, 2017, p. 36). We extract predominantly virgin fibres for textile

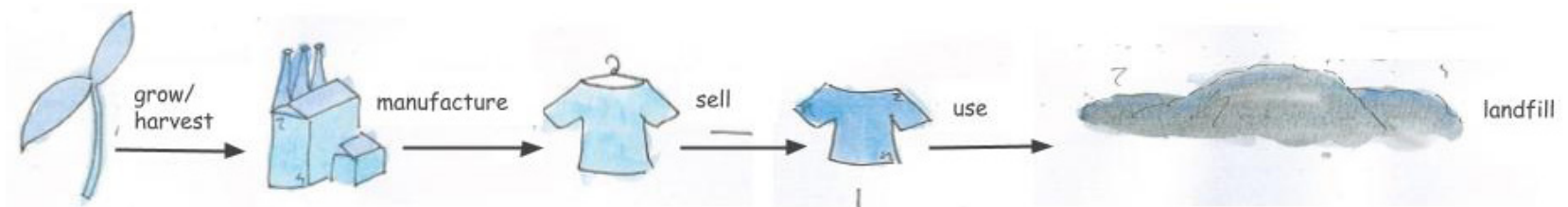


Figure 1: Linear fashion production model.

manufacturing, produce clothing en masse, have a short use phase and ultimately discard the clothing into landfill (refer to Figure 1, to see how this linear system currently operates).

Along with the loss of materials, we squander their inherent economic value when we discard them. In fact, a recent industry report written by the Global Fashion Agenda, ‘Pulse of the fashion industry’, estimated that “the overall benefit to the world economy could be about EUR 160 billion (USD 192 billion) in 2030 if the fashion industry were to address the environmental and societal fallout of the current status quo” (as cited in Ellen MacArthur Foundation, 2017, p. 19). The Global Fashion Agenda suggests that it is small to medium-sized producers and manufacturers that have had the least uptake of sustainable strategies (Global Fashion Agenda, & The Boston Consulting Group, 2017). This highlights that research, such as the research

undertaken within this thesis, which aims at engaging small to medium-sized businesses in sustainable enterprise, would be advantageous as a model to effectively illustrate a sustainable strategy. Fashion industry writers propose that, the solution to the issues raised by this linear system, is the shift towards a circular model (Ellen MacArthur Foundation, 2017; Global Fashion Agenda, & The Boston Consulting Group, 2017; McDonough, & Braungart, 2012). The ‘New Textiles Economy’ report 2017 positions “low levels of recycling, the current wasteful, linear system [as] the root cause of this massive and ever expanding pressure on resources” (Ellen MacArthur Foundation, 2017, p. 20). This helps to establish the substantial effect recycling could have on our fashion systems’ well-being. This project aims to explore sustainable strategies that engage with recycling and consider textile waste as a source of new materials. Recycling our existing materials would significantly lessen the impact on valuable resources.

### 2.2.3 Barriers to a systemic approach

Fletcher (2014) suggests that a possible way to overcome boundaries in industry lies in the reframing of sustainable fashion and textile systems as ‘positive feedback loops’ with a potential to make change through knowledge growth and alteration of practice. This means that tackling multiple smaller problems cumulatively could have a big impact on consumer behaviour. Peter Senge’s ‘Systems Thinking’ approach (1990) describes reinforcing loops as being a fundamental function of a modern organisation and suggests how to run a more efficient and effective management system that has evolved from the quality control circle style of organisational behaviour. He defines complete systems holistically with positive impact that transforms little cycles within a system; when analysed and palpated they flow in a harmonious manner. He proposes that this shift in organisational behaviour requires a quantum leap of

leadership in all tiers of management and labour, not just the top and not just the bottom. He advocates a need for all levels to ‘buy in’ to the concept of wholeness and engagement, and apply strategic goals. When you apply the principles of what he terms ‘leverage,’ “actions and changes in structures can lead to significant, enduring improvements” (Senge, 1990, p. 104) in business growth, capacity and culture. In theory, this establishes a concept that is very applicable to an existing organisation and suggests that drivers towards sustainability could be applied to it in a reinforcing and positive way, one step at a time. However, these admirable shifts in occupational culture rely on ‘buy in’ from all tiers within the organisation. This is problematic until corporate perceptions around waste management shift away from that of concealment and move into a more transparent mode (Hunting, González, & Nienhuis, 2018). A recent design project in New Zealand, which explored the re-use of commercial waste streams, suggests there are still negative

perceptions towards waste management and a direct resistance to change. The ‘Navigator’ project developed in response to the Rekindle ‘Resource: Rise Again’ exploration spearheaded by Dr Amabel Hunting explains that her team “encountered challenges as many providers didn’t want us recording their waste or taking it away, preferring instead to send it straight to landfill” (Hunting, González, & Nienhuis, 2018). This denial of access would be detrimental to any pragmatic solution of leverage being actionable within a system. Hunting also suggests that “there appeared to be a sense of shame surrounding waste and while it was legal to dump it they didn’t want to be identified as doing so” (Hunting, González, & Nienhuis, 2018). This example highlights an entrenched attitude toward commercially sensitive materials being redeployed through sustainable initiatives. The described scenario was also a factor faced in this PhD research and influenced how aspects of the project were navigated.

#### 2.2.4 Sustainable investment

Whilst stigmas exist around manufactured waste by those that manufacture it, indications are that direct legislative intervention into linear waste streams is distinctly possible and a fiscally damaging risk that industries could face. The recent Pulse of the Fashion Industry Report advocates that self-regulation is not only desirable but essential. They propose that “voluntary self-regulation of the industry may change—and change quite suddenly—if the industry finds itself blamed for sustainability shortfalls. To avoid unilateral regulation, it is incumbent upon the industry to regulate itself” (Global Fashion Agenda, & The Boston Consulting Group, 2017, p. 106). It is recognition of self-inflicted damage that highlights an emerging shift in commercial risk management. Compounding this is a new fiscal reality forming in the area of investment. Mercer’s recent report, *Investing in a Time of Climate Change*,

identifies four key risk factors to financial systems and investment strategies related to projected climate change models, technology, resource availability, impact and policy (Mercer, 2015). The report focuses on sustainable financial investment strategies in a time of climate change. Romm praises the work in the Mercer report and suggests that “investors who remain ignorant of or deny climate science will be big money losers compared to those who are climate-savvy” (Romm, 2015). The report categorises investment behaviour into three distinct phases: “Climate-Unaware Future Takers”; “Climate-Aware Future Takers”; and “Climate-Aware Future Makers” (Mercer, 2015, p.81). These phases are more fully described in the Figure 2.

This report affirms that sustainable practice is at the forefront of global development. They outline a change from traditional modes of investment into a new fiscally holistic approach that acknowledges the finite nature of resources,

and targets future opportunities that are renewable to mitigate risk and maximise return. While this is anchored in fiscal language it is a significant change in investment narrative. This shift in focus is in line with the aims of this project, positioning the researcher as a ‘climate-aware future maker’.

#### 2.2.5 A sustainable counterpoint narrative

A critical issue that sustainable design currently faces is one of the negative messages that repetitively embeds consumers with “psychologically passive-aggressive narratives that try to guilt or brow-beat us into change” (Gillespie, 2013). Pessimistic messages of melting ice caps, environmental disasters and rising landfills dominate our media. Gillespie suggests “stories that empower us as heroes and capture our imaginations inspire and galvanise us into action more effectively” than fatalistic percussive maintenance (2013).

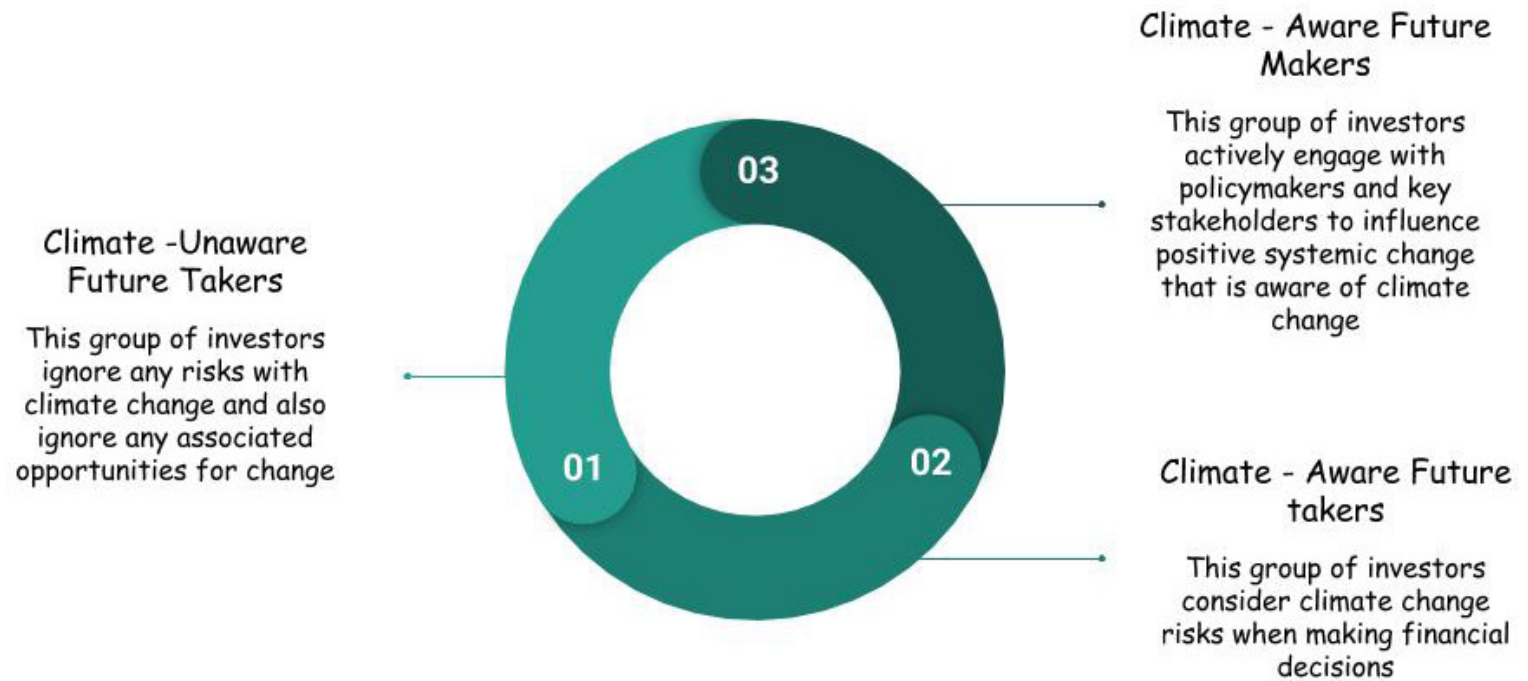


Figure 2: From future taker to future maker.

Tonkinwise proposes such negativity could be detrimental to the cause as “humans evolved responses to threats tend to be denial, flight, and even materialism” (2011, p.69). He infers that broadcasting negative apocalyptic views as a means of communicating the issues of environmental sustainability could in fact lead consumers to further entrench themselves in cycles of consumerism that deny the very existence of sustainability. Tonkinwise advocates a new sustainability which promotes positive outcomes rather than a constant barrage of negative information but rather shows what the positive outcomes could be and how people could participate. He goes on to suggest a reframing, that “sustainability must ... be represented and tailored to specific audiences and the particular barriers they face to practicing more sustainable ways of living” (2011, p.74). He proposes that sustainability as a concept and lifestyle decision requires a connection with values that not only makes it feasible but also desirable. Gillespie evolves this

view into an organisational mandate and states “as small and large businesses wrestle with the transformative demands of living and embodying sustainability in practice, the words, stories and metaphors they use to stay focused and motivated are crucial” (2013). This suggests that to future proof and embed sustainability in practice, businesses need to engage with the heroic metaphor as a key point of difference.

Earley suggests “businesses worldwide are exploring the growing potential of storytelling to engage their audiences with complex social and environmental issues, inspire behaviour change and enhance brand reputation” (Earley, 2013). This offers a multimedia platform to humanise the narrative and focus attention upon real people, their real problems and real solutions. It is the symbiotic interaction between organisations, consumers and sustainability that yields “a ‘hero’ or central character and take(s) the audience

on a journey through trials and tribulations to a new destination” (Earley, 2013). French brand Veja successfully “increased its sales dramatically from €313,000 in 2005 to €5m in 2012” (Earley, 2013) by sharing its brand story with consumers via multiple media strands rather than traditional advertising strategies alone. This suggests the potential for transmedia to have real traction as an agent of change by generating empathy between industry and consumers, and could offer a positive understanding of a brand’s ethical culture.

The US-based outdoor company, Patagonia purposefully targets its role as a responsible corporate entity by introducing interventions into its garments’ lifecycle. They successfully implemented multiple alterations to their global supply chain systems so that their environmental impact as a company was attenuated. One of these radical changes was “developing the Worn Wear program, which

allows customers to return all Patagonia products for recycling” (cited in Gasperini, 2013). This was further reinforced by a strategic collaboration with eBay which encouraged consumers on selling their garments to tell heroic stories of the garments’ journeys in the wilderness. This offered a gregarious incentive for consumers to brag about their garments’ prowess and encouraged further use before recycling, prolonging the garments life cycle. This offered a new self-directed narrative for the clothing, and gave the garments an incorporeal value that enhances its material state.

Textile is such a common part of life that its exceptional values are often overlooked. Its close contact to body gives it emotional power. And in addition to many other properties, it also has the

ability to record stories from the past - personal, intimate, but also collective. The historical memory of textile, as well as the private one, tell of past values, skills, relationship to the world and shift the legacy of its content towards the future. (*Textile Forum Blog » The 17th International Mini-Textile Exhibition in Bratislava, 2014*)

The embodiment of garments could be extended to the fibres they are made from, thereby offering a new narrative for the recycling of textile fibres. This highlights a new scope for research, one that has the potential to capture this emotion and offer a new trajectory for textile waste recycling.

Perhaps more radical is Nixon and Blakley's (2012) proposition: a design methodology, aptly named 'fashion

thinking'. A key feature of the fashion thinking approach is "its engagement with temporal, spatial and socially discursive dimensions, as well as the priority it places on the articulation of taste and balancing commercial goals with artistic movements" (Nixon & Blakley, 2012, p.154). They propose that fashion itself could be the innovator for advancing changes in sustainability, recognising fashion's fast-paced ever-changing system works well, and suggesting that if others do not follow the same approach, they will be left behind. Dolce and Gabbana's use of social networking platforms like Twitter illustrates how social media can play a vital role in communicating with consumers and feeding relevant, on-the-street information to the designer instantly by leveraging transmedia to give instant data on consumer purchasing behaviour that can be translated into projections for just-in-time manufacture of garments. This suggests that social media feedback loops could be economically beneficial to companies with global supply chains.

This approach seems to imply that large companies like H&M, producing upward of 18 collections per year, would reduce over-manufacturing or excess clothing if they were more responsive and received faster feedback on consumers' desires and shifts in trends. However, this would inevitably produce more waste, as consumers update their wardrobes more often (Michels, 2017). In addition, with companies such as H&M introducing clothing take-back systems, consumers come to believe that over consumption is acceptable as the companies will be responsible for recycling. However, "the truth is that only 0.1% of these clothes are actually recycled to be used as fibers in new clothes" (Michels, 2017). This disinformation communicated by the organisation can be seen as contemporary green-washing. Green-washing is a term used to describe the false or exaggerated environmental claims of a company or product (Nyilasy, Gangadharbatla, &Paladino, 2013).

## 2.2.6 Green-washing and preconceived aesthetics

As consumerism popularised green jargon in the pursuit of sales, uncertainty emerged. This led to mistrust amongst consumers who were not sure if they had made a good choice. Charter (1992) believes " 'ethical', 'green' and 'sustainable' are words which ... have been abused, leading to green wash of ethical efforts and a confusion for both companies and consumers" (as cited in Cervellon & Wernerfelt, 2012, p.3). This has caused a backlash and a detrimental perception towards sustainability ultimately blurring realities. Alice Payne suggests that "it is becoming crucial for a company to demonstrate their social and environmental responsibility, as customers are quick to respond on social media at perceived discrepancies between brand story and brand actions" (Payne, 2014, p.24). Fashion companies are operating in an increasingly 'moralized brandscape' where any unethical behaviour

is rapidly noticed by savvy and connected consumers (Salzer-Mörling & Strannegård, 2007). This highlights the importance of organisations being transparent and seeing this as an opportunity to harness the power of an ethical experience.

However, preconceived ideas of what sustainable design looks like have also interfered with an impartial view. This is a barrier which sustainable fashion and textiles will need to overcome to facilitate a reconnection with value that is not exclusively fiscal. Fashion is an industry characterised by style over content and image over substance (Quinn, 2010). Unfortunately, “consumerism and social trends have hijacked the notion of sustainability at the expense of its core principles, leading to exploitation and a bad reputation” (Cleveland, 2012), adding to the notion that “many consider great design and green design to be separate pursuits” (Hosey, 2012, p.2). One view is that sustainability

compromises design aesthetics. Hosey (2012) states that “designers care about image, and the green movement, like it or not, has a reputation for being all substance and no style” (p.2). He adds that “the ugly truth about sustainable design is that much of it is ugly” (Hosey, 2012, p.2). This is due to both associations with negative connotations, such as green-washing, fast fashion, eco fashion, ethical fashion and remakes (Blanchard, 2008), and the historical origins of the hippie, upcycled and recycled era of the 1970s. This aesthetic has developed over the last forty years, possibly deriving from a hangover from the 70s where people from the environmental movement looked for functional solutions to the growing issues caused in the environment by the process of fashion design (Fraser, 2009; Gwilt, 2016). This resulted in a divide where the aesthetics of sustainable fashion were not associated with the aesthetics of fashion (Gwilt, 2016). Sustainable design needs to overcome these preconceived ideas to move forward. Essential to this

will be transparency, where the fundamental principles of design are entwined with an emerging sustainable 'aesthetic' design; one that also considers a transmedia consumer-scape that is alert to authenticity and aesthetics. This research project aims to overcome stigmas generated by such preconceived notions of sustainable design, thereby reconnecting people with the monetary and aesthetic value of their textile waste materials using design-driven strategies. For the purposes of this research value in textile waste is considered as the accumulative worth generated by the monetary costs involved through manufacturing, the extracted environmental resources used to develop them and the social cost to the people involved in the process.

### 2.3 Materials Future

Currently our manufacturing system is dominated by cradle to the grave designs "with more than 90 percent of materials

extracted to make durable goods in the United States become waste almost immediately" (McDonough, & Braungart, 2013 p.27). As discussed previously, our fashion industry's current linear economic approach, results in a massive textile waste stream (Girling, 2005; Fletcher 2014; McDonough, & Braungart, 2012). "Yesterday's textiles are tomorrow's toxins; an estimated 1 million tonnes of fabric waste ends up in landfills each year" (Quinn, 2010, p.109). This system has generated a one way route for products from cradle to the grave, a sequential process in which the World Economic Forum terms the "take, make and waste model" (The World Economic Forum, n.d.). Once in landfill the "synthetic fibers in these mountains of clothing breakdown slowly releasing toxic gases into the atmosphere" (Fraser, 2009, p.6). Quinn suggests that the fashion industry's clothing manufacturing processes, such as dyeing, printing and bleaching, put it on "par with petro-chemical production" (2010, p.109). Discarding these garments

means squandering all the accumulative energy that was used to grow, make and manufacture the clothing (Claudio, 2007). Reusing or recycling before sending clothing to landfill provides a number of advantages. Fletcher (2014) suggests recycling fibres demands 80% less energy than growing or fabricating virgin fibres. In addition, the most recent New Textiles Economy report states that “more than USD 500 billion dollars of value is lost every year due to clothing underutilisation and the lack of recycling” (Ellen MacArthur Foundation, 2017, p. 3). Such data suggests a cycle of reuse and recycling would be beneficial. This project seeks to close the loop at both the manufacturing stage of production and the post use phase of clothing, therefore designing with waste at the end of its life cycle. This intervention has the potential to alter the future path of design at all stages of the garment life cycle, to design out waste. The New Textiles Economy report states:

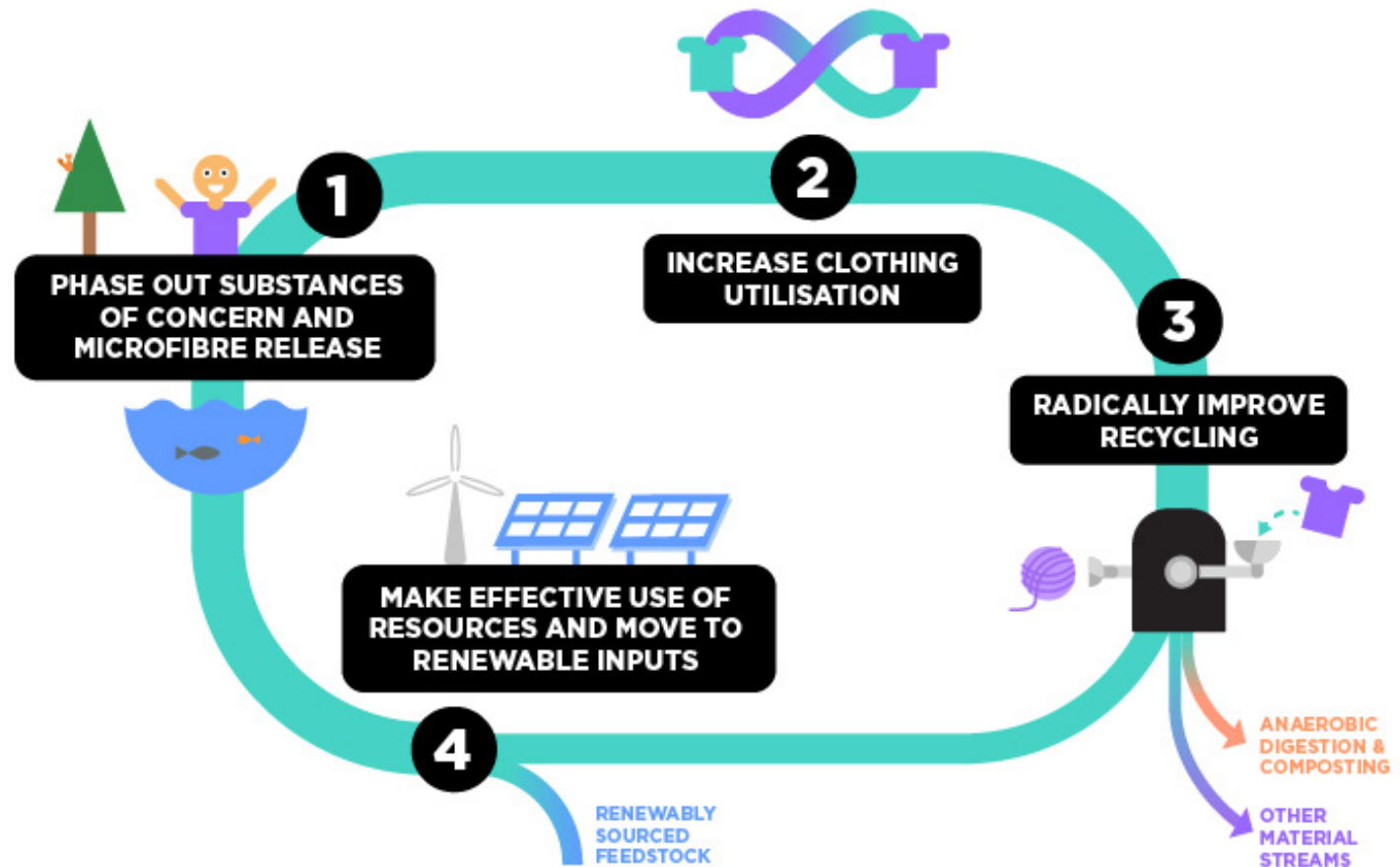
Today’s linear system uses large amounts of resources and has negative impacts on the environment and people. The textiles industry relies mostly on non-renewable resources – 98 million tonnes in total per year – including oil to produce synthetic fibres, fertilisers to grow cotton, and chemicals to produce, dye, and finish fibres and textiles. Textiles production (including cotton farming) also uses around 93 billion cubic metres of water annually, contributing to problems in some water-scarce regions. With its low rates of utilisation (leading to high levels of throughput) and low levels of recycling, the current wasteful, linear system is the root cause of this massive and ever expanding pressure on resources. (Ellen MacArthur Foundation, 2017, p. 20)

The key findings of the New Textiles Economy report indicate four critical points in the current linear system (refer to Figure 3) where energy would be best spent for maximum impact; making effective use of resources and moving to renewable inputs; phasing out substances of concern and microfibre release; increasing clothing utilisation; and radically improving recycling (Ellen MacArthur Foundation, 2017). This supports the relevance of this research to explore ways to reverse current textile waste streams and redirect current recycling practices.

### 2.3.1 Current international recycling system

The current global textile recycling system represents a large-scale pipeline industry, but offers barely viable business opportunities for companies interested in recycling. The percentages of converting recycled fibres into new products offer minimal returns to investors (Hawley, 2006).

# Creating a new textiles economy



[tiny.cc/fibres](http://tiny.cc/fibres)

Figure 3: Creating a new textiles economy. Retrieved from <http://www.ellenmacarthurfoundation.org/publications>

The shortfalls of the system are multiple and self-limiting. Unpacking what is at the core of global textile waste and current textile recycling systems, Hawley highlights an antiquated, incongruent system that is dynamically limited by trade restrictions (2006). Hawley describes a generationally controlled system of sorting houses that are family owned and operated by third or fourth generation business owners; these are ones that are not particularly lucrative and are currently dependent on manual labour to sort and grade textiles. She also comments on limitations of growth which are often problematic due to certification, trade restrictions and market saturation. In addition, increased textile waste is constantly being generated, as textiles are not recognised beyond charities or op shops, and other disposal methods are not considered. Hawley asks:

How is it, then, that the American consumer negotiates the wearing of

the latest fashions when their closets are already over-flowing with perfectly wearable merchandise? One way to justify their behaviour is to donate their wearable, but slightly-out-of-fashion, clothing to charitable organizations. In this way, their appetites for fashion are satisfied and guilt is erased with benevolent acts through donations. (2006, p.10)

Consumer behaviour naively disregards the journey that used textiles take. The current rate of consumption and rejection is a disproportionate progression that materialises in increased textile waste being generated. Hawley suggests a solution could be in an attitude shift of consumer patterns and the cooperation of the textile industry to search for new viable, value-added products made from textile waste. This

provides an opportunity for this project to alter perceptions through positive narrative and communication with vendors inside the New Zealand textile industry. This research aims to demonstrate a tangible mechanism which, through the process of making, produces small batches of high value luxury recycled materials.

Another illustration of an incongruous system is Norris's investigation of the creation and logistics of humanitarian aid blankets which highlights a global, dysfunctional and disabled textile recycling system that is fraught with moral and ethical dilemmas (Norris, 2012, p.395). The system, professionally managed by the UN, recycles charity clothing into emergency aid blankets, which, Norris determines, undermines the recycling system and completely undervalues the original clothing. Through the examination, Norris found that a profit-driven mentality

was a key component in a matrix of re-commoditisation of textile waste. Although the agency, through a global network of contractors, manufactures aid blankets from mixed fibre, post-consumer textile waste for disaster relief, she questions the limitations of this type of mixed fibre recycling, outlining the "problems of promoting shoddy yarn as recycled fiber due to the difficulty of establishing which fibers were in the end product and what chemical processes they had been subjected to previously" (Norris, 2012, p.390). This highlights a problematic, consistent variable in the recycling of textile waste on any scale.

Walker describes these as associated risks within the fibre recycling business and suggests that "fiber recycling is a risk-taking entrepreneurial pursuit that is best suited to smaller companies that can adjust quickly to changing market conditions" (Walker, 1995, p5). Over the course of this PhD research, it has become evident that the risks

associated with recycling textiles are unpredictable and constantly changing. A solution proposed in this research is to build an innovative textile recycling platform in a small and localised manner; also, implementing sustainable strategies that are responsive, scalable or repeatable in other situations.

### 2.3.2 New Zealand Context

One recent change in the global recycling system has forced a radical and immediate redirection. China has “not renewed its recycling company import licenses, in a move dubbed the ‘National Sword’” (Reidy, 2017). This denial of service was prompted by Chinese concerns around public health as massive volumes of the world’s waste has been pipelined to China for processing; the reverberations of this are yet to be felt. However, it is forecast that New Zealand companies which have been selling their waste (plastic, paper and

textiles) will have to pay to have their waste removed (Reidy, 2017). We currently have no textile recycling facilities in New Zealand other than carpet recycling and small-scale textile reuse initiatives. John Gibson, chief executive of recyclable collecting company Reclaim, states that although “the volume of recycling had increased here ... there was still not enough rubbish to justify opening specialised recycling mills in New Zealand” (as cited in Reidy, 2017). In addition, personal communications with the operations manager at Textiles NZ Ltd also details a perceived lack of quantity in New Zealand to be able to recycle textiles at scale (Borgfeldt, 2013).

The international system aside, the Ministry for the Environment records indicate that some ten years ago, over 120 million kilos of textile waste was disposed of into New Zealand’s landfill annually (Ministry For The Environment, 2007). It is likely these amounts have increased over

the past decade, in parallel with international trends. At present, options for unwanted textile waste in New Zealand are reductive. Methods for disposal currently include: using them as rags, down-cycling them into insulation or disposing of them in landfill. New Zealand industry currently recycles raw low-grade textile fibres like wool carpet into various products such as insulation, batting and stuffing; however, we have no systematic methods in place for recycling pre-consumer textile waste or post-consumer textile waste.

In New Zealand, post-consumer textiles (garments) are collected through schemes, such as the 'charity bin model' where Bernadette Casey, creative director of The Formary, suggests "all is not what it seems" (Casey, 2018). She suggests that while we think we have done a good thing in gifting our unwanted clothes to charity that in fact "we provide free stock for multimillion dollar private businesses" (Casey, 2018). She states that only "30% ... is retained

onshore and sold through second hand clothing stores. The other 70-75% is unsold to developing countries" (Casey, 2018). Therefore, it is not donated through a charitable model that reaches those in need. She also divulges that the majority of our used clothing in New Zealand is shipped to third world countries across the Pacific. Last year the export value to Papua New Guinea alone was \$14 million. This has a serious impact on their environment, and "decimates the local clothing and textile industry", which in turn has economic and social implications (Casey, 2018).

However, even with such initiatives, according to Fraser, 4% of New Zealand landfill is made up of textile waste and "should at least be considered a problem requiring attention" (2009. p.54). Langley, Kim, and Lewis state that materials "worth \$15 to \$25 per square yard when new, loses all value when ... landfilled. Remnants of cloth from apparel manufacturing in particular are a disposal

and cost problem” (Langley, Kim, & Lewis, 2000, p. 1). In addition, in New Zealand we have no infrastructure in place to collect and recycle pre-consumer textile manufacturing waste. Although there is little data available on how much pre-consumer textile waste is created in New Zealand, international studies show that the process of apparel manufacturing results in more than 15% of the textiles ending up on the cutting room floor. Langley et al. also suggest that mixed fibre blend textiles are very hard to recycle and that “currently there is no effort to recycle the mixed-fiber fabric remnants” (Langley et al., 2000, p. 1). The advent of more complex fibre blends used in textiles creates another issue, which makes the sorting process of any fibre recycling problematic. Langley et al. state that as “fiber blends (such as polyester/cotton, wool/nylon) (have) increased, it has become more difficult to standardize further processing” (Langley et al., 2000, p. 27). Langley et al.’s technical report, conducted for the Chelsea Center for

Recycling and Economic Development in 2000, concluded that new applications for mixed fibre textile recycling are where “future work should be directed [through] in-practice field trials” (Langley et al., 2000, p. 27). Preliminary investigations indicate that technological boundaries in this area are a significant factor. At a microscopic level, there are apparent hurdles, specifically the behaviour of mixed fibre blends in the recycling process. Cutting and shredding fibres can damage the length of virgin fibres, some more so than others, thus rendering it complicated to process.

One European initiative concerned with the industry’s rising demand for polyester and cotton fibre textile blends, is the WornAgain initiative, whose inception was based on the upcycling of materials and who are now in the process of developing a model ‘chemical-to-chemical’ which recycles textiles by extracting polyester and cotton from discarded clothing and textiles (Rhoades, 2017). However, this process is in its infancy and at present does not have the

capability to extract other fibre blends.

This PhD project sets out to address some of the issues surrounding mixed fibre blends by the redirection, reanimation and revaluing of each waste stream fibre. This is a departure from commercial mixed fibre recycling, which involves an industrialised process that removes the identity from the fibres, either through indiscriminate shredding or chemical extraction. Although this research involves a series of small pilot studies, that may seem insignificant when compared to New Zealand's large waste statistics; the research explores ways to recycle both pre-consumer and post-consumer textile waste with varying mixed fibre content. It was intended that the breadth of the study would offer credible proof of concept by considering the fibres' origins and creating a bespoke customised platform for recycling.

All of the textile waste involved in this project were previously destined for landfill. Waste stream A, whilst post-consumer textile waste, is atypical in that it is in a very particular form of retired academic rental regalia. The fabrics mostly comprise either polyester blends or wool blends. Waste streams B and C were also destined for landfill but are both types of pre-consumer or industrial waste. Waste stream B is pre-consumer manufacturing waste which comprises mostly merino, possum and nylon fibre mixes. Waste stream C is pre-consumer emerging designer waste and is composed of a very wide range of materials.

The aim was to justify the need for a platform that is transformable, where the scale of intervention and style of innovation matches the changing scales of textile waste. Finn and Smith (2013) suggest a break away from traditional manufacturing cycles for sustainable and aesthetic reasons. They state the "fashion market in New

Zealand could become more innovative by focusing on developing methods of manufacturing that are not reliant on economies of scale [and] are flexible” (Finn & Smith, 2013, p.13). This proposes solutions that are responsive and adaptable and would be most beneficial.

However, the quantifiable data needed to begin to match the scale of innovation with the scale of textile waste is not current. The last known figures of how much textile waste ends up in our landfill is from a 2007 Ministry for the Environment report: Recycling: Cost Benefit Analysis. The report tables statistics from 2002 and makes projections for 2006. The report estimates that in 2006, 3.9% of our landfill waste will be textile (Ministry For The Environment, 2007). It also excludes textiles from their list of projected recyclable materials. This failure to include textiles as a recyclable material and the lack of current data is a disparity that supports the need for this research project.

This research seeks to match the scale of the innovation to the scale of the textile waste stream, without preconceived ideas surrounding the limitations of having too little or too much waste to make recycling advantageous. This enables a departure from being a solution provider to that of a platform creator.

Since the inception of this PhD research project in 2014, two other significant textile recycling and reuse initiatives have developed in New Zealand. One of these is the collaboration between the Space Between team from Massey University’s College of Creative Arts, New Zealand Post Ltd and Earthlink Apparel. The business model uses the designers from Space Between and the not for profit, Earthlink, to upcycle the materials from old corporate New Zealand Post uniforms. The input of freshly graduated designers not only gives vibrancy to the designs but also acts as a new way of connecting consumers with sustainable strategies centred

around the reuse of textiles in the fashion idiom. This approach seeks to embed a move away from fast fashion by highlighting a continued use in a contemporary mode. In addition to this collaboration, Earthlink have their own subdivision, Earthlink Kids. This initiative takes in used corporate uniforms and downsizes them into a micro range of children's clothing. Both of these systems are reliant on patterning and pattern placement to maximise the yield from each disassembled garment. This provides a low unit quantity of renewed garments.

This approach can be contrasted with the strategy of the second initiative which pitches itself as an industrial textile waste solution provider. The Formary is a commercial entity that partners with large companies to recycle problematic waste streams (The Formary, n.d.). In 2016 they partnered with NZ Post and other prominent New Zealand brands to launch the NZ Textile Reuse Program. The mandate was to “create a step change in how end-of-life clothing

is managed” (The Formary, n.d.). Phase one was both an audit of the available waste to help determine the scale of the problem and a review of available reprocessing systems. Due to commercial sensitivity, the data generated by this program has not been published. It is notable that the Auckland City Council has contributed funding and a venue for phase two of the project, which will pilot the sorting and redistribution of end-of-life garments. To date, there have been no discernable outputs marketed by this program.

These examples indicate that other people see textile waste in New Zealand as a problem worth tackling. Although situated in this same arena, the approach that this PhD has taken proposes a shift in focus, one that centres around the materials. The intricacy of the fibres inherent in the textiles is considered with regard to the materials and materialism.

## 2.4 Design and innovation

Is design the problem or the solution? Ezio Manzini states that “despite the good intentions of many, design still continues to be far more ‘part of the problem’ than ‘part of the solution’ ” (Manzini, 2008, p.4). Historically the ability to design objects is much older than the role of being ‘a designer’, which emerged with industrialisation (Mitcham, 2001). The capability of conceiving what we make before it is fabricated is a fundamental characteristic of being human (Mitcham, 2001). However, this basic feature of being a human, coupled with the speed of technology and the drive of economic progression has arguably had a detrimental effect on the planet and places it in a new epoch, that of the Anthropocene (Crutzen & Stoermer, 2000). Manzini insists that when confronting such profound environmental issues, we “cannot remain neutral” (Manzini, 2008, p.5). William McDonough and Michael Braungart go as far as

pronouncing that “human beings don’t have a pollution problem; they have a design problem” (McDonough & Braungart, 2013, p.132). Attitudes like these have resulted in a vast field of design that recognises a need for new models of engagement. During the course of this research, it became clear that there is a myriad of sustainable design strategies in operation and that although they arguably all work towards the same end goal of sustainability, alone they do not solve the problem. Their individual approaches and ethos all have different trajectories that are useful individually or in set circumstances, but are not a complete solution. It could be argued that the reduction of design into tightly defined disciplines exacerbates the problem. This leads to a sustainable fashioner designer approaching sustainable design solutions with a ‘less bad’ approach (McDonough & Braungart, 2010). The advent of holistic design strategies, whilst in theory they are admirable, they are not achievable in a timely manner. Tony Fry

defines design as ‘world shaping’ (Fry, 2009) in its force and potential as a redirective practice in developing and deploying strategies for change; even so, he states that:

since the 1990’s, various forms of ‘sustainable design’ have arrived in most industrialised economies but for all the rhetoric, organisations, policy and examples advancing ‘sustainable design’, the actual and enormous changes required to establish the ‘sustain-ability’ of the artifactual world we create, use and occupy has hardly begun. (Fry, 2014, p.7)

McDonough and Braungart suggest that if designers created more perceptive design solutions from the beginning, we could avoid the inherent issues of waste (McDonough & Braungart, 2013). This PhD project considers textile waste

as the result of a systemic design flaw and as a source of raw material. Cyndi Rhoades, founder of Worn Again, suggests that “there’s more than enough clothing and textiles in existence today to provide our annual demand for new raw materials” (Rhoades, 2017, p. 83). As previously mentioned, the Worn Again initiative is exploring ways to separate fibres back into usable raw materials, and Rhoades suggests that processes like theirs need to be established and new technologies scaled as rapidly as possible (2017).

In addition, Fry’s design philosophy proposes a pathology that is reinventive in nature, and suggests a redirective premise of design, ‘design futuring’ that is anchored in practice. He argues that the status quo of design is engaged in the act of unsustainable ‘de-futuring’ and details ‘a new design intelligence’ which is focused on the being of a designer and the world we live in now (Fry, 2014). He suggests designers need to make fundamental changes in

our own being, that are not only involved in materiality but also have a new awareness of what is being designed and what the implications are of that design, in a world that has finite resources. This re-imaged design ontology promotes singular transdisciplinary practice as a mode of operation as “by its very character, redirective practice can never be universally or theoretically generalised - it can only ever be situated and circumstantially reactive” (Fry, 2014, p.10). This presents an opportunity for a redirected, action style of materials research with a designed sustainable outcome. Supplementary to this, Kane and Philpott propose a heuristic style of interdisciplinary practice, seated in textiles and sustainability that they call ‘textile thinking’. They propose that “until recently this knowledge or way of thinking - ‘textile thinking’ - has remained largely unarticulated” (Kane & Philpott, 2013, p.1). They suggest practitioners working directly with textiles hold a ‘specific blend’ of materials’ knowledge essential for developing sustainable


solutions. They state that “hand-making and craftsmanship are key processes used by textile practitioners to develop understanding of both materiality and concept” (Kane & Philpott, 2013, p.5). Their acknowledgement of mastery and a heightened metacognitive state are relevant to this research as it suggests that techne is a vital component and goes hand in hand with design principles in the emerging field of sustainable textile creation. In the context of this research project, the premise of techne is considered as a doing and making, bound together with the craft knowledge generated through material practice using a physical approach. Cameron Tonkinwise describes this relationship of design practice as one where “designing involves the tacit discernment of aesthetics, a prejudicial yet flexible analogue of ethical hermeneutics [where] there is clearly an art and craft to the science of practicing design” (Tonkinwise, 2003). This PhD project attempts to reconfigure sustainable designing by embracing Fry’s (2014) premise of redirecting

practice, where the emphasis has shifted away from blue sky ideals and holistic systems into an actionable approach that is reflexive to circumstance. To realise two of the aims of this research, re-thinking and re-valuing textile waste, the designer literally located herself in the process to redefine the status quo and establish an approach of doing and making, thereby focusing on the materiality of the textile waste. This shift in practice enabled a new understanding of the materials and highlighted the potential for re-thinking and re-valuing them.

## 2.5 Conclusion

The literature review examined current sustainable strategies that combat textile waste and the impact on the world's limited resources: the take, make and waste reality. Aspects reviewed considered sustainable practices, current

manufacturing cycles, fast-paced fashion, the barriers to a systemic approach, sustainable investment, counterpoint narratives, green-washing and preconceived aesthetics. Discussion of the literature reviewed and critical thinking purposed and provided context for the creation of, and support for this research project. Focusing on the futures of materials, current international recycling systems, the New Zealand context, the materiality of the textile waste and the question of whether design is the problem or solution, led to the research approach and proposed practice-based methods.

A close-up photograph of a layered material, possibly a composite or fabric, showing distinct horizontal layers. The top layer is a light tan color with a fibrous texture. Below it is a dark, almost black layer. The bottom layer is a medium brown color, also fibrous. The layers are slightly curved and separated by thin, dark lines. A semi-transparent grey horizontal bar is overlaid across the middle of the image, containing the text '3 : Research approach' in a black serif font.

### 3 : Research approach

### 3.1 Introduction

Having positioned and contextualised the research through the literature review, this chapter describes and discusses the approach taken by the researcher and the methods employed to conduct and realise the project. Certain terms relevant to these methodological approaches are defined here and throughout the chapter as a clear use of terminology, often drawn from different disciplinary fields, is critical in interdisciplinary design research projects. For example, the term ‘affect’, drawn from product design literature, is used to describe the change that occurred when the researcher was both physically and cognitively engaged with the textiles (Norman, 2002). Quantitative research refers to mapping and collating quantifiable and measurable data generated throughout the research. Different modes of practice are positioned as a combination of the designer’s internal tacit physical knowledge with external cognitive

data to elicit changed outcomes.

The role of the designer is addressed, including the challenge of balancing theory and practice in an academic research setting, where the researcher as a theorist also remains connected with the materials to realise an approach to conceptualising, experimenting and developing a design. Different research frameworks were drawn from to inform a mixed method approach to practice that includes qualitative and quantitative data generation, technical and creative experimentation, analysis, reflection and sustainable textile design. Due to the complexities of the mixed method approach, different conceptual frameworks were considered for their relevance and potential. Drawing on cognitive models allowed engagement with research practice at differing scales and levels of complexity.

### 3.2 The role of the design and the designer

The position of the designer as a design researcher, located within an academic environment has been critical to the framing of this project. This context enabled the designer to operate as a design researcher, outside the restrictions of commercial research or product focus of professional design practice. However, to work towards a key aim of this research, to build a platform for change, the researcher needed to engage with both research and practice. Banerjee suggests that “designers in PhD programs, in order to conduct doctoral level work, often turn into ‘designologists’ rather than remaining designers” (2008, p.6). He states that designers often turn to theorising about design in a departure from the practice of design. He suggests design researchers should stay connected by operating in a mode that accommodates both theory and practice. The worldwide problem of textile waste offered this research

tangible context. It was critical that the research practice was undertaken using genuine textile waste from industrial streams. It was also paramount in working towards another one of the project's aims, to develop a model where the scale of textile waste is matched with the scale of intervention, that the textile waste was processed on available machinery that could offer scalability and repeatability.

This approach to knowledge generation has at its core, values anchored in sustainable practice. Tony Fry describes design as an active agency capable of 'sustainment' which acknowledges the finite materials available to mankind (2014). He suggests that designers should build frameworks for a holistic shift in design practice to provide a sustainable future. He proposes that designers need to take on a mode of extended responsibility for the objects or systems that they design. This project engages with these sustainable ideals. In this way the role of the designer was central to

the methodological framework of this research, enabling the development of a platform for re-futuring the materials (Fry, 2014).

However the role of the designer did shift focus as the project developed. The project was initiated using design thinking methodology (Brown & Kätz, 2009), which viewed the designer's role as a fulcrum, facilitating the industry partners and providing logistical processes of waste management. It was envisaged that the research would elicit design feedback on the recycled textiles and explore ways the new materials could be used by each company. A key aim of the proposed project was to provide feedback on how recycling their waste could positively influence each company's ethos and brand narrative. What became apparent as the research progressed was that New Zealand companies were looking for a position to negate their unsustainability rather than a reconsideration of sustainable

practice. This position focused on what the fibres could not do and placed the emphasis on the technical aspect of recycling. Kate Fletcher suggests that entrenched social pressures, values and resource depletion are often neglected in favour of solutions that only address the technical aspects of sustainability in fashion and textiles (2014). She proposes a holistic, systemic approach that builds a “framework for life” (Fletcher, 2014, xvi), rather than one that is merely concerned with decreasing the negative. Furthermore, as the project developed, academic feedback on refining the focus of the project combined with the realities of industrial processing added new positioning filters. This shifted the role of the designer and instead situated the designer as a research practitioner.

### 3.3 Research Approach

The complex issues around the need for sustainable design have introduced a critical point for the agency of design in general. This paradigm shift demands a reconsideration of the role of the designer. Banerjee suggests that “designers assume different roles as specialists in sub-fields such as industrial design or generalists who simply assume different modalities over varying periods of time” (Banerjee, 2008, p.2). This project embraces the premise of utilising mixed methods with the aim of creating a platform to effect change that is supportive of this paradigm shift. This seats the designer as an agent of change, and the methods selected as agencies that support this aim. The resulting gestalt of cognition, methodology, framework, practice and structure indicates a type of strategic behaviour needed by the designer to operate as a change maker. Design culture, positioned between the sciences and humanities, encourages

interdisciplinary practice. At a macro level this is realised by the building of a theoretical platform that could inform future research or be enacted by others. Throughout this project the designer also operates at a micro level of practice by changing modes from designer to manual labourer, as well as researcher.

Some of the key design theories that underpin this research approach are developed from Bruce Archer (1966) who presents attributes of design and designers that differentiate design from the fields of science and the humanities. Archer recognised three distinctive approaches to design research, research about design, research for design and research through design (1966). This last category recognises design practice as a methodological approach to research. Kristina Niedderer recognises the value of such an approach and suggests that “developments of using practice within research have pointed to knowledge creation within

and through practice” (Niedderer, 2007, p.4). In his work, Archer defined a systematic approach which was applied to industrial design in the 1960s during a time of radical transformation. He also elucidates the reasons for and what is designing (Archer, 1966). This is anchored in intent, intuition and creative process. Whilst Archer was tussling with justifying the discipline of design as a contemporary field, it should be noted that his thoughts were influential and are still relevant today within the areas of design research and design practice.

In more current methodological design discussions, Fry (2014) recognises tacit knowledge as being a product of skilled practice. Michael Polanyi, who introduced the notion of tacit knowledge, suggests that this type of knowledge “cannot be told” (2009, p.4). Fry fuses this understanding with the explicit knowledge of technical mastery as one of the foundations of ‘re-futuring design’ as a

redirective methodology (Fry, 2014). Fry extends Archer's foundational theory and augments it with a philosophical framework that illuminates the redirection of design practice to enable a sustainable future that recognises the finite state of our resources. Fry champions the idea that the designer is directly engaged with redirecting practice through material knowledge that transforms the relationship between the designer and the designed (Fry, 2014). Fry's approach elucidates a design manifesto anchored in social responsibility. Acknowledgement of both tacit knowledge and the importance of making and doing gives this research unrestricted access to practical research tools. Niedderer categorises these types of knowledge as propositional, procedural and experiential (2007). In this research practice, these tools are used in a dynamic way that allows for varied communication methods, "description/narrative, examples, models, prototypes, case studies [video] and demonstration" (Niedderer, 2007, p.12).

Banny Banerjee describes a 'design complex' that is an expansive model, recognising designers as having multiple attributes classified as structural attributes, core cognitive models, modalities of operation and attitudinal (2008). He suggests these "attributes are pertinent for casting designers in increasingly strategic roles, and the combination of which make design unique" (Banerjee, 2008, p.4). He recognises these attributes as being reflective of a 'meta-discipline' that is "positioned to engage in complex multi-dimensional problems" (Banerjee, 2008, p.6). This research project operates as a mixed method mode of inquiry that reflects the notion of design as a meta-discipline, whereby the design process and research engage at different scales and different levels of complexity. This does not deny expert technical opinion, academic rigour or possible trans-disciplinary interactions, but rather enfolds them into a process of 'meta-disciplinary' modality. This is achieved by embracing the premise of extended designer responsibility

and the extension of the designer's own practice. For example, the researcher placed themselves in the position of a textile recycler to gain understanding of the system and the materials. This research project has the intent of building a platform which could be used by others, to create change. Banerjee presents a map of modalities within the design process that explicates this stance and hints at possible nodes of intersection that might be fertile for extension in the future (Refer to Figure 4).

Banerjee depicts where and how the designer navigates the design process and where points of possible intersection with other disciplines could be beneficial. In this research project, the designer has worked independently using a mixed method approach to attempt to bring about change. In this way, possible intersections that are multi-disciplinary and work towards Banerjee's approach have been identified. The researcher has aimed to provide a platform for change

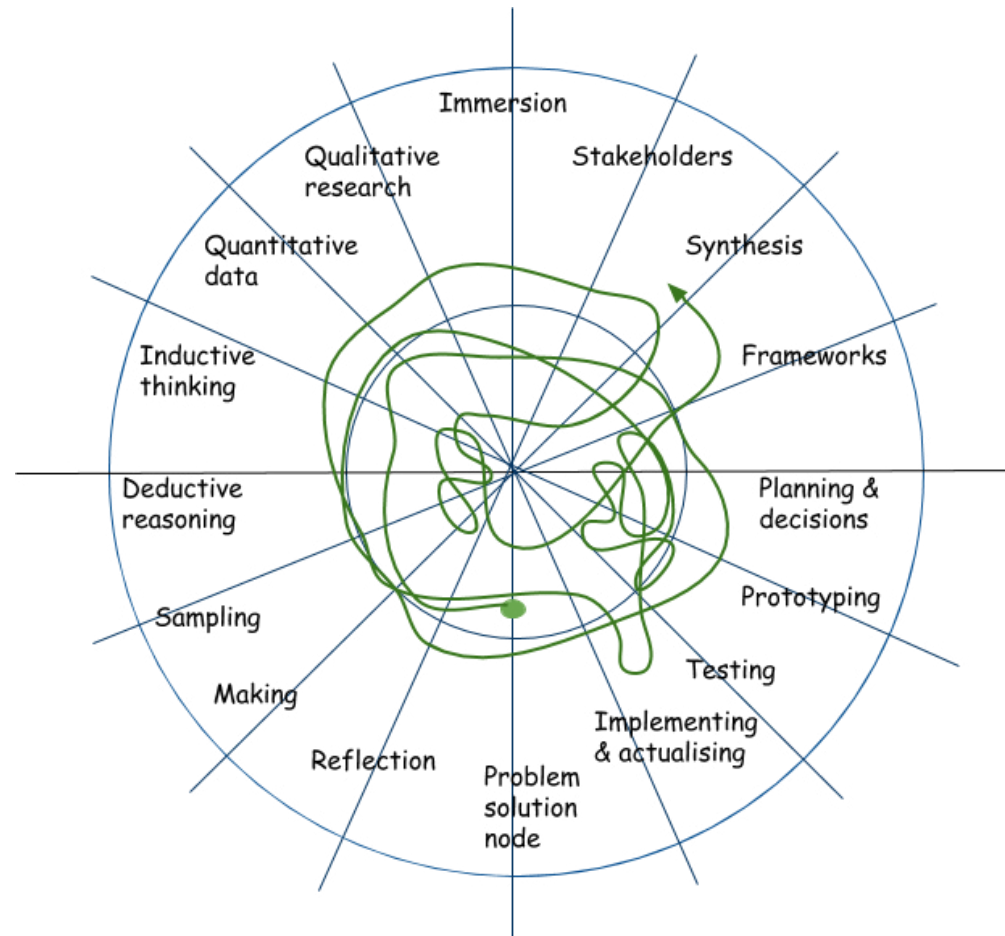


Figure 4: The various modalities in the design process.

that others could adopt and has been mindful to design the project to be adaptable, repeatable and scalable in the future.

Against this background of multi-disciplinary practice the design of the research interweaves a mixed method approach. These approaches work as a continuum of six overlapping phases, referred to as: selection and collection of textile waste; quantitative and qualitative data generation and mapping phase; the disassembly phase; the fibre experimentation phase; the processing phase; and the textile design phase (refer to Figure 5). Each of these phases and the different methods employed in them are discussed in more detail in the next section of this chapter. It should be noted that these six phases relate to the design of the practical realisation of this research, which is the main focus of this thesis. It should be noted that processes of reflection, analysis and synthesis occurred throughout these phases and at the end of the project. Rather than address

these analytical processes as a separate phase in the research design, they are discussed as they occurred in relation to these six stages. The final stage of reflection and synthesis is presented as the conclusion in Chapter 5.

The mixed method approach promoted a flexibility to adapt and transform systems, collate data and embrace sensory perception in a non-reductive manner, that enabled a positive sustainable design ethos towards knowledge generation. It was established early in this project that the designer would be both theoretically and practically engaged, working towards building a platform for localised textile waste reuse. However, navigating the journey was not prescribed, rather a disciplined deployment of multiple methods, adjusted where appropriate, were adopted, resulting in a flexible and responsive research model. Operating around the composite, nebulous and antiquated frameworks of the fashion and textile industries requires adaptive tactics when

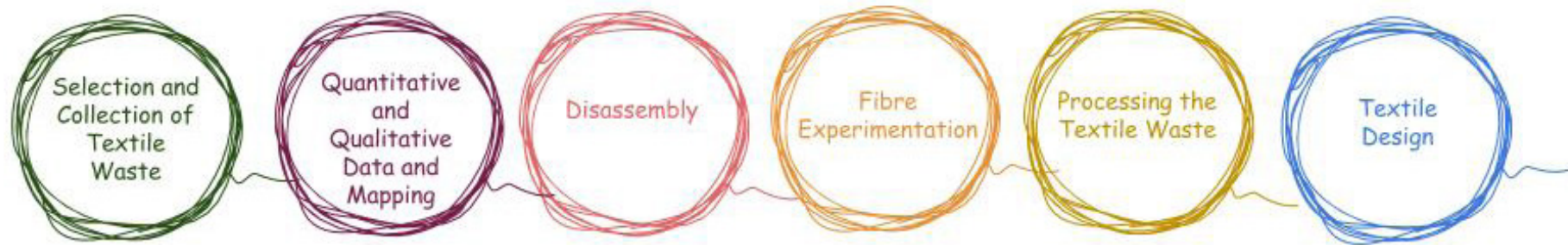


Figure 5: Six phases of research practice.

aiming for making change. This research took a multi-faceted approach that drew from different disciplinary modes of inquiry to facilitate a practice-based methodology.

Kane and Philpott (2013) suggest variant cognitive models that can command methodology with their premise of 'textile thinking'. They promote a "textile metaphor, exploring the advantages of 'sack' and 'box' thinking" (2013, p.6) based on a model developed by Barnett (1999) and Lomax (2000). This premise, informed by the writings of Gilles Deleuze (2003), presents 'box' thinking as a structured, rigid system that is determinate and leaves no room for conjecture. This can be applied to processes that have clearly defined boundaries as it is "measurable, amenable to precise mathematical prediction and practically applicable" (Kane and Philpott, 2013, p.6). On the other hand, 'sack' thinking offers a realm where quantification is less specific and the results are range based; in that, the model "does

not replicate, in detail, the particular outcome that occurs in reality" (Kane and Philpott, 2013, p.6). The recognition that working with textiles involves indeterminate complexity due to their nature has led this research to seek and deploy modes of operation that value "the malleability of textiles and textile modes of thinking... creating an approach where connectivity and continuity are key to the development of novel and innovative ideas" (Kane and Philpott, 2013, p.6). This metaphysical approach produces a new sentience that can affect the practitioner's/ researcher's vision of what the practice is achieving and inform how best to unfurl the new knowledge generated within the world it will operate. In other words, the designer handling the materials, understanding their composition, and allowing the senses of touch, smell, seeing and feeling, all serve to guide the making of innovative decisions about the design. This is often a less acknowledged aspect of decision making within a textile designer's role. The resulting 'textile thinking' has

a cognitive elasticity that provides fertile ground for this research.

In addition, a complementary yet epistemologically distinct approach was applied to the inherent binary qualities of the materials of this research; unveiling a resource for not only empirically informed subjective reasoning but also a tangible, firmer rationale. For example, this research employs methods, such as quantitative indexes, colour coding, composition analysis, along with material synthesis. The information correlated from these methods affected the continuum of processing, experimenting and making that was iterative throughout the research. The resulting blend of affect and quantifiable data was essential when dealing with the complexities of mechanised processes. Since one of the aims of the research project was to utilise existing accessible machinery to process the recycled fibres, both the quantifiable data about fibres and the researcher's

qualitative approach (touch, feel and look) was needed to convince these vendors into processing out of the gamut of textiles and fibres, as the vendors had not processed recycled fibres through their machinery in this way before. It was necessary to meet their expectations by showing them hard data, not only the quantities and typologies of the fibres, but also to champion the fibres by portraying their positive inherent qualities to ultimately obtain buy-in. For example, a shredding process undertaken in Onehunga by a large commercial carpet recycling plant, and a carding process tackled by a small boutique carding mill in Kaukapakapa required different approaches to elucidate and convince them of the value of this research. This is discussed further in the text in Chapter 4.

### 3.3.1 Affect

For the purposes of this research, the term ‘affect’ defines how the cognitive and physical encounter with the materials has transformed the researcher’s perceptions and practice. This concept has been discussed by design theorists, including Archer (1966), Norman (2005), Kane and Philpott (2013), and Fry (2014). ‘Affect’ was generated when the researcher assumed a manual labourer mode. By physically disassembling and processing all of the waste (a process that took up thousands of hours of work), the researcher took on a manual labour mode akin to a process that Hawley (2006) describes in her focused analyses of textile recycling using a systems perspective. As discussed previously (2.3.1), the current international textile recycling pipeline indicates the importance of uncelebrated yet specialist skill sets of the manual labourer and their intrinsically learned knowledge (Hawley, 2006). This is required to expediently grade

volumes of textile waste into recoverable portions so as to maximise profit. This research recognises that these manual labourers (specialists) have a refined view of materials knowledge, which is in part due to iterative practice, tacit knowledge and heightened senses. To be able to not only have empathy but experience with the condition of the status quo, a substantial engagement with the raw materials of this research project yielded a shift in the habitual practice of the researcher. This broadening of the designer’s role shifted the researcher’s perspective, physically and cognitively. This tuning of the designer’s cognition and practice led to a heightened phenomenological focus. The designer stopped being overcome by the volume of the textile waste and affronted by the qualities of it. What developed through iterative practice was a hyper-sense of touch, smell, visualisation and sensibility. This new experiential state had ramifications that included a refocusing of the analytical lenses available to the designer. To have experienced the

raw materials of this research during an initial phase, in an intense cognitive and physical encounter, it embedded a regenerative engagement which continued to inform decisions throughout the research.

### 3.3.2 Quantitative approach

In this research, a quantitative approach was used to collect and process data into measurable components that could be used to inform the research practice. This approach was important due to the scope of the project where a number of outside vendors were engaged to partially process the materials at different stages of the recycling. Each of these commercial enterprises required forms of information and language specific to their individual conditions. For example, when discussing the fibres with a small customised service provider, such as a local carding mill, colloquial language was used to label each waste stream. This approach was not

acceptable when dealing with a larger productivity-driven company, such as industrial textile waste shredders, where a formal description using numerical data was considered appropriate. To maintain consistency and control of the logistical operation, a metric was developed that could stand outside the researcher's personal experience, and represent the information concisely and logically, that could record and be used to predict patterns, cross-references and communicate with external agencies.

To enable the collected textile waste to be sorted, processed and recorded, a qualitative and quantitative index was built. Mapping and categorising the waste by the amount, the type and colour were first steps towards creating data sets. For example, spreadsheets were developed to record the amount of textile waste in various colours (refer to Figure 6).

waste stream B final kilo colours.xlsx

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	A	B	C	D
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10				
11				
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13				
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15				
16				
17				
18				
19				
20				
21	<b>Waste stream B</b>			
22	<b>Colour</b>	<b>Kilo</b>		
23	Yellow	23.6		
24	Red	25.6		
25	Blue	14.4		
26	Black	28		
27	Green	11.6		
28	White	5.4		
29	Grey	16.6		
30	Brown	1.2		
31	Beige	16.4		
32	Pink/Purple	10.2		
33	Red/Black	3.8		
34	Red/Black/beige	7.4		
35	Blue/Beige	5.6		
36	Black/Grey/Coloured	5		
37	Pink/green mohair	1		
38	Brown/black	1.2		
39				

Figure 6: Spreadsheet showing the weight of colours mapped from waste stream B.

This data was quantitative in that it involved ontic or factual knowledge, such as how many kilograms of each waste stream was available across the various typologies; for example, fibre composition. Crouch and Pearce state that “quantitative research builds around the collection of numerical data, which is analysed using statistical or other means of measurement” (2012, p.68). This quantitative approach was the most appropriate means of tabulating properties of this waste, as it provided factual information based on measurement, that could be used for communication, projection or modelling. The dissemination of the captured data in this project was inherent to each specific industry waste stream. The development of tangible possibilities in terms of how the waste could be processed and utilised was informed in part by the analysis of volume, type, colour and state of the individual textile waste streams. To further support this position, qualitative analysis of conditions, such as the structure and the aesthetic value

of the textile waste, was chartered by sensory perceptions, including smell, handle, look and feel. The effect of using these different modes of measurement resulted in the development of a flexible hierarchy. Drawing from both the quantitative and qualitative criteria aiding the interpretation and progression of each waste stream, conditions, such as material size, type, colour, structure and aesthetic, were converged with logistical considerations, such as volume and vendor selection. This development of a flexible hierarchy encouraged a more dynamic interpretation and enabled a more creative, designerly response to specific situations, rather than defining exactly how a specific waste stream should be used. To combine the multiple strands of this project, a design research through practice model was adopted to integrate the different types of objective and subjective knowledge. Zimmerman, Forlizzi, and Evenson state that this fusion of specific approaches, data sets and behaviour patterns “provide concrete embodiments of

theory and technical opportunities” (2007, p.6), resulting in coherent, focused outputs.

### 3.3.3 Quantitative and qualitative data generation, mapping and analysis

A mapping method was used to collect and record the quantitative and qualitative data. The approach of correlating different forms of data and recording them enabled the researcher to analyse specific aspects of the materials and use this information to inform decisions about the fibres in future phases. Before commencing the data collection and mapping phase, a studio space was converted into a waste sorting zone. The waste streams, once delivered or accumulated, were mapped and categorised to highlight the amount and types of waste generated. This mapping was quantitative in nature. A tally of each type of waste was kept and then collated into tables to give a datum measurement

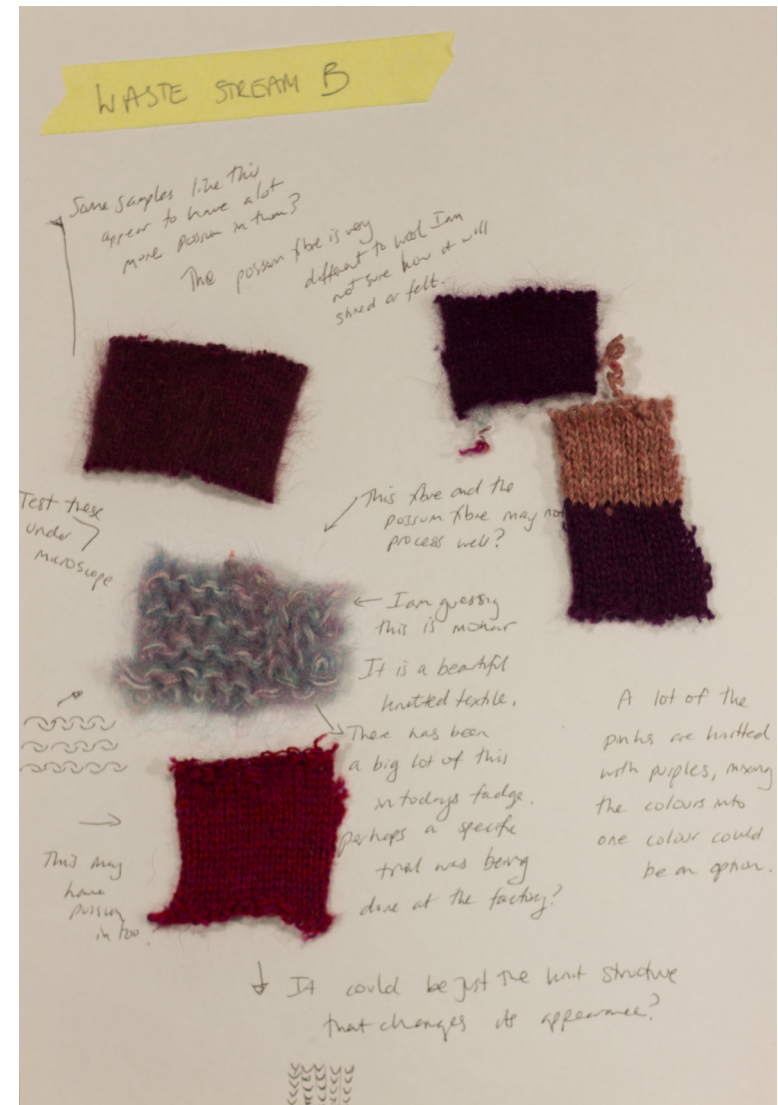


Figure 7: In situ notes about the typology of fibres from waste stream B, recorded at the storage sheds.

of the volumes that had been collected. Qualitative notes, images, textile swatches and details were also generated and recorded as a baseline of the general condition and specific typology of the materials (refer to Figure 7).

This procedure satisfactorily generated an initial bank of data that not only grew during the course of the research, but was often referred to. This method provided concrete, quantifiable evidence. Mapping was an essential tool that gave the data context in a readable and concise manner which supported the research and its core principles of re-thinking and re-valuing the textiles. This information was documented as a series of tables that presented the data in a clear format and allowed for agile examination of the recorded data. The data was charted in a number of forms such as, pie charts and bar graphs, to identify patterns and trends (refer to Figure 8).

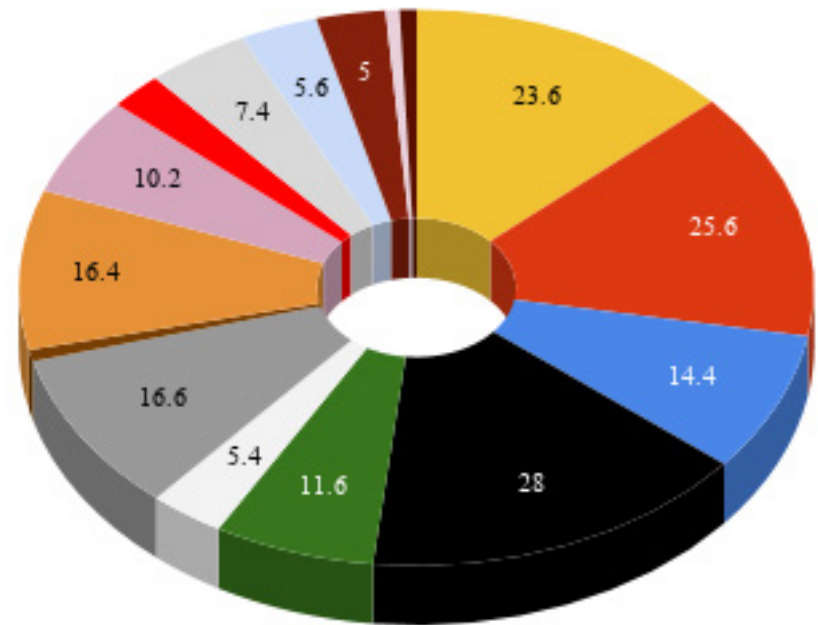


Figure 8: Pie chart of waste stream B colours measured in kilograms.

It was imperative that the data collected in this phase was clearly presented so that the analysis of the numerical patterns and trends could be emphasised. Crouch and Pearce suggest “the goal of all analysis is to produce a new text, in which the research and ‘story’ is told effectively and convincingly, by drawing on the important patterns and themes that have emerged from the research” (2012, p.74). These methods of data collection, mapping and analysis were employed to provide clear data to inform the next phases.

#### 3.3.4 Disassembling the textile waste

The disassembly phase involved pre-processing the waste by deconstructing it. This was achieved with hand tools including Stanley knives, scissors and pliers. This physical encounter with the materials took considerable time, requiring diligence and space. While many of the actions

were repetitive, they were not simple. The experience gained during this phase was invaluable to this research, as, at a micro level, the designer absorbed a thorough understanding of the various components and the materiality of the fibres. The methods used in this phase were cyclic and moved between an iterative practice of disassembly, sorting and classifying the waste, visually recording the textiles’ transformation, as the waste objects were deconstructed (using photography, video and collecting textile swatches), and then reflecting on these recorded processes using notes to document any insights. As the researcher was deconstructing the objects, the process of this manual practice became refined. Informed by a heightened sensory state, this process reached a point where the researcher was not consciously directing the hand. Cutting, ripping and manipulating the tools and the materials became second nature. The researcher’s thoughts were free to be focused on the design of the artefact itself. Through the process of



*Figure 9:* Traces of previous human interaction were revealed, for example a hairpin indentation.

deconstructing the objects, reflecting on the process and documenting insights, a new experience emerged. As the researcher began to closely regard the individual objects, traces of previous human interaction were revealed as a type of phenomenon that provided evidence of its former life (refer to Figure 9). The close encounter with these objects changed the researcher's thinking and regard for the object, and therefore the design knowledge residing within the object itself.

Nigel Cross, in his taxonomy of design research describes "the study of the form and configuration of artefacts" as "design phenomenology" (2006, p.101). Cross states that an understanding about the object itself is where "design knowledge resides in products themselves: in the forms and materials and finishes which embody design attributes" (2006, p.101). Cross's study implies an understanding of the object itself. This research project extends this by understanding the object in both its assembled state and

through the process of disassembly. The new experience and description that emerged from the researcher disassembling the objects, viewed through the lens of design phenomenology generated knowledge that was both new and concrete.

The recording process was carried out in a series of large industrial storage sheds that were hired to facilitate and store the textiles (refer to Figure 10). Textile information and textile samples were recorded in a research journal, in situ at the storage sheds; any additional images taken or support materials were organised into a set of tables back in the studio and were filed according to each waste stream. These records documented how the disassembly process was undertaken in both a hard data format, and also annotated more subjectively through a process that was anchored in the researcher's feelings and reflections on the process and the materials (refer to Figure 11).



Figure 10: Large industrial storage sheds that were hired to facilitate and store the textiles.

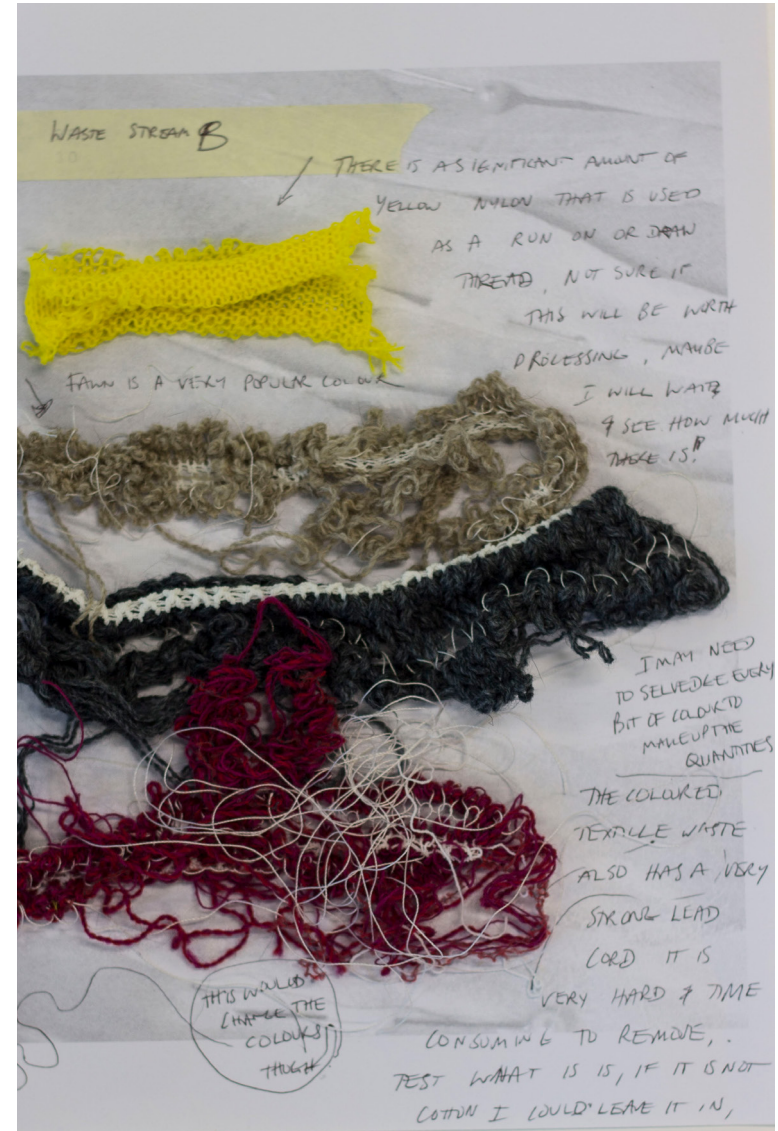


Figure 11: Documentation of the disassembly process showing the researcher's feelings and reflections on the process and the materials.

Jones explains how the use of a journal involves “multiple methods of recording, processing and data gathering, these methods include drawing, photography, writing and reflection” (2011, p.63). Darren Newbury (2001) recognises the research journal as “a self reflexive and media literate chronicle of the researchers’ entry into, engagement with and departure from the field” (p.7). The act of recording data in a journal format allowed the researcher to be self-reflective. The process of recording the researcher’s subjective response was as important as recording the numerical data. This ongoing conversation with the work of disassembling and measuring was promoted by using a variety of media technologies, such as sketching, collage, writing and photography, thereby enabling the researcher to view, disassemble, analyse and evaluate the process in a continuum.

### 3.3.5 Experimental cycles of practice

Phase three involved cycles of textile prototyping to test individual waste streams fibres, structural textile fabrication processes and the capabilities of existing machinery. This fibre experimentation occurred continuously throughout this research. This was due, in part, to the two-year waste stream collection timeframe, and the need to problem solve throughout the other phases of the project. Experimenting iteratively with the fibres and their capabilities was crucial to moving the research forward through the following phases. The practice of experimentation allowed micro-cycles of inquiry informed by the researcher’s tacit knowledge, new knowledge from the disassembly phase and knowledge gained through making and doing. The experiments served several purposes, including technical and aesthetic issues, and exploring fibre possibilities and testing material capabilities. This approach to fibre experimentation

functioned as cycles of action research (Schön, 1983). Schön defines action research as a methodology where the researcher's tacit knowledge is the central locus of 'reflecting in practice' (1983, pp.59-69). For the purposes of this research, acknowledging the influence of the researcher's tacit knowledge and establishing the process of 'reflecting in practice' afforded the research new material understandings. Schön suggests that by adopting this "epistemology of practice [which] places technical problem solving within a broader context of reflective inquiry, shows how reflection-in-action may be rigorous in its own right, and links the art of practice in uncertainty and uniqueness to the scientists' art of research" (1983, p. 69). This framing supports the legitimacy of the approach taken in this project, enabling a deeper, wider and more rigorous form of inquiry. For example, the ability to rapidly prototype and analyse experimental combinations of fibres that might be useful in the process of textile recycling.

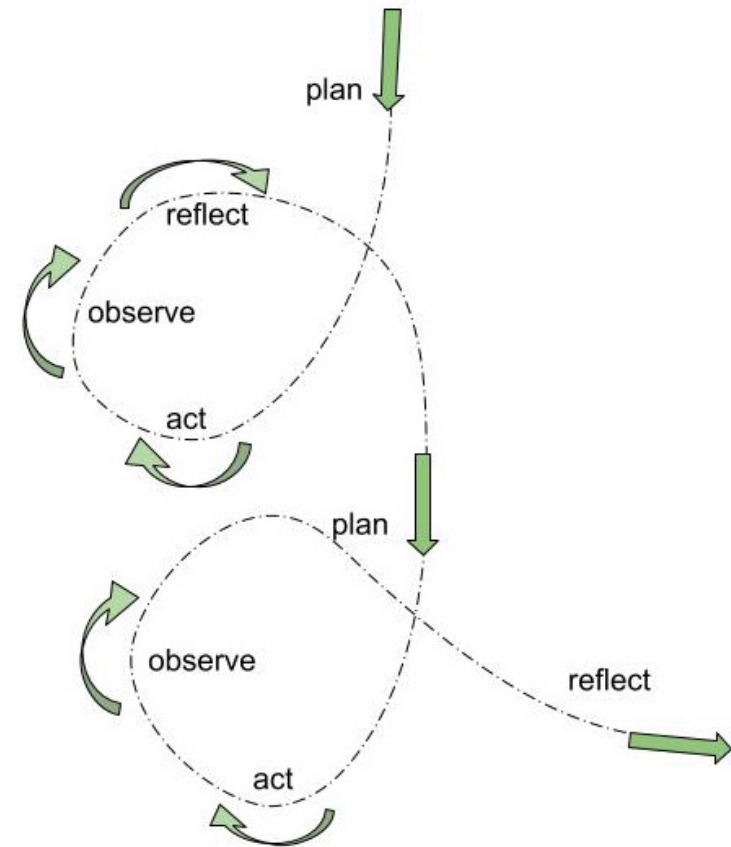


Figure 12: Cyclic mode of inquiry, that involved the researcher in stages of planning, acting, observing and reflecting.

As the research progressed, new questions were generated and fed into this cyclic mode of inquiry, that involved the researcher in stages of planning, acting, observing and reflecting (refer to Figure 12). Reflection occurred both during and after the experiment. Depending on the outcome, a new cycle of experimentation was generated, or the cycle was repeated. These experiments were vital in moving the research forward, suggesting new possibilities and at times providing a proof of concept to communicate with the vendors, who were engaged in processing the textile waste, especially in the early stages of the research.

This experimental phase was informed by the earlier disassembly phase, as the researcher's observations of the textile's properties and behaviours were refined and recorded; for example, when the researcher observed, experienced and recorded a specific waste stream component as having a low grade mixed fibre content. Predominant

theories of textile recycling claim that mixed fibre content is detrimental to the fibre being successfully transformed into new textiles (Langley, 2000; Norris, 2012; Walker, 1995). A hypothesis generated by the researcher was that a specific needle felting technology had the potential to felt mixed fibres together if the recycled fibres had a crimp or were a natural fibre. An investigation of felting technologies suggested a FeltLOOM® machine (Appendix A), located in the Auckland University of Technology's Textile Design Lab, could needle felt fibre to fibre of mixed fibre types.

A sample of fibres was tested by the researcher and refined several times using different quantities and typologies of fibres until a satisfactory result was achieved: that the textile did not fall apart after felting. The outcome of this experimental cycle was a sample that enabled some propositions to be developed about the relationship between the specific blend of fibres and the needle felting

opportunities. These experiments were recorded using photography, videography and the creation of textile swatch samples that carried specific written information about each sample, including what it contained and how it was produced (Appendix C). These experimental textiles could be directly linked back to their original waste stream and the processes which had been applied to them.

### 3.3.6 Processing the recycled textiles

This phase involved the organisation and configuration of a platform of existing textile machinery and possible vendors to process the three waste stream textiles into new recycled fibres. At the time this research was conducted, there was no suitable infrastructure in place in New Zealand for recycling textile waste that retained any value or added value to the fibres of the recycled material. It has been argued that New Zealand does not have large enough quantities of textiles

to warrant a specialised textile recycling program (Reidy, 2017). An imperative of this research was to explore ways to overcome this perceived infrastructural limitation and identify or re-work ways to recycle textile waste. To counter these structural issues surrounding textile recycling a localised approach was adopted, identifying appropriate machines for each stage of the recycling process. This was necessary as there was no option of a single vendor solution for appropriate processing. The approach of building a working platform was outside the specific remit of a textile designer and demanded a wider view and deeper understanding of the entire system. At a macro level, this approach required a consideration of the entire lifecycle of the textiles and the processes used at all stages. At a micro level, the researcher needed to comprehensively understand the materials to be in a position to advocate for them. Some of these insights were gained in the previous phases of practice where the researcher was involved in the role of

a manual labourer in sorting, mapping and disassembling the textile waste. The technical knowledge gained through this process was a primary learning experience that was essential to an understanding of the material and supported a shift in practice, where reconsideration of sustainable practices was promoted rather than a position that negates unsustainability. Kate Fletcher is an advocate of holistic systems that not only recognise technical issues around decreasing the negative environmental impact, but have a wider ambition of building a “framework for life” (2014). This research actions Fletcher’s ideals by connecting a comprehensive vision for the whole system with the technical ramifications of working with recycled fibres.

### 3.3.7 Possibilities for textile design

In this phase, a collection of textile prototypes were developed as a proof of concept. It was imperative

that the design of the textiles reflected the extensive energy that had gone into the fibres’ previous life cycle: inception, manufacture and use. The fibres’ individual characteristics were celebrated and valued. For their value to be realised, the integrity of the new textiles needed to communicate the transformation they had been through. Realising the potential of each waste stream fibre happened simultaneously alongside the processing phase. Recognised methods of design practice, such as sketching, prototyping, moodboard development and making were used to develop the textiles. In addition, the philosophy of ‘refuturing’ (Fry) informed the practice and the design decisions. The lenses of sustainable strategies, material futures and design innovation were interchanged as the process developed. For example, during the shredding of the fibres in the processing phase, the fibres were considerably damaged, and the fibre length became very short. This determined that the fibres could not be developed into yarn. This was not regarded as

a technical failure, rather an opportunity for the researcher to reconsider the fibres' potential using different textile techniques, such as felting the short fibres or blending them with virgin fibres. In this way, the researcher's cognitive processes were informed and expanded by the possibilities of what the fibres could be. This is comparable to the way Banerjee and Cross suggest designers think, and how they are innovative (Banerjee, 2008; Cross as cited in Buchanan & Margolin, 1995). They both propose that shifting focus from the technical aspects of a problem, which involves 'inductive and deductive thinking', and engaging with 'abductive thinking', designers could amplify possibilities into new designs.

Both traditional and new textile technologies, such as knitting and needle felting were explored as methods for re-animating and re-futuring the fibres (Fry, 2009). The design of the textiles took into consideration the possibilities of

what the fibres could be rather than what they could not be, as a form of abductive thinking (Banerjee, 2008; Cross as cited in Buchanan & Margolin, 1995). Unique to this phase was a hybrid practice that balanced both the qualitative and quantitative nature of the fibres. The qualitative aspect involved creative thinking informed by the fibres' intrinsic qualities of aesthetics, touch, handle, colour, mobility and their historical narrative. The quantitative aspect, and the amount of textiles available to the project dictated that a planned approach to the textile design phase was necessary. The finite nature and the qualitative characteristics of the re-animated fibres determined the amount of fibre to commit to different textile design processes, such as yarn or felt. This determined a new reality whereby the recycled textiles previously thought of as waste became a valuable commodity. The volume of re-animated fibres available for designing into new textiles was limited to the textile waste initially collected for this study. Additionally, another

limitation was the volume of waste that had been developed into usable fibres in the processing phase. Not all of the initial textile waste collected could be fully recycled in the processing phase. This was in part due to the aims and scope of the study, and in part due to the limits of mechanical processing. Because of the research limitations, the textile outcomes were taken to be a proof of concept stage, as an ongoing commercial solution for each waste stream provider, rather than the finished products.

### 3.3.8 Reflection and analysis

Reflection and analysis occurred throughout all stages of the project. Processes included tabulation and analysis of quantitative data (3.3.2) and reflection in and on action during practical phases of the project (3.3.5 and 3.3.6). The final stages of the research approach reflected on the overall project, analysed the practice and synthesised the research.

This process took place through reflection, mapping and the process of writing the exegesis. The outcomes of this stage are presented as the conclusion in Chapter 5. The material samples, knowledge and insights gained are considered in relation to the overall project aims, and formulated to provide exemplars and strategies for a localised textile waste recycling platform. This stage drew from specific instances and examples from the project to initiate a framework that could inform other researchers and companies interested or involved in textile waste recycling. The decisions that were made during the processing of the textile waste and the design of the textiles were mapped out and formulated into a decision tree (refer to Figure 13).

Simple conditional control statements were developed that required a yes or no decision. An example of a control statement was, can the textile waste be shredded? This was followed by a 'yes' or 'no' option, dependent upon the unique

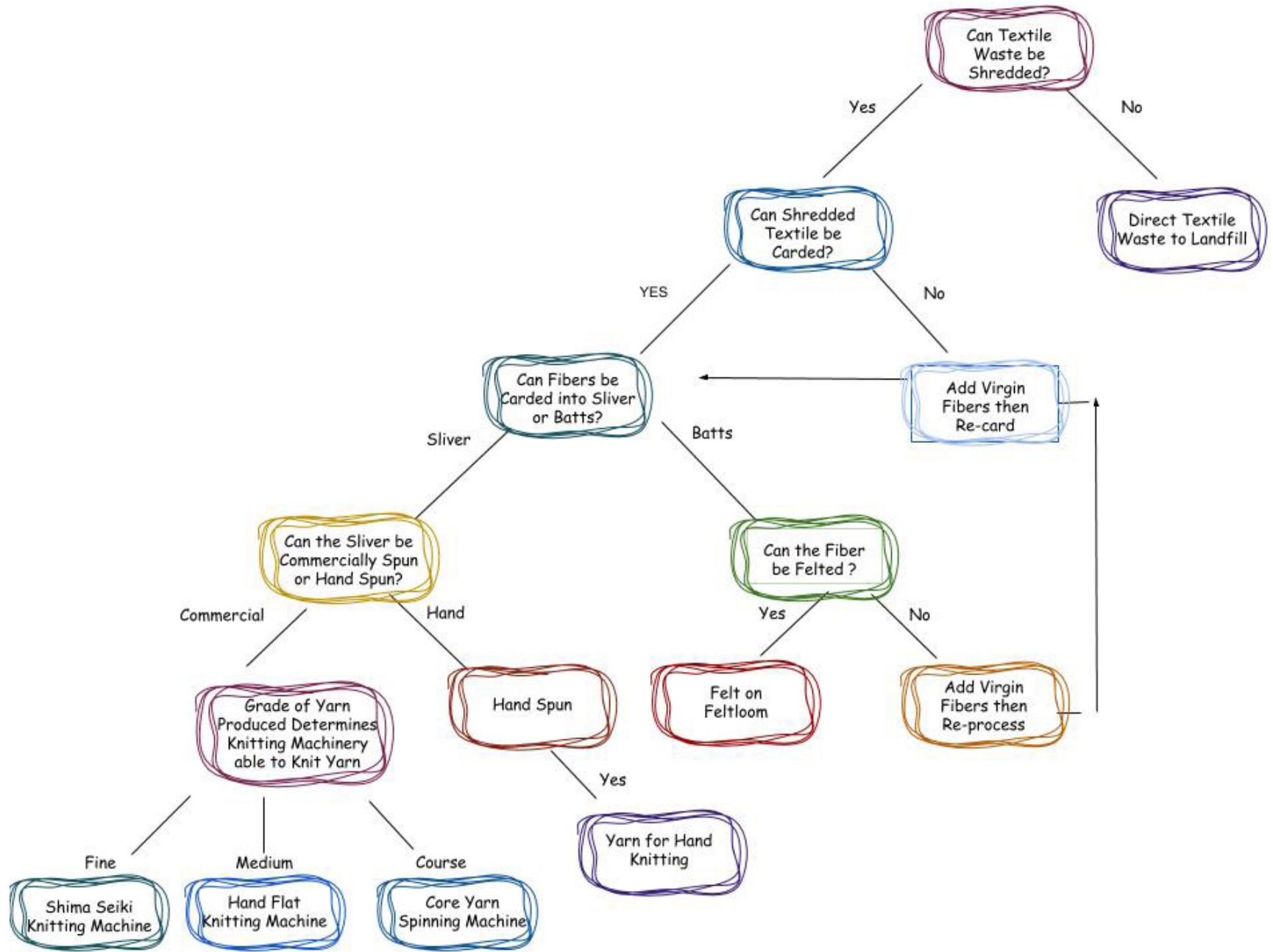


Figure 13: Processing of the textile waste and the design of the textiles was mapped out and formulated into a decision tree.

response of each waste stream to the different mechanised processes. It was a useful way of documenting the project's decisions but also offered a visual representation of the logic that was followed about why the textiles moved in different directions. In this way, the decision tree also provided an overview and reflection on the whole process, rather than just stages; it represents the process as a system rather than just a step by step process.

### 3.4 Conclusion

The methodological approach employed in this research project was examined in this chapter. This lays the methodological foundations that informed the research approaches to the collation, analysis and interpretation of data. A mixed method approach was used. This was multi-dimensional in that different theoretical frameworks and associated methods were considered and selected in


relation to the specific scale, scope, situation encountered and the overall research aims. This was elucidated through a detailed examination firstly of the role of design and the designer and secondly, the research approach.

The role of design and the designer addressed the specificity and complexities of this project. The researcher focused on design research using genuine textile waste without the limitations of industry or product focus. Due to the nature of this PhD research, balancing design theory with a material physical connection presented challenges. However, the theoretical underpinnings discussed in this chapter provided an operational framework.

The research approach described the synergism between cognitively and physically engaging with the materials and the new knowledge that the researcher gained. The manner in which this informed the researcher was

identified as 'affect' for the purposes of this research. This progression of thought led to changed habitual practices, and the outcomes generated were described. Quantitative and qualitative approaches that supported the collection of the data, mapping and analysis were comprehensively documented. This provided results that were analysed and interpreted to inform the next phases of the research. The collection, sorting and disassembly of the collected textile waste were detailed. During the process of deconstruction, the repetitive manual actions became more refined, and the researcher, through the action of disassembly, experienced new understandings and a changed physical connection with the materials. The mechanisms utilised for fibre experimentation and processing the textiles were recorded, and the development of fibre prototypes resulted in a proof of concept and highlighted the possibilities for textile design. Finally, reflection and analysis through different lenses of mixed methodological perspectives provided

insight for ongoing practical research, so that strategies and exemplars were formulated through processes of continual reflection, mapping, writing, material samples, and knowledge and insights gained. Drawing from these and also specific actions and examples, a framework was initiated that could inform other researchers and companies interested or involved in recycling textile waste at a local scale.

A close-up photograph of a stack of several layers of felt fabric. The colors from top to bottom are: dark grey, red, a semi-transparent reddish-brown layer with text, light beige, dark blue, black, and magenta. The felt has a fibrous, non-woven texture. The text '4: Research Practice' is centered on the reddish-brown layer.

## 4: Research Practice

#### 4.1 Chapter introduction

Utilising the previous theoretical analysis of the methodologies, this chapter discusses and details the application of the outlined principles to the processes undertaken in the research practice and to the actions employed by the researcher, in order to realise the goals of this project. Analysis in practice during the different stages of the process demonstrates the synthesis between method and action research when seeking solutions to practical problems. The textile waste contributors are introduced and differentiated. The process of gathering quantitative and qualitative data to generate textile knowledge integral to this research are described. How this informs decisions within the design practice are evidenced, for example with new textile experimentation processes. The methods of collecting and recording the data, the tools used to analyse and interpret the data, how the information is utilised and

also the ways that this informs future phases are set out. All the practical actions over a three year period from the disassembly of waste streams to experimentation of the production of new textiles are detailed and recorded.

#### 4.2 Phase one: The selection of the three textile waste contributors

The company which is identified as waste stream A made contact after seeing comments on the PhD project in the news media and proposed that their textile waste be included in the study, as they were interested in looking for sustainable solutions for their redundant regalia. The waste stream from an academic regalia rental company consisted of post-consumer garments, such as gowns, trenchers and capes. This waste stream offered a consistent colour block of predominantly black tones, which offered an opportunity

to work with a solid colour without sorting. An initial inspection of the textiles indicated that the fibre content was of a fairly low grade of blended fibres. This provided an opportunity to research and practice with blended fibres, a type previously identified in the literature as problematic and undervalued because recycling mono fibre types is viewed as more straightforward. In addition, the inclusion of this textile waste stream overcame one of the issues raised from my previous research, that identifying large amounts of a single colour was beneficial to the textile shredding process, as the machinery used in this process required large quantities to operate (Cleveland, 2013).

The company which is distinguished in this project as waste stream B was identified through research, as a beneficial source of textile waste for five reasons. Firstly, the fibres were post-industrial but pre-consumer waste which was distinctly different to that of waste stream A. Secondly, the

fibres used by the company to manufacture knitwear were of a significantly higher quality and price point. Thirdly, the textiles were predominantly a wool-based blend of fibres, a factor that was identified in earlier research as a key to successful reanimation of the fibres due to their natural ability to join together (Cleveland, 2013). Fourthly, this waste stream offered a unique fibre that is produced only in New Zealand, in the form of possum and merino blended yarn. New Zealand possums, introduced from Australia in 1837 for the fur trade, are considered to be an agricultural and conservation pest (Predator Free NZ, 2016). Lastly, the textile waste consisted of some mohair, fabricated from the hair of the angora goat, which generated another point of difference.

The textiles identified as waste stream C in this project were generated by students in an academic design studio environment. As this textile waste stream had previously

been studied in earlier research (Cleveland, 2013), it presented an opportunity for building on and refining this earlier research. It also offered a counterpoint to the other waste streams, in that it was a byproduct of pre-consumer and pre-manufacturing design waste. In addition, it broadened the range of fibre types (polyester, stretch nylons, silk, linen) and the variety of colours (a diverse combination of colours due to the printed fabrics).

#### 4.2.1 The logistics of collecting and storing each stream of waste

Methods for the collection of each textile waste stream were formulated in order to manage the collection of textiles, and the logistics of moving the waste across areas of Auckland to either the researcher's private studio or the storage sheds hired to store the textiles as part of this project.

The pattern of waste disposal for waste stream A was based on their annual stocktake, which varied from year to year. This audit filtered end-of-life garments from rental stock, such as faded, discoloured, worn or discontinued lines. Some of the garments had been in use for over twenty years before being retired. Prior to this project, where appropriate regalia had been donated to schools, universities and theatre groups for their own use however unusable garments were bagged and sent to landfill. For the purposes of this research, commercial sensitivity was considered with regard to their disposal, as the garments had previously held academic significance. It was agreed that the textiles would be shredded to prevent the garments being reused elsewhere. The garments were delivered in two large van loads after each annual stocktake. This posed significant logistical challenges as the scale of delivered goods was at the maximum capacity of this project (refer to Figure 14). Some of the waste, such as the trenchers, needed to

be disassembled for storage as they took up large volumes of space. This meant some of waste stream A had to be pre-processed in the researcher's studio environment before being moved to the storage facility. The disassembly of the trenchers is discussed further on in this chapter as a specific example of the process.

At the beginning of this project, waste stream B had a set of procedures in place whereby employees would aggregate all textile waste with any other waste into rubbish bins located around the factory floor. There was no process in place for collecting exclusively textile waste. After consultation with the managing director and the operations manager, a new arrangement was put in place to collect all the textile waste as it came off the line. These small systems change to redirect the textile waste resulted in a pack or fadge of waste being collected onsite and then dropped off at a meeting point closer to the researcher. The waste was picked up each time



*Figure 14:* The logistical challenges of managing the textile waste from stream a when it was delivered.

To play video open interactive PDF

one fadge had been filled (refer to Figure 15). Each fadge weighed approximately 50-60 kilograms and was moved in the back of a car. This procedure was repeated over two years until the available storage space reached capacity, and decisions were made as to how the waste would be processed.

The textile waste from waste stream C was collected by the researcher from the fashion design studio rooms at the end of year clearout after students had finished their studies. The first step involved determining appropriate methods to collect the waste from the studios and establishing a process of selection to determine which waste to keep. This process, in the first instance, was used to eliminate any waste deemed completely unusable, such as mouldy fabrics and non-textile elements. The collection happened over three consecutive years, the first year being part of my honour's project (2013), and the two subsequent years as part of the



*Figure 15: A fadge of textile waste.*

PhD project (2014-2015) in November/ December of each year.

#### 4.3 Phase two: quantitative and qualitative data generation, mapping and analysis

The focus of this phase was to generate textile knowledge specific to this project. This information then informed decisions within the design practice stages. For the purposes of this thesis, phase two will be discussed in four parts: (1) the mapping of the typologies of the textile waste; (2) the methods of gathering and recording the data; (3) the tools used to analyse and read the data; and (4) the deployment of the data and how it informed the future phases.

##### 4.3.1 The mapping of the typologies of the textile waste

After collection, it was necessary to sort the waste by mapping

and categorising it so as to highlight the amount, type and colour of textile waste that had been generated. Each waste stream had a different typology that significantly impacted sorting and mapping processes. For example, waste stream A was mapped according to salvageable textiles as the type of fibre content, and the colour remained fairly consistent. On the other hand, waste stream B had a consistent fibre content, but a wide range of colours and combinations of colour. Waste stream C was entirely different as it had no consistent fibre content and no consistent colours.

Due to the differences and variable flows of the textile waste streams, the mapping phase required a selection of different methods at different times to be used for an efficient mapping process. This mapping method and means of gathering data worked in tandem, including qualitative and quantitative approaches. The quantitative data was anchored in measurement of weight, for example determining how

many kilograms of a colour or a type of fibre was available. This quantitative approach was the most appropriate means of mapping the waste as it provided factual information based on measurement. The quantitative data was a means of accruing factual information regarding the weight in kilograms of the various typologies of the textile waste determining an impartial binary in relation to qualitative processes, such as determining colour typologies.

#### 4.3.2 The methods of gathering and recording the data

The qualitative mapping included methods, such as grading the fibre compositions and fabric structures, colour categorising and evaluating the potential recyclability. The agency of these methods was founded on not only expert technical advice on machine capabilities, but also the researcher's tacit knowledge blended with thinking about what was possible or abductive thinking. Knowledge of the



*Figure 16: One load of waste stream B, showing the various colours.*

materials influenced the choice of methods used and their application. These initial mapping methods considered the inherent value of the fibres and the possible synthesis that could further add value. For example, waste stream B generated a wide range of core colours (refer to Figure 16).

However, the weights of each colour were insufficient to move into the recycling process. Previous research (Cleveland, 2013) indicated that mixing colours resulted in an overall brown sludge colour with flecked tones. As the research sought defined colours with an improved aesthetic, mixing colours was not an option (this is further explained within the methods section on pg.126). This presented an opportunity to evaluate the qualities of sympathetic colour hues. To facilitate this approach, colour libraries (Appendix B) were developed in which textile swatches were moved around in various configurations to evaluate their compatibility (refer to Figure 17). As part of this



*Figure 17: Example of a colour library of waste stream B.*

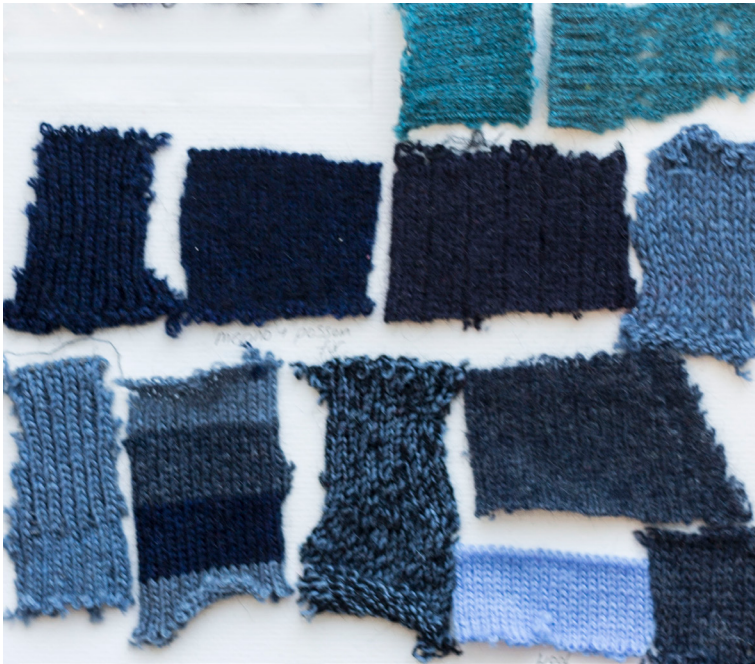


*Figure 18:* Fibres from waste stream B were separated to see 89  
how they related to one another.

process, a small amount of the fibres were separated out and placed into similar colour stories to assess how they were aesthetically related (refer to Figure 18).

Crouch and Pearce (2012) define this type of creative investigative process as “qualitative research design [that] is focused on ways to find out more and more about less and less” (p. 72). This strategy, they suggest enables a more in-depth and focused consideration of aspects of the research. Using a systematic approach, similar to the process used in qualitative research, was advantageous as it naturally narrowed the scope of the mapping phase, ultimately allowing an interplay between hard data, such as weights and subjective evaluation, for example, colour categorisation. In this way, the quantitative and qualitative methods interacted to enable a viable approach in terms of the scale of the research. For instance, a known parameter of the research was that the process of shredding the

textiles used a piece of machinery, the La Roche Shredder (Appendix A), that could not operate without a minimum of 200 kilograms of textile waste at any one time. As each colour was weighed, it was apparent that colours would need to be blended in order to reach this target weight. However, decisions based on quantitative data and qualitative data needed to be reconciled in situations where the advantage of a colour could be evaluated by either weight or aesthetic value. For example, teal could be placed with either blues or greens to achieve the 200-kilogram goal. Equally it needed to be evaluated on its aesthetic position. Adding it to blue or to green groupings would affect the aesthetic balance (refer to Figures 19 and 20). In this way, using both quantitative and qualitative research in tandem offered a platform for new knowledge to be generated to inform the next phases of textile development.



*Figure 19:* The teal colour from waste stream B grouped with the blues.



*Figure 20:* The teal colour from waste stream B grouped with the greens.

#### 4.3.3 The tools used to analyse and read the data

A series of field notes were taken in situ at the researcher's storage sheds and studio to record the weights and typologies of the textile waste. These were then transferred into spreadsheets, to allow the charted numerical data to be configured into electronic tables. The data was then readily available to formulate into graphs, so that the analysis of the numerical patterns and trends could be emphasised. Crouch and Pearce (2012) suggest "the goal of all analysis is to produce a new research text, in which the research and 'story' is told effectively and convincingly by drawing on the important patterns and themes that have emerged from the research" (p. 74). This form of notation and analysis was the most effective method to use in this phase, as the aim was to draw on the data for trends to inform the research process. For example, in waste stream C, the data was organised into several different graphs

to examine the textile waste using three criteria, weight, textile composition and colourway. This data was plotted in several formats to identify relevant patterns and trends over the three typologies. It was necessary to format the graphs across two axes simultaneously, reducing the complex mapping into smaller parts. This was used to gain a better understanding of the viability of the resource. This information was mapped to show the type of textile and the weight and then reconfigured to show the type of textile and colour relationships (refer to Figure 21 and 22).

#### 4.3.4 Deployment of the data and how it informed the future phases

Having the data in a readable and concise format provided a deterministic reference that could be used throughout the other phases that sometimes required new strategies to move the research forward. Additionally, this reference informed

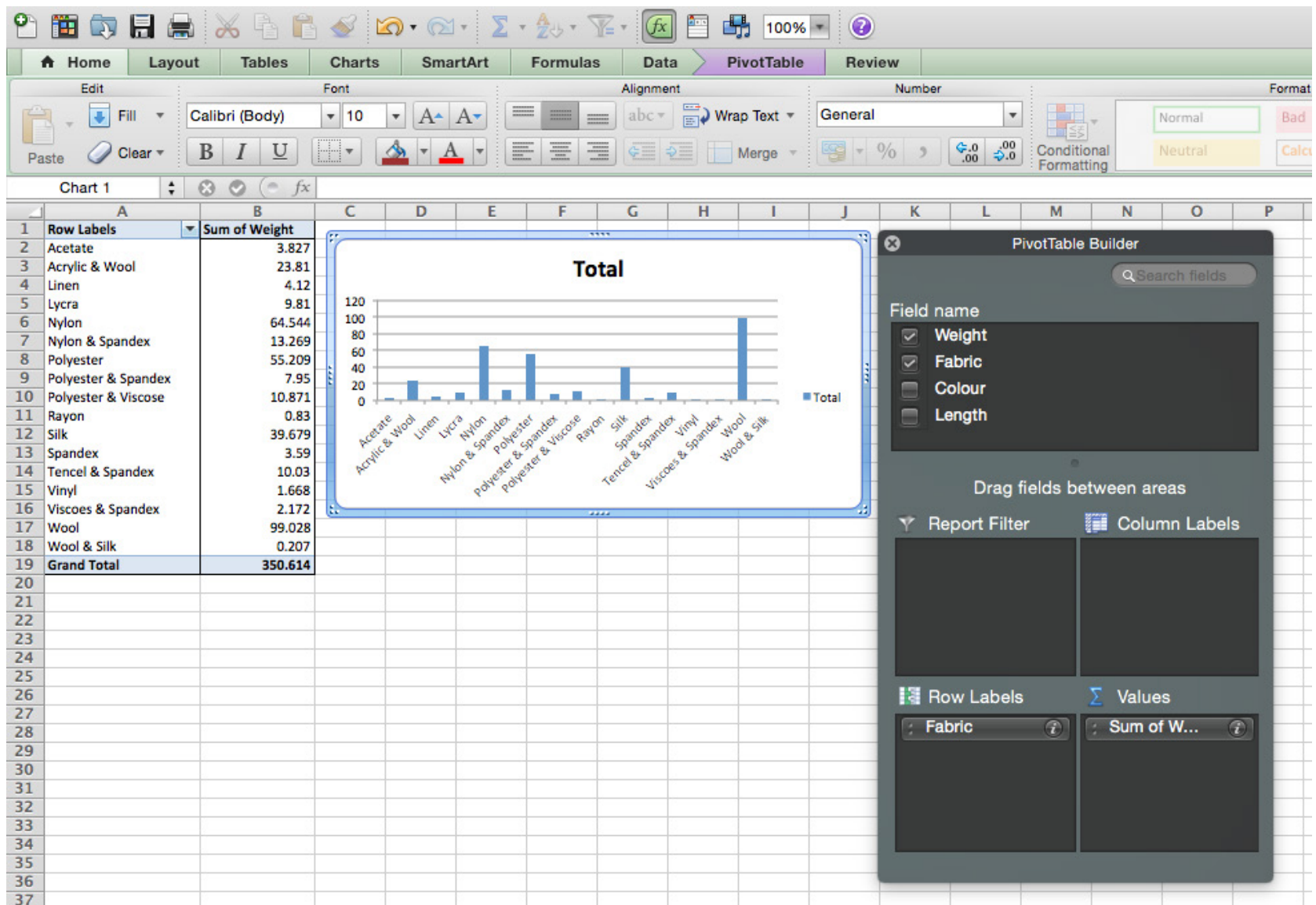


Figure 21: Textile waste stream C mapped by weight and type of textile.

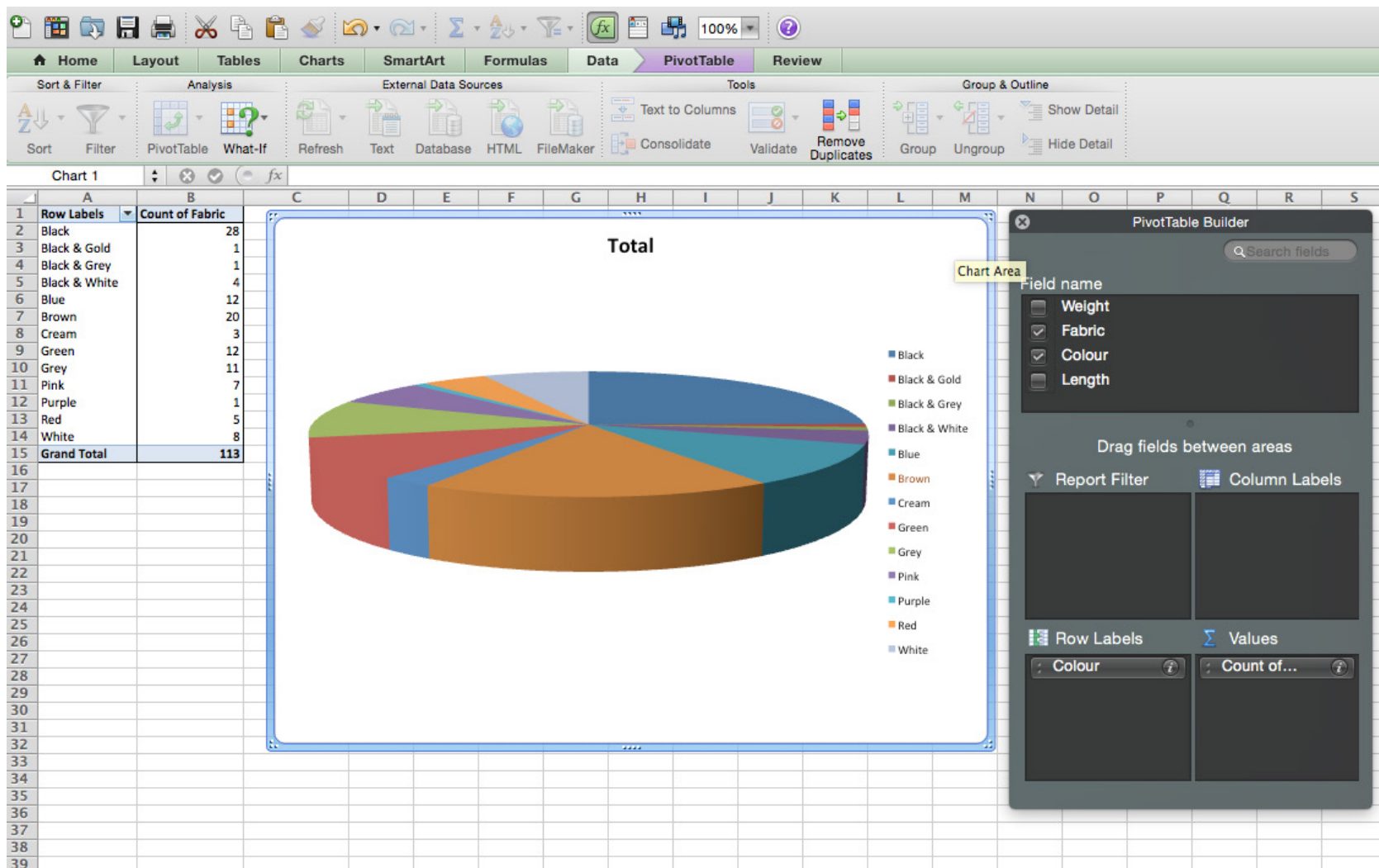


Figure 22: Textile waste stream C mapped by type and colour of textile.

decisions about how much of each type of textile to commit to any future processing. For example, the mapped data was critical when faced with a dilemma around the quantities of colourways generated by waste stream B and the La Roche Shredder and La Roche Opener (Appendix A), machines which had minimum requirements to operate. The data was used to predict collection rates of colours and quantities over the time frame of the project. It was evidenced that the minimum goal weight of 200 kilograms was not going to be achievable for each colour within the timeframes and available space.

#### 4.4 Phase three: Disassembly

The disassembly phase was not conducted within a singular block of time, nor was it practised in isolation from the other phases. For example, this phase often overlapped

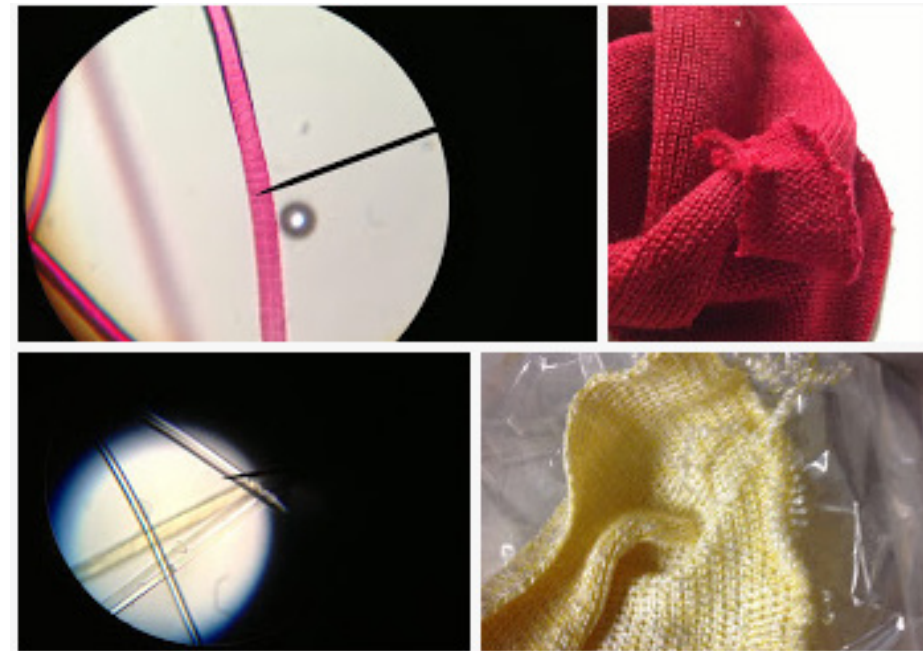
with phase two, where the waste was disassembled as it was collected and mapped. It also overlapped with phase four as fibre experimentation was conducted in tandem with disassembly. In part these overlaps were due to the staggered intake of each waste stream. The scale and timeframe of this research was such that it sat outside the standard industrial premise of survey, process and solution. The Formary, a Wellington-based 'Textile Reuse Program', (The Formary, n.d.) has engaged for several years in long-term mapping and auditing processes to quantify potential recyclable waste streams simply to determine the scale of the problem. Such an extended time frame was not suitable for this three-year PhD study where the collection and processing needed to work in unison. This research also took a practice-led approach, rather than a more traditional problem-solving approach. These two factors informed a more designerly approach to the development of strategies for local textile waste recycling. In addition, a possible

set of scenarios for processing the fibres needed to be considered in advance, due to logistical considerations and formats required by outside vendors for different aspects of the processing. For example, balancing the weight requirements of process machinery, such as the La Roche shredder, with the potential weights of the accessible waste. So in this way, often a specific set of circumstances in this disassembly phase influenced and gave insight into possible scenarios for the processing of the fibres in phase four. This phase of disassembling the garments and textiles was a pre-processing step to be able to recycle the textiles. There were two key drivers that determined the operations of this phase: to separate out the non-machinable textiles and componentry, and to assess the value of the fibres.

#### 4.4.1 Separating out the non-machinable componentry and textiles

Previous experience working with processing machinery, including a La Roche shredder, La Roche opener and a Haign fibre carder (Appendix A), helped determine some preliminary boundaries. The textile waste fed into the La Roche shredder must be free of any componentry, such as zips, domes, buttons or manufacturing items such as needles and pins. In addition, the La Roche shredding and opening machinery cannot process any cotton fibres as they ‘ball up’ in the machinery causing a stoppage. A cotton ball up in the machinery would be problematic due to the fast production environment, and the costs associated with machinery breakdowns and maintenance. An assurance had to be given that there was absolutely no hard componentry or cotton in the textile waste. This was particularly relevant to the disassembled textiles from waste stream C, as they

were collected from a design studio; the textiles were garment samples and were often finished with zips, domes and buttons. In addition, the studios were used by many design students making samples or one-off garments, so the textiles were all different and less similar to what might be produced in the workroom of a single designer or a small production company. The origin of the fibres of each piece of textile was unknown without some form of testing. This was mostly achieved by an initial look and feel (hand) of the textile, where the researcher's fibre knowledge could determine if the fibres were cotton. At this stage, pieces were placed into two categories, definitely not cotton or needing further testing to determine if it is cotton. The latter was then subjected to textile burn tests and even microscopic analysis to determine the fibre content before being included in the recycling process (refer to Figure 23).



*Figure 23: Microscopic analysis to determine the fibre content of waste stream C.*

Due to the detection of both cotton fibres and hard componentry, waste stream C was the most time consuming to disassemble (approximately 250 hours). It was evident that the production environment determines the scale of sorting that would be required. Waste stream B was from a private company that produces lines of knitwear from a boutique range of natural fibres: merino, possum and mohair. This determined that the fibre content would be consistent. On the other hand, waste stream C was generated in an academic design studio where the textile selection was not tied to a manufacturing model, and therefore the range of textiles and fibres was extensive. Waste stream A generated by the rental company, though in a similar category to waste stream B, did not know the origins of their fibres or the fibre content. However, in this instance, once the fibre content of one garment, like a gown, was established, the process of disassembly could easily be repeated without continuous fibre content examination. This highlights the individual

properties inherent in any source of raw materials for any recycling platform would need to be evaluated for long-term viability.

#### 4.4.2 Assessment of fibre value.

The disassembly phase enabled an assessment of the value of recycling the fibres. Working in a micro-processing manner, in contrast to industry's mass, homogenised approach, recognises the value of a specific waste stream and their fibre types. This provided insights when selecting which fibres to recycle and how to process them. For example, initially, it seemed that the black academic gowns could be recycled in their entirety and would not need disassembling. However, through a quality control investigation, it was discovered the shoulder section of the garment had a white cushioning interface or lining. This material was rejected both because it was white and would alter the all black colour block, and

because it was deemed to have little value in being recycled due to its structure (refer to Figure 24). Thus, for the gown to be recycled, it was necessary to remove the entire shoulder piece as the interfacing was bonded to the fabric and could not be removed.



*Figure 24:* Disassembly of a gown from waste stream A showing the white unusable interfacing.



*Figure 25:* Rejected items such as small patches, logos and colour banding all needed to be separated.

#### 4.4.3 Disassembly for colour stories

Waste stream B presented a different set of challenges for disassembly. In order to maintain uncontaminated colour stories and also to keep rejected articles to a minimum, items such as small patches, logos and colour banding all needed to be separated (refer to Figure 25). For example a typical possum merino knitted glove, which was predominantly blue, had an iconic, white logo knitted into its structure. As a patch of white of that size would inevitably affect the overall tone of the colourway, each of the logos needed to be removed. The process meant making a cut starting from the wristband of the glove, cutting around the logo to isolate it and then removing it (refer to Figure 26).

The blue glove minus the logo was added to the blue colourway bag and the logo piece, because it was both



*Figure 26:* Isolating a logo from a glove to retain as much uncontaminated colour as possible.

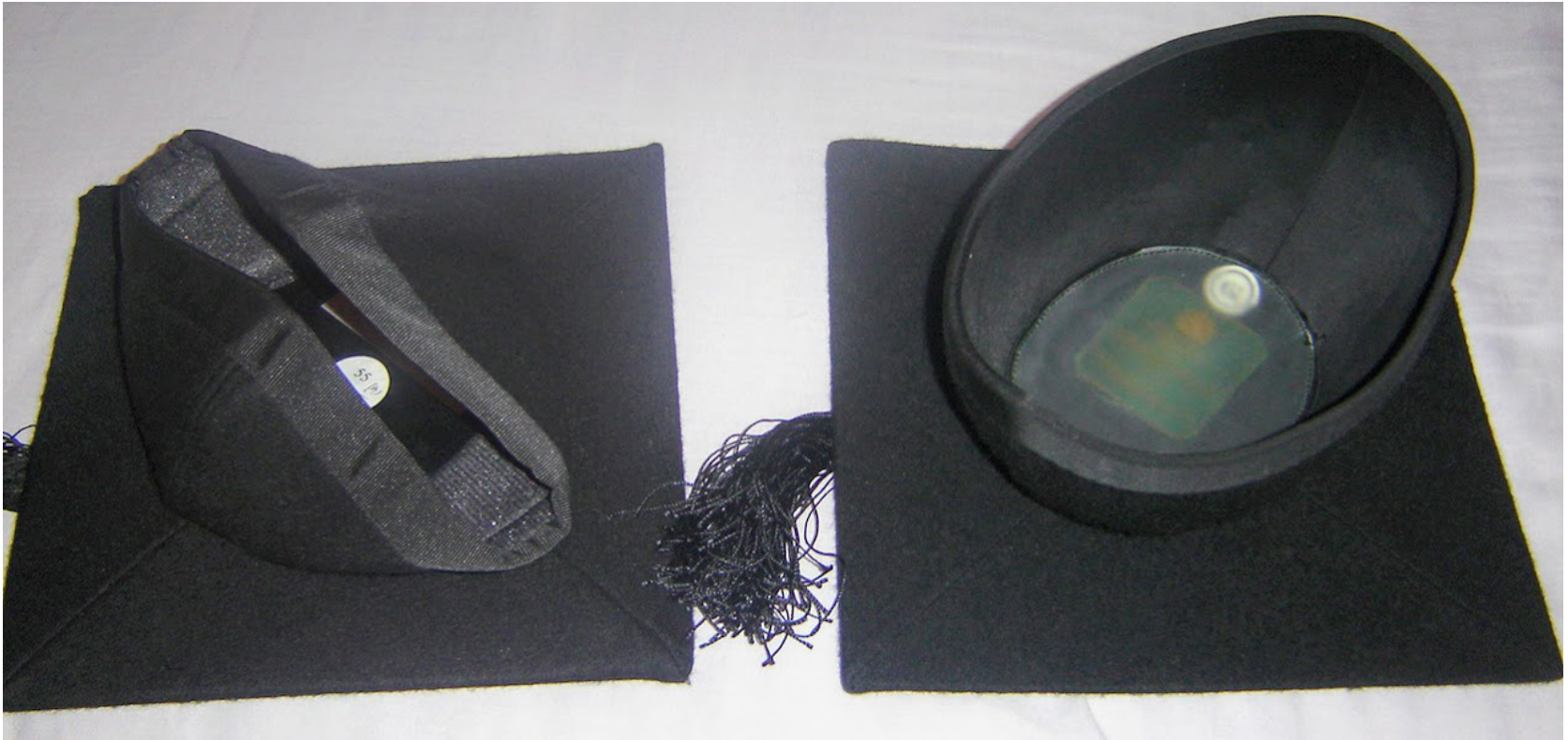
blue and white, and was placed into a multi-coloured bag. Similarly, multi-stripped gloves, scarves and socks had their block colours detached from the multi-stripped components. This practice utilised every usable part of the garment right down to the individual fingers of gloves.

#### 4.4.4 Logistics of disassembly

The academic trenchers presented a unique challenge in that they required partial disassembly even to be stored. The three-dimensional nature of the raw waste was physically cumbersome (refer to Figure 27). The large bags of trenchers took up too much room in the storage sheds. Before considering the disassembly process, it was necessary to remove the skull caps from the mortarboards (refer to Figure 28). To process the trenchers for storage presented a time challenge (approximately 40 hours). Therefore a decision had to be made as to which parts of

the trenchers could viably be recycled, as storing non-recyclable waste was not an option. When accessing the skull cap, it was evident there were two types: a rigid and a folded type. The rigid was much more difficult to remove. Both of the types of skull cap were deemed non-recyclable in this project, as they were a composite of dense short fibres, almost like a flocked surface. A decision was made at this point to discard all of the skull caps. Initially, the skull caps were removed, carefully ripping and pulling the cap off, saving as much of the black trencher fabric as possible. However, because some of the skull caps were riveted to the trenchers (refer to Figure 29), the researcher's technique evolved into a considered swift movement using a Stanley knife to cut the parts off the trencher.

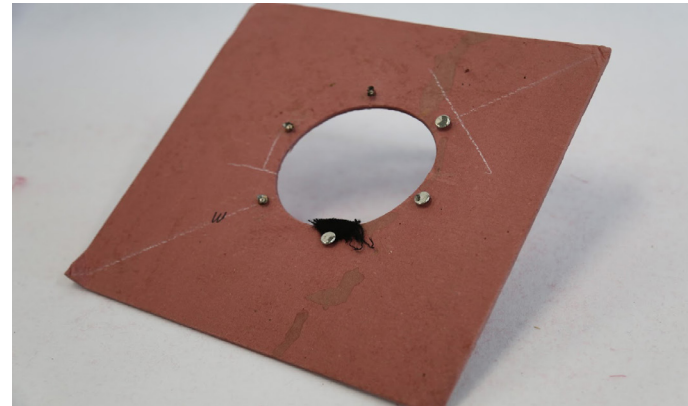
While this method cut away some of the usable fabric from the trenchers, it sped up the process considerably. This phase of pre-disassembly aided decision making in



*Figure 27: The three-dimensional nature of the trencher made them physically cumbersome to store.*



*Figure 28:* Storing the trenchers after the skull caps had been removed meant they could be stacked.



*Figure 29:* Some of the mortarboards had been riveted on and were much harder to remove.

the disassembly phase. It raised issues for the researcher around what type of tooling would be required; what type of workspace would be needed; how much time the disassembly would take; and the care that would need to be taken. After the second delivery of stock arrived, the workspace was adapted to form a specific disassembly line that took into account both the praxis and techne involved in practical deconstruction.

#### 4.4.5 Black trencher – knowledge through disassembly

When disassembling an academic black trencher, the initial approach was to apply the minimum amount of cuts required to take the components apart. This gave a production-type imperative to the work. The workflow proceeded from a careful dissection into seven definitive and repeatable steps (refer to Figure 30).

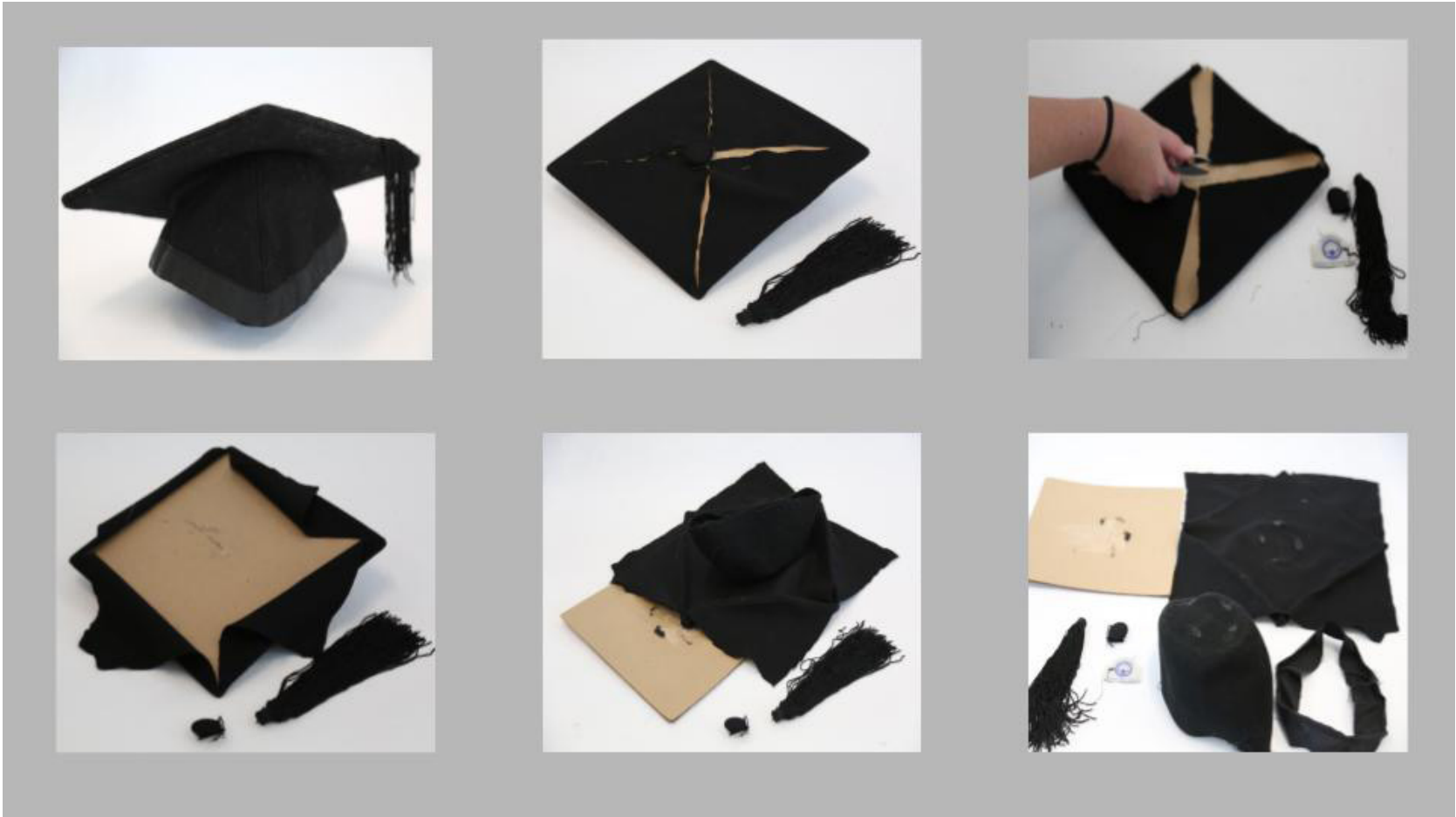


Figure 30: The stages of disassembling an academic black trencher.

1. Make a circular cut around the base of the skull cap  
detaching the mortarboard

2. Turn the trencher over and remove the button

3. Separate the tassel from the button.

4. Make four diagonal cuts away from the centre making  
sure you slice around the button.

5. Remove the cardboard inner

6. Remove the binding off the skull cap

7. Remove all the labels

Each of these steps was repeated 590 times (refer to figure  
31 and 32). This gave the researcher ample time to develop  
a technique, becoming very efficient with the disassembly.



*Figure 31: A pile of button componentry from the academic trencher.*



*Figure 32: A pile of black tassels from the academic trencher.*

The process changed from initially taking nearly five minutes, to only taking three minutes towards the end of the disassembly phase. This freshly acquired autodidactic skill set became second nature. Fry recognises the value of such skills gained through practice, stating “it is this condition that provides the ground for the ability to innovate, create, exploit and critically deploy the capability gained” (2014, p.19). This building block of new habitual practice allowed a deeper understanding of the world of the textile processing labourer, which is one of repetition and specialisation. This was a very new mode for the researcher and gave not only a new appreciation of the materials but also transformed the identity of the designer. This translation of agency was important to this project as it augmented the relationship the researcher had with the materials and their inherent qualities. This was a compound of iterative practice and handling the materials while manually manipulating them. Through processing the trenchers, the researcher began to be

able to sense small variations in each item without having to look closely. This cognitive shift happened in tandem with a shift from being regimented and goal-oriented to being in a creative-thinking mode, that was temporally emergent. This thinking was flexible and opened up the researcher’s mind to a discourse centred around the possibilities. Kane and Philpott describe this internal dialogue as being a usual state of mind that develops from both a sensitivity towards the materials and an elastic cognitive process which reveals itself as “a pliable style of thought that twists, turns, stretches and folds in on itself” (2013, p. 6). The purpose of extracting squares of fabric to obtain a maximum yield of recoverable fibres gave way to the possibilities of the componentry and an awareness that the materials held stories and had a presence of their own. The researcher’s thoughts moved from thinking about how dusty and dirty the materials were and what they were constructed of, to thinking about all the people who had worn the trenchers and the challenges they

would have overcome to be in a position to have worn the trencher. The wear of the trenchers was subtle and unique for each item, such as slightly worn on the front corner perhaps from constant readjusting on the head or the faint indentation left on the cap from the hairpins used to hold it in place (refer to Figure 33).

These traces humanised each trencher as each imprint revealed itself. This experience affected the researcher by introducing a new narrative. Carole Hunt, describes this mnemonic phenomena as “the capacity of textiles to retain and communicate memory, both privately and publicly” (Hunt, 2014 p.207). Hunt’s described phenomena materialised in this research project while the researcher was engaged in repetitive processes; in turn, this stimulated reflective practice. This determined the direction the researcher took when making decisions about the textile outcomes. It also created a new sense of knowledge and a

desire to value the fibres. The effect of this experience and reflection was to transform the researcher’s mindset from using the materials to being used by them. The materials, through the agency of disassembly, revealed themselves not only as having new material potential but also as a form of material memory bank. The researcher considered whether the fibres themselves could hold memories (Hunt, 2014). With the action of disassembling each trencher, new abstract and tangible stories unfolded. The researcher became conscious of the need to save the fibres from an impoverished destiny as waste, and instead celebrate their individuality and potential. These insights into previous use and wear were gained from unconsciously reading clues and impressions transferred onto the textile by its past users (Hunt, 2014). This experience reconnected the researcher with the vitality and value of the fibres and the need to re-future them (Fry, 2009). This ignited a new appreciation for not only the trenchers as objects that contained narrative,



*Figure 33:* Slightly worn front corner on the academic trencher perhaps from a constant readjusting on the head.

but also the energy involved in manufacturing them. The origins of the fibres were unclear, but there was no doubt that extensive energy had gone into the life of the fibres and this would be squandered when sent to landfill. At every stage of the fibres lifecycle, either by peoples input, or the resources extracted from the planet, or the financial cost involved in the manufacturing of that fabric, energy has contributed to its worth.





The disassembly, grading and cutting had a significant phenomenological outcome where touch and sense triggered cognitive resonance and a change in direction. The predetermined design outcomes the researcher had initially held shifted, as the physical handling of the materials evoked a deeper connection with the history of the fibres and the inherent knowledge they held. This interdependence of process and understanding became a key lens through which the designer could inform the re-animation of the recycled fibre.

#### 4.4.6 Documentation

During this phase, methods of documentation were developed to record the sequences of the practice, visual recordings and reflections. Generic tables were designed and printed and taken onsite to record relevant information from each waste stream. This was used to document applicable data, add fabric swatches, jot down notes and reflections. These tables (refer to Figure 34) were then reconciled with photographs and additional fibre investigations such as microscopic imagery, which was carried out by the researcher at the Auckland University of Technology engineering labs.

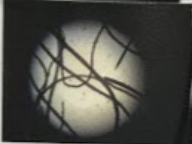
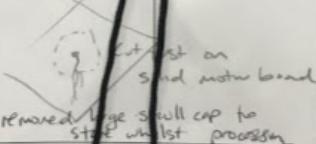
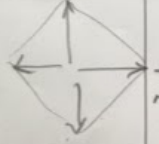
This documentation formed an intersection where the physical nature of the disassembly process and the emerging phenomenological narrative could be located. Newbury describes this type of approach as “a melting pot for all

video of hats de/reveal!

PROPERTY OF  
UNIVERSITY OF  
TECHNOLOGY  
ACADEMIC DRESS AUCKLAND

Waste stream A

Undergraduate hat	590
Swatch of material	
Material / fiber makeup	 <p>poly wool - very short fibre length</p>
Steps to disassembly	<ol style="list-style-type: none"> <li>1. Detach skull cap from motor board (same rigid same folder)</li> <li>2. Circular cut - blade around skull cap</li> <li>3. Remove button</li> <li>4. Remove cardboard inner</li> <li>5. Remove binding off skull cap</li> <li>6. Remove...</li> <li>7. Remove...</li> </ol>
Image/drawing	 <p>cut first on skull motor board. removed large skull cap to stop whilst processing</p>  <p>cut remain cardboard</p>
Time it took to disassemble	5 mins that → down to 3 min after a rhythm was established
Thoughts	<p>Yucky, smelly, dirty, energy output is big compared to the small square of fabric left for recycling.</p> <p>Blisters on fingers</p> <p>Need new blade every 20 hats</p> <p>feet attached to the bottom + angles -</p> <p>feetings have shocked from dirty fabrics + small robot to taking about all the people that have worn these -</p> <p>very dirty wear gloves + apron because of bleek Fibres</p>

Can't be fibres tell string of the post

Figure 34: Documentation recording the sequences of the practice, visual recordings and reflections. 112

of the different ingredients of a research project - prior experience, observations, readings, ideas - and a means of capturing the resulting interplay of elements” (2001, p.3). This method of evidencing practice was familiar to the researcher and was suitable for this project as it allowed a non-linear approach to recording reflexive and reflective thoughts about an evolving materials inventory. The classification of the textile waste streams required a repository of tangible data that directly connected to, and often informed, knowledge generated through practice. Schön defines practice as a “form of research, and the reflective journal a means of capturing and communicating knowledge” (cited in Newbury, 2001, p. 4). Over the course of this phase, it was vital to refer back to captured data and impressions as a base from which to carry out an ongoing coherent conversation with the work. This enabled the researcher to view, disassemble, analyse and evaluate the process in a continuum.

#### 4.5 Phase four: Fiber experimentation

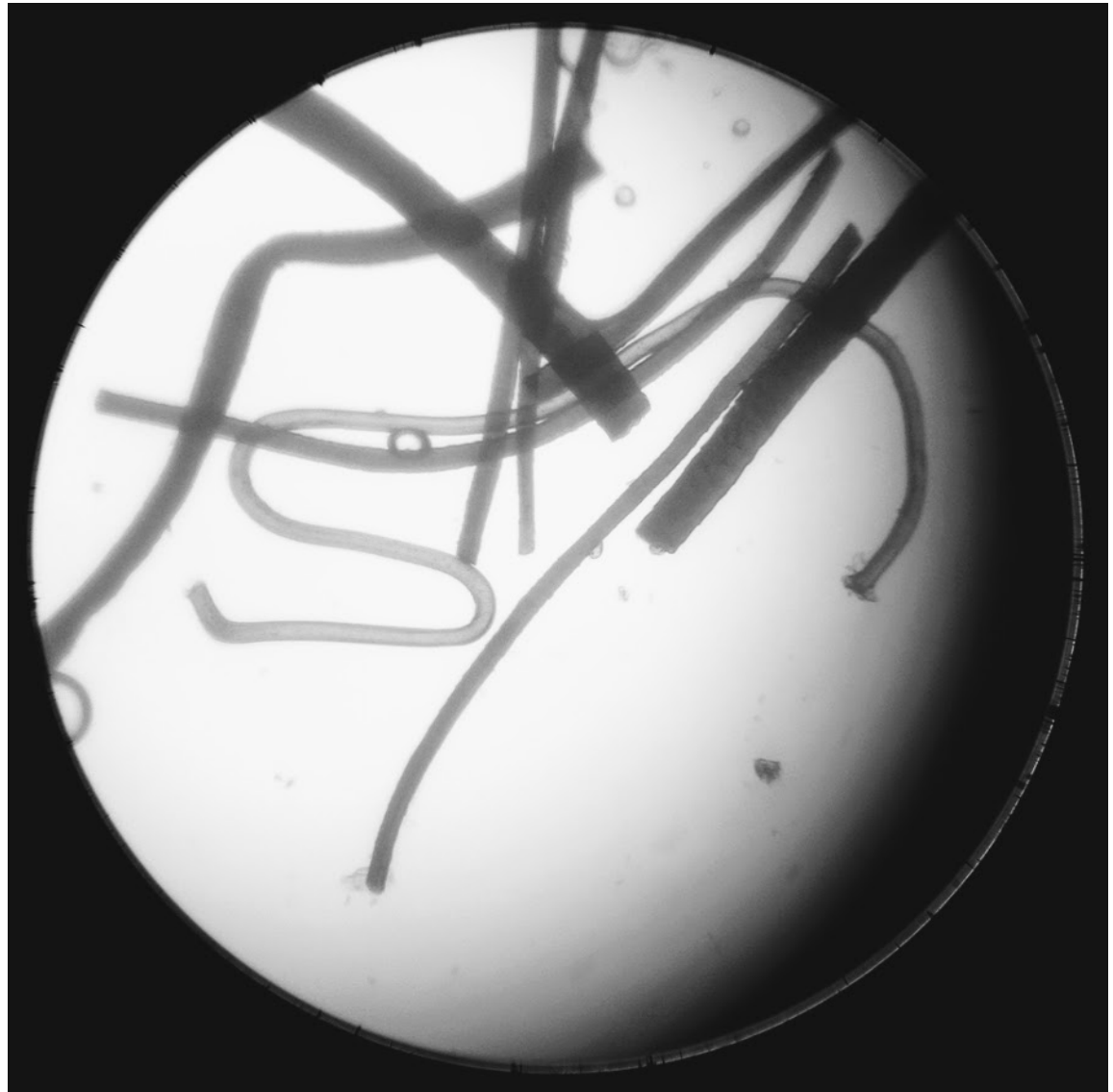
The fibre experimentation phase of the research was conducted throughout the project to solve technical and aesthetic problems that arose. The method of experimentation was used to test with small quantities of fibres before committing them to a commercial process. The phase worked as cycles of action research: moving through processes of planning, action, observing and reflecting (Schön, 1983). This cycle of action research acknowledges the researcher’s own tacit knowledge as fundamental to the inquiry. The observations from the experimental research were key drivers in the decision making processes, specifically surrounding fibre content, fibre capabilities, fibre blending, fibre technologies and ways to re value the fibres.

#### 4.5.1 Fiber complexities

An initial cycle of fibre experimentation was conducted when the textiles from waste stream A arrived, to investigate the material properties and behaviours through a simulated process before sending the entire stream of waste for shredding. Previous research had highlighted the need for the textile waste to have some content of wool to be able to be reanimated back into fabric through the process of shredding, carding and felting (Cleveland, 2013). However, the percentage of wool content needed for this process to be successful so that the new felt would hold together, was an unknown variable. The first step was to inspect the fibres in isolated detail, using a microscope to ascertain their constitution. A small fabric sample was taken off the black trencher and the black gown, and a razor blade was used to separate off singular fibres from a strand of thread. The small particles were suspended in a drop of

water and were placed onto a glass slide to gain a precise longitudinal view under the microscope. The magnified images were then recorded using a camera to photograph the view from the lens of the microscope. In this case, it was determined that the fibres were both wool and a man-made synthetic fibre, most likely polyester. This was evident as under the microscope, the wool fibre was irregular, had a rough barbed surface, that was almost scale-like which are typically seen on wool fibres, and the polyester fibre was structureless, had a uniform diameter and a smooth surface (refer to Figure 35).

The gowns consisted of predominantly polyester, and the trenchers were a wool and polyester blend. The fibres in the trenchers while they were wool, were extremely short and appeared more like dust than fibre. The finding of a short fibre length, along with the knowledge that fibre length is a critical component of the felting process, instigated a cycle



*Figure 35:* Fibres investigated under the microscope.

of fibre experimentation focused on percentages of wool content and fibre lengths. A hypothesis was formulated to support the aim of creating valuable textiles from textile waste. The hypothesis was proposed that the small percentage of short wool fibres present in the trenchers would be effectual in carrying the larger amount of polyester fibres from the gowns through the shredding and carding process and be beneficial in binding them together in the felting process.

Initially, mini-experiments were used to simulate the processes of the commercial machinery before committing the entire collected waste stream to the process. A handful of the fibres, proportional to the weights calculated in the quantitative charts, were hand shredded, carded on a rotary hand carder into a small batt and then felted through the FeltLOOM® machine.

A carding machine uses a mechanical process to card mostly natural fibres, such as wool and alpaca. It cleans and aligns fibres in parallel formation. The many cylindrical rollers work at different speeds and in different directions to open the fibres and align them as they pass over (refer to Figure 36). At the end of the carder, the fibres can be drawn off into a sliver (a narrow bundle of fibres), or into a batt (a blanket of aligned fibres) that are drawn off over a drum (refer to Figures 37 and 38).

Observation of the fibres showed that the wool appeared to hold the fabric together. However, an additional discovery was that the FeltLOOM® machine was able to needle felt polyester fibres together without wool content. This was established by repeating the process with different amounts of wool and polyester. Upon reflection, the wool fibres had held together into a new felted fabric, but the short length of the fibres could still be problematic in processing as they



*Figure 36:* The Haign Carding machine has many cylindrical rollers that work at different speeds and in different directions to open the fibres and align them as they pass over.



*Figure 37:* Fibres being drawn off the Haign Carder in a sliver.



*Figure 38:* The fibres being drawn off into a batt on the back of the Stone Hedge Carder.

were so short they often fell out of the fabric. The look of the solid black colour was successful in that it did not have the flecked tones that recycled fibres often have. Although it was a solid colour, it did possess considerable texture. This was because of the different fibres and their individual qualities, such as different yarn structure, crimp and sheen (refer to Figure 39). One structural concern was that the fabric, made from polyester and wool, was quite thin and weak in areas. It was decided a strategy to counter this would be to increase the thickness of the batts, either by increasing the weight of fibres collected off the back of the Haign carder onto the drum or by felting several batts together in the FeltLOOM® machine.

The black fibres, from waste stream A, had several iterations of experimentation throughout the processing phase. This was due to unexpected production issues or specific machine setting problems. For example, while being processed, the black textile waste fell through the Haign carding machine



*Figure 39:* Handmade black fibre felted batt showing the individual qualities, such as different yarn structure, crimp and sheen.

and onto the floor. This was an unexpected outcome as the previous experiments had indicated the fibres would travel through the carding process successfully forming a batt. However, the industrial Haign carding machine had a different feed intake rate and roller configuration from the rotary hand carder which meant the fibres behaved differently. The consequence of this was problematic. If the fibres could not pass through the carding process they could not be made into any new materials. As a result, a new phase of fibre experimentation was conducted, and a new method of processing was formulated. This was informed by the researcher's tacit knowledge of fibres and the machine operator's expertise in the carding process.

The Haign machine operator suggested that the short fibre length was inhibiting the fibre's ability to proceed through the rollers in the machine. There was no machine setting that could counter this. Although waste stream A contained

both wool and polyester fibres, the wool fibres were very short. The researcher then considered the fibres the machine usually processed and found that although they were all normally natural fibres, which meant they had a significantly longer staple length. A new question was formulated: how would adding a percentage of longer staple length, virgin fibres, affect carrying the short recycled wool fibres (from the trenchers) and the recycled polyester fibres (from the gowns) through the carding process?

It was imperative that the new experiment that addressed the above question supported the aim of creating valuable textiles from the waste. Working towards this aim, two elements were considered in the choice of virgin fibres to blend with the existing recycled fibres: colour and fibre length. Several virgin wool fibres were explored including merino, polworth, romney and gotland. After conducting some mini-blending experiments, gotland fibres and

romney fibres were selected, as they offered a natural black fibre and a long naturally crimped fibre length. Shades of black, grey, light grey and brown virgin wool fibres were sourced with the aim of keeping the overall colour, tonal shades of black. Different percentages were combined with the recycled textile waste, 80/20, 60/40 and 50/50, hand carded and felted into samples (refer to Figure 40). The results indicated that a 50/50 blend of fibres would be the best to process through the Haign carder. The new blends were introduced to the Haign carding machine, and the results were favourable. The polyester and short wool fibres from textile waste stream A were carried through the carder by the added virgin wool fibres. The outcome was a series of tonal batts that could be processed into felt. The batts were charted and reflected upon in relation to several design criteria, including weight, size, quantity available, colour, feel and structure (refer to Figure 41).



*Figure 40:* Different percentages of the recycled textile waste were combined with virgin wool and hand carded and felted into samples.

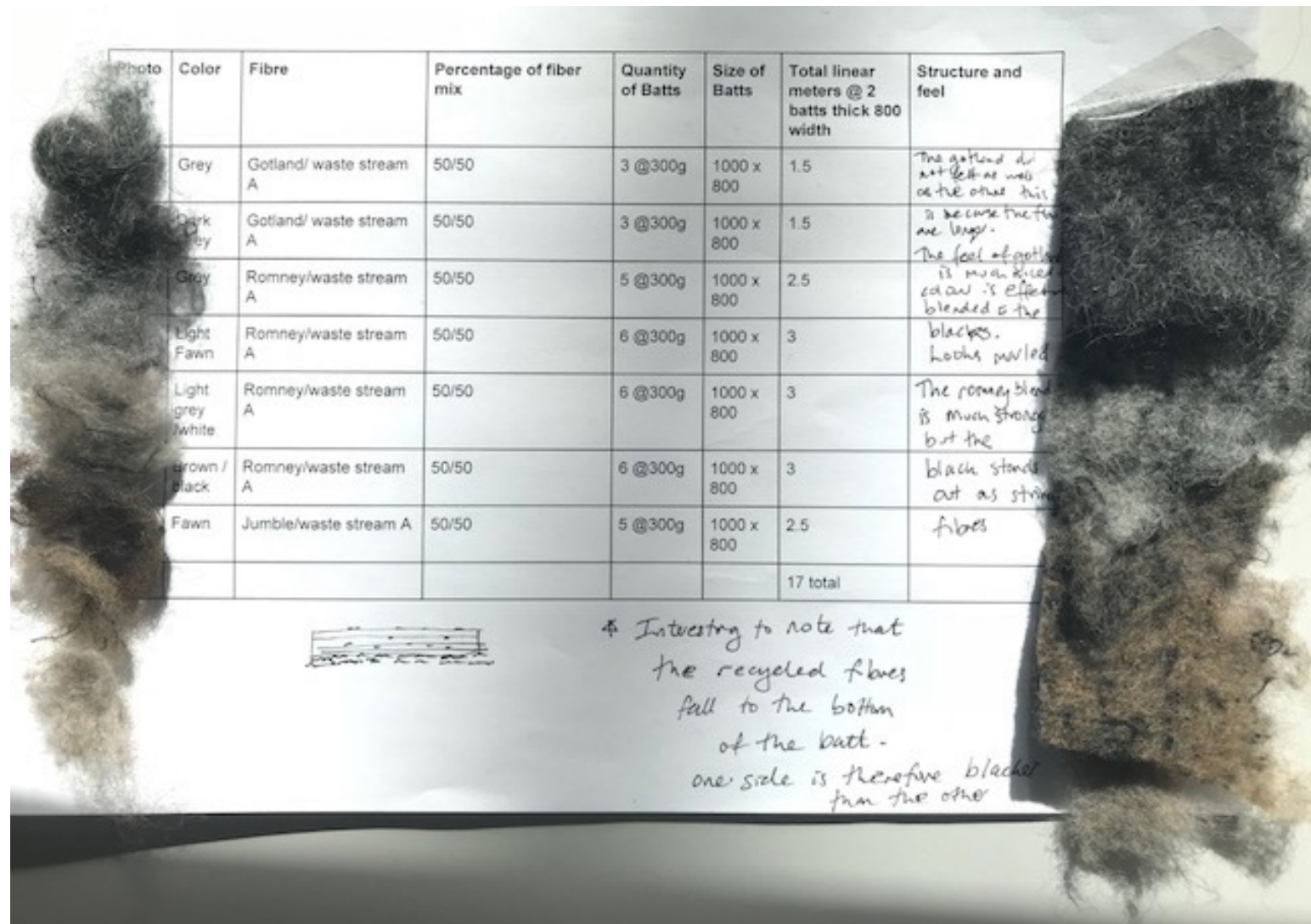


Figure 41: The new mixed batts were charted with several design criteria, including weight, size, quantity available, colour, feel and structure.

#### 4.5.2 Colour palette

Further fibre experimentation was centred around colour. To work towards one of the research aims of re-valuing textile waste, the aesthetic characteristics of colour became an area of experimentation. A goal of the project was to use the properties inherent to the already dyed fibres, rather than over-dyeing the recycled materials. As previously discussed in the thesis, section four phase two, mapping the typologies of textile waste (4.3.1), a focus of sorting waste stream B was configuring the waste into colourways. This was due to a finite quantity of material to run the shredding and opening machinery. To establish the colourways, fibre experiments were conducted to determine which colours combined to produce aesthetically pleasing hues. Through experimenting with a type of manual cut and paste, a colour library was established that could assess colour possibilities before committing the textile waste to the shredding process (Appendix B). The textile

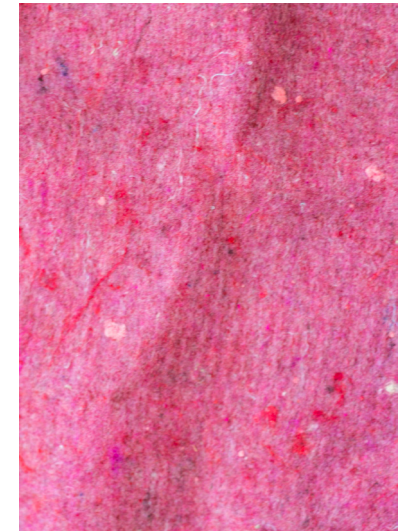
waste swatches were matched according to an analogous palette, whereby colours that stand next to each other on the colour wheel, were grouped together. When combined, colours grouped in this way support each other because they come from a similar place on the colour wheel; their transitions are gentle, and the overall effect they give is one of harmony and balance (Colour Wheel Artist, 2017). For the purposes of this research, the developed colourways for waste stream B were standardised into eight colour mixes: red, pink/purple, green, blue, black, brown, grey and white (refer to Figure 42). These choices were based on the colour options available as sourced from the waste stream provider. The colours from textile waste stream B, while they varied in each fadge due to production cycles, were determinate overall, as the company manufactures knitwear with the same base yarn colours. Once the colour library was established, incoming textile waste was directed into the appropriate standardised colourway as determined by the pre-waste colour options discussed above.



*Figure 42:* The developed colourways for waste stream B were standardised into eight colour mixes: reds, pinks/purples, greens, blues, blacks, browns, greys and whites.

The findings from the experimental colour classifying of textile waste stream B and the findings from previous research (Cleveland, 2013) informed the colour coding for textile waste stream C, the textile waste collected from the studio environment of emerging design students. The 2013, preceding research had resulted in two fairly solid colours (pink and blue). These were the two colourways with enough volume to process at the time. An unexpected aesthetic outcome was the random brightly coloured fibres that were present in both colours (refer to Figure 43). They were as a result of colour contamination due to limitations with separating colours such as prints. These were a complementary result, unlike the brown sludge-coloured with flecks often present in an expected recycle aesthetic (refer to Figure 44).

The waste recovered as part of this project was wide-ranging in its composition, structure and colour. The textiles



*Figure 43:* Random brightly coloured fibres that were present in the pink fabric.



*Figure 44:* Brown sludge-coloured felt with flecks often seen in a recycled aesthetic.

were pre-consumer in that they were being used in garment manufacture, but post-industrial as they were already manufactured fabrics. This produced new challenges, as the fabric patterns added potential colours and colour combinations that were interminable (refer to Figure 45). Initially, the textiles were sorted into colour hues: black, grey, blue, green, brown, pink, red, cream, and white. The colours were not as defined as those of waste stream B, mostly because of the inclusion of printed fabric, which could not be separated into main colours. Based on the earlier findings, further controlled colour experiments were performed. Bright, unexpected colours were purposefully introduced to the main colourways. For example, copper fabrics were added to the blue colourway. Similarly, bright pink was added to the red and white colourway, and silver was added to the grey (refer to Figures 46). The outcome of these experiments was a series of unique colourways to be processed.



*Figure 45: Textiles collected from waste stream C show interminable fabric patterns, colours and colour combinations.*



*Figure 46:* Copper fabrics were added to the blue colourway and bright pink was added to the red colourway.

#### 4.6 Phase five: Processing the textile waste

The aim of this phase of the research was to process the textile waste generated as part of this project. This was facilitated through active communication with potential vendors to gain insights into their processes and machinery, including material shredders, textile carding mills and commercial spinners. Initially, different facilities, geographically spread across Auckland, were visited and connections with owners, operators and line management established. Ensuing discussions determined: different machinery's capabilities and limitations; potential costs; timeframes; and availability. It also presented opportunities to explain the project and its aims, that helped gain support for the types of non-standard requests that were inevitable with this research. This was important as often the machinery selected was not always used for this purpose, such as the textile shredder that usually shreds recycled wool carpet. In

addition, as the project developed, some machinery outside of the Auckland region was tested to ascertain if different machinery would deliver different results, such as a carder in Dannevirke and a plucker and carder in Kentucky, USA (Appendix A, Appendix C).

#### 4.6.1 Developing a textile recycling platform

The current international model of industrialised textile recycling, where all of the waste is processed in a pipeline as a homogenised mass is a cycle which does not consider the value of the fibres. The intention of this project was to build a localised platform that valued all of the fibres on their individual potential value. During the development, it was necessary to assess the fibres at each stage of the processing. The textile waste would need to move through multiple processes to reanimate them into new materials, such as shredding, opening, carding and spinning. It was

important that this was achieved by acknowledging the original identity of the fibres and their potential value. The vendors with the machinery to process the fibres were approached, and the research project was discussed with them in relation to their particular machinery's capabilities and limitations. A program was developed where the textile waste moved through these processes on a case by case basis. Each time the textile waste came back to the researcher, the fibres were reassessed. The materials were subjected to a series of shredding or opening processes, resorting, carding, blending and spinning in order to recycle them. This was an orchestrated process where different waste streams were at different points in the emerging system at different times. Thus timing was a key part of successfully managing the different vendors each with their own timescales and at different locations.

#### 4.6.2 Overcoming perceived barriers in the processing of textile waste

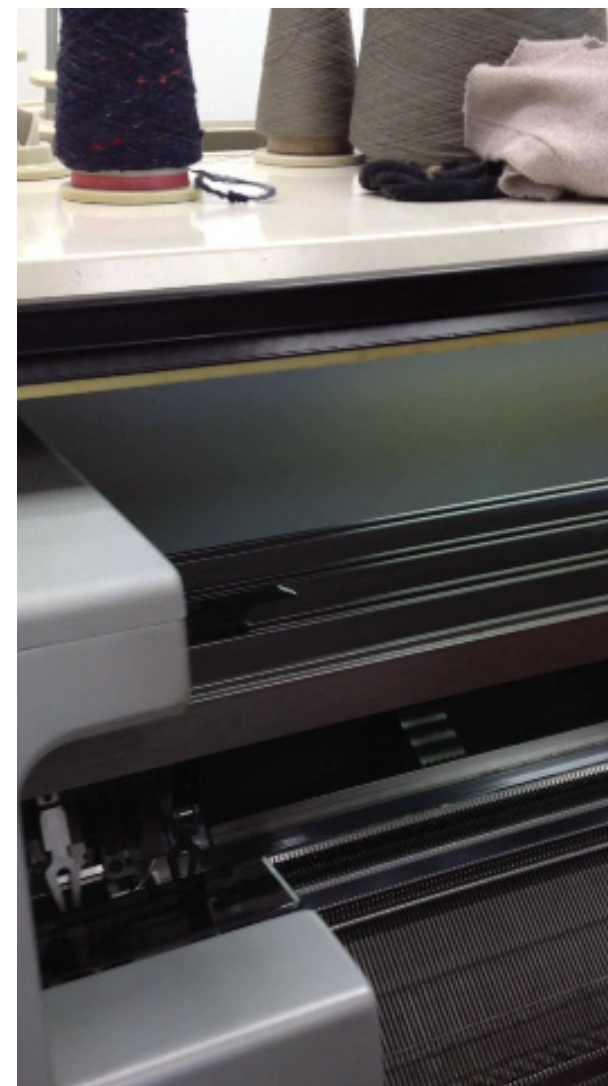
Engaging commercial entities with the view of processing the textile waste was often difficult. The vendors who had the machinery to shred, card or spin the recycled fibres had their own ideals around the scale, quality and value of processing recycled textile waste. These were based on their depth of technical experience, their specific machine knowledge and their preconceived ideas on the advantages of recycling textile fibres, specifically using a mechanical process. For example, the companies that were approached with regard to spinning the fibres considered the fibres would be too short to spin as they had been mechanically shredded and opened. Previous experience and technical knowledge had led to a negative opinion surrounding the commercial value of re-claiming the short recycled fibres. This precept was based on technical considerations about the

strength of any yarn produced from mechanically recycled fibres (Langley, Kim, & Lewis, 2000). A limitation revealed during this research was the commercial spinners' ingrained ideas around the outcome of spinning the fibres. This stage of the processing was the most problematic because of these issues. In order to gain a deeper understanding of the spinning process and how the fibres would behave, the researcher turned to the process of traditional crafted hand spinning. The researcher developed yarn samples by hand to a fine gauge with the intent of being able to knit them on an industrial manufacturing Shima Seiki knitting machine (refer to Figure 47, 48 and 49) (Appendix A).

Using the samples, and previously formulated qualitative data about the fibre length, a commercial spinner agreed to spin the fibres on their Bigagli B7 machine (Appendix A) for research purposes only, on the understanding that the quality of yarn would not be a representation of their



*Figure 47:* Fine gauge hand spun yarn from waste stream C.



*Figure 48:* Fine gauge hand spun yarn samples knitted on the Shima Seiki knitting machine.

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*Figure 49:* Knitted sample from hand spun yarn and Shima Seiki knitting machine.

spinning technique, but rather the quality of the original fibres. This perspective reinforced the notion that recycled yarns are inferior. This perception hinders the use and growth of using recycled fibres (Langley, Kim, & Lewis, 2000). The company offered to process a small run with a minimum amount of 20 kilograms of fibre for this research project. This was a pivotal point in the research, as it provided a scalable solution to spinning the fibres rather than only being able to hand spin them. As there was a finite amount of fibres to work with during this project, it was critical to consider the fibres all the way through the processing and into the design phase. Therefore, it was determined that trialling the longest fibre length available to this study, which was the merino/possum blend of fibres from waste stream B, would be the best use of resource. In addition, the reality of commercially spinning only a specified quantity of the recycled fibres informed the decisions around which colour to spin. The colour choice and the grade of yarn to

spin was not only based on these technical parameters but also involved forecasting possible textile design outcomes. For example, it was necessary to consider which colourways would sit next to each other in an aesthetically pleasing combination and which grade of yarn would be knittable in the Shima Seiki and inlay knit machines at AUT (Appendix A). It was determined that black and grey would offer a wide-ranging design potential, where each colour could sit alone, sit together or potentially be twisted together to fabricate a plied yarn. Two colourways of sliver were spun, exactly 11.2 kilograms of the black mix and 8.8 kilograms of the grey mix. After spinning the grey, it weighed 6.5 kilograms and the black weighed 9.1 kilograms. The yarn was spun at the finest grade thought possible 1/150 tex (density of fibre in grams per 1000 meters of length). A twisted yarn was also fabricated using one end of black with one end of grey 2/150 tex (refer to Figure 50).

Black/grey 2/150 tex	Grey 1/150 tex	Black 1/150 tex
4 kilograms	4.5 kilograms	7.1 kilograms

This inquiry successfully developed an output which highlighted the possibility for recycled yarn to be robust enough to knit on the Shima Seiki knit machine. This moved the handspun yarn out of a craft context into possible digital fabrications. This process provided an opportunity to engage in the design of the knitted textiles to overcome any technical restrictions. The rationale was that if the yarn was weaker due to a short fibre length, this could be overcome in the design of the knit structure in the textile design phase.

#### 4.6.3 Core spun yarn

Through the hand spinning process, it was discovered that the short length of the recycled fibres made them



*Figure 50:* Samples of commercially spun yarn from waste stream B.

difficult to hand spin. When drawing the fibres from the sliver, the short fibre length determined a short draw. The fibres could only be drafted 2 centimeters at a time with very little tension applied. Through an evaluation of these handspinning trials, the technique of core spinning the fibres was explored as another possible way to overcome a shorter, weaker fibre length. Core spun yarn is a process where the fibres are wrapped around a strong core yarn, typically cotton or nylon. The core yarn gives the spun fibres strength. To test the viability of the process, samples were again developed by hand, as they had in the previous yarn developments (refer to Figure 51). Various densities of spun fibres wrapped on different core yarns were explored. Drawing the fibres from the sliver and wrapping them over a core was more successful than spinning without a core as the sliver did not have to be drawn as such. This technique produced a range of handmade core spun yarns (refer to Figure 52).



*Figure 51: To test the viability of the core spinning process samples were first developed by hand.*



*Figure 52: A range of handmade core spun yarns.*

It was deemed a viable solution to take into a commercial spinning environment. The red colourway from waste stream B was selected as there was a substantial amount of this available and the core spinning technique required more fibres than other processes. The Belfast Mini Mill, Rug Yarn Maker (Appendix A) draws the fibres straight from the carding machine and introduces the core at a 90 degree angle to the fibres as they exit the carding machine (refer to Figure 53).



*Figure 53:* Fibres being drawn straight from the carding machine and wrapped around a core as they exit the carding machine.

To play video open interactive PDF

As the the core yarn passes, the recycled fibres coming off the Stone Hedge Carder (Appendix A) form a sheath of fibres around the core. The cone of yarn that is created is termed a bump. In total 4.5 kilograms of recycled red merino/possum blend, from waste stream B, were core spun into four bumps (refer to Figure 54). Each bump was approximately 40 linear meters, giving a total of 160 linear meters. The outcome was a strong chunky yarn that extended potential textile design possibilities.



*Figure 54:* A bump of red recycled fibres from waste stream B.

#### 4.6.4 Fibre recycling narrative

To facilitate the logistics of the recycled fibre processing system the researcher needed to communicate with the vendors, often face to face. It was imperative that the incorporeal value and future possibilities of the fibres were given a positive narrative. Portraying the journey of the fibres and acknowledging their inherent value became a prerogative of the research in communicating with the vendors about processing the fibres. Positive language was used to communicate with each of the vendors about their machinery and the nature of the textiles involved in this project. New terminology evolved to enable the researcher and the vendors to communicate about how the fibres behaved through their machinery. Not only had some of the vendors not put recycled textiles through their machinery before but they had often never put that type of fibre even in a virgin state through their machine before. One of the mills

who carded the fibres for this research had previously only put virgin wool and alpaca through their machine. Carding shorter recycled textiles was a first, as was attempting to card possum or polyester blends, virgin or recycled. When a complication did arise, as was the case when the black polyester waste from stream A, fell through the Haign carder (4.5.1), it was important to use positive language about the textile waste to change ingrained perceptions around the value of fibres. Using terminology that referred to the origin of the fibres such as ‘academic fibres’, when discussing the textiles rather than demoting them using terms like ‘black shoddy’ encouraged a shift in revaluing the fibres. In addition, the focus moved from merely the technical to advocating ways to recycle the fibres and save them from their predestined pathway to landfill. This approach allowed the researcher and expert to engage in an exchange of knowledge around the future possibilities of the fibres rather than dismissing the fibres as technically

unsatisfactory. This knowledge informed a new cycle of fibre experimentation which explored blending the fibres and re-carding them (4.5.1). By giving the fibres a hero status, the vendors underwent a transformation in attitude and willingness to work with this project to re-future (Fry, 2014) the recycled materials. At this point for the textiles to be considered valuable, the model relied on convincing the textile waste suppliers, the textile recyclers and the other textile processors that the remanufacturing process is worthwhile. In this way the focus shifted to a business-to-business model.

#### 4.6.5 Re-thinking the textile waste

It was imperative to gain buy-in from the vendors as processing textile waste of this type was new to them. Empathy combined with data and samples were key factors in persuading vendors to convert their lines to process

the fibres. For some, the shift from high production into a pattern of sampling for research practice meant extending machinery and service to meet the needs of this research project. The vendors expert opinions about particular plant and its operation, was essential knowledge that the researcher used to re-configure practice while minimising the impact on commercial operations. For example, the vendor with the textile shredder and opener had to stop the whole production line, clean the shredding and opening machine, reset the outflow of the machines and significantly change the way in which the textile waste was introduced at the inflow of the machines. The commercial reality of repeating this process would need to be addressed in future research and is discussed in Chapter 5.

A target weight of 500 kilograms per operation was the initial expectation of the vendor to shred the textile waste for this project. During the collection and mapping phase,

it became apparent through quantitative deduction that the quantities of available colourways for waste stream B and C would not meet this criteria without combining the colours. Combining the colours en masse is standard industrial practice when recycling fibres and results in an undesirable mixed colour (Fletcher, 2014). By viewing the recycling system as a whole, which included considering the aesthetic value of the fibres and not locking into a fascination with only the technical aspects of the shredding machinery, a strategy was devised based on the absolute minimum amount of textile required by the machine to operate. The absolute minimum amount of textile waste that the machinery could physically run with was 200 kilograms. This reconfiguration of the textiles in the system relied on inductive thinking. In this case, the premise that the machine could operate with a substantially less amount of textile was based on threading together advice from the vendor and researching the capabilities of the machine. Working within this new parameter, the researcher consulted the quantitative data

collected in phase one, to rethink how to meet this goal. The colourways were examined so that the target weight of 200 kilograms could be achieved. An approach was devised whereby the colourways were ordered into an entire colour story. This enabled the colours to transition in a logical sequence where any incidental colour mixing in the shredder and opener would be harmonious. The colourways



*Figure 55:* The colourways were packaged and labelled so that the textile waste was introduced into the shredder and opener as a procession.

were packaged and labelled so that the machine operator could clearly identify the order in which the textile waste was introduced into the shredder and opener as a procession (refer to Figure 55).

This was successful in that the opened textile waste exited the machine in the same procession it entered, with minor merging between the colourways, demonstrating the value of rethinking how the textile waste could be rearranged to be able to be processed while maintaining the aesthetic value of the fibres. This action of rethinking the system is comparable to the approach suggested by Banerjee (2008), whereby a designer operates in a ‘meta-disciplinary’ mode to solve complex problems (previously discussed in 3.3). In this case, the identification of a leverage point in both the vendor’s machinery and the researcher’s practice was a result of rethinking the operational parameters and desirable outcomes for the textile waste. This abductive approach

(previously discussed in 3.3.7) followed a ‘logic of the possible’ (Banerjee, 2008) to reveal new ways of addressing this problem of the requisite scale of waste required in relation to the need to maintain fibre value through distinct colourways.

#### 4.7 Phase six: Textile design

The aim of this last phase of the research practice was to design new textile samples from the fibre batts and spun yarn generated in the previous processing phase of the project (Appendix C). Both traditional and new textile technologies were explored as methods for re-animating and re-futuring the materials namely: machine knitting, inlay machine knitting, hand knitting, weaving and needle felting. In addition, other craft and design technologies, such as screen printing, digital printing, embroidery and smocking were explored. It was paramount that this design

process aimed to assess the materials on their individual potential and explore ways to retain or even improve their value. To realise this aim, the researcher used a hybrid practice that balanced the previously gathered qualitative and quantitative data of the fibres, with an understanding of textile technologies and an aesthetic awareness, to inform the design of the new textiles.

#### 4.7.1 New approaches to balancing quantifiable data with textile integrity

Tables were developed that recorded both the qualitative aspect, informed by the fibre's intrinsic qualities (aesthetics, touch, handle and colour) and the quantitative aspect, the amount of spun yarn and carded batts that the processing phase had produced. The quantitative amounts shifted from recorded volumes into linear meterage of batts, bumps and cones of yarn. For example, in the processing phase 200

kilograms of black textiles from waste stream A had been shredded; however, all 200 kilograms had not been carded as the materials had fallen through the Haign Carder. As a result of previous experimental practice, 5 kilograms of shredded textiles from stream A had been blended with an equal weight of virgin romney and gotland wool fibres and processed again on the Haign Carder (previously explained in 4.5.1). This resulted in 34 new mixed fibre batts that measured 1000 centimeters long x 800 centimeters wide. Samples of the new batts were needle felted on the FeltLOOM®, and the results were charted. The new charts were used to inform textile design decisions, such as which textile should be committed to what design process. In addition, some textile waste streams had been processed into yarn, and fibre batts, such as with waste stream B. This meant a re-calibration of the textiles was necessary to establish what processed fibres were available to be used for designing (refer to Figure 56). Therefore, the design of

the textiles needed to balance the quantitative data on the waste stream outputs with the qualitative nature of the yarn and fibres, to consider their best individual outcome. It was critical to re-calculate the amount of textiles available now as batts and yarn, to re-think their potential as newly designed textiles. This process determined what could be designed that best demonstrated a proof of concept for the innovative materials' recycling initiative.

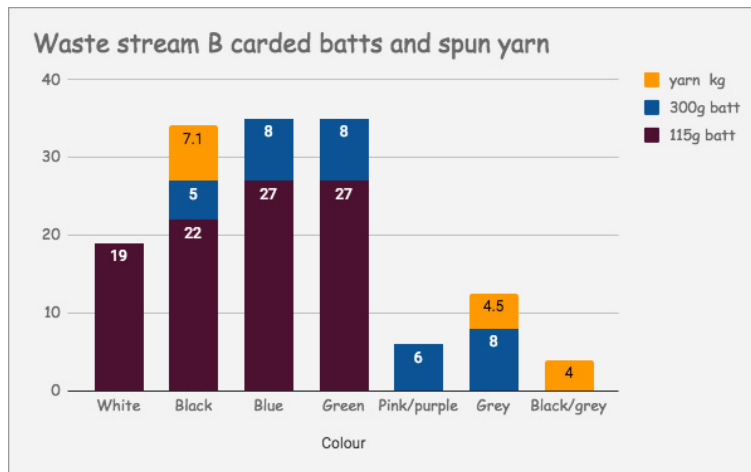


Figure 56: The new amounts of yarn and batts charted.

Managing this part of the project presented many difficulties, as it entailed projecting outcomes based on multiple factors: weights, quantity, look, trends, colour, fibre strength and the behaviour of the textiles in different textile technology applications. Making decisions to commit certain fibre content or colourways of yarn or batts to different designed textiles was complex and relied on previous textile technologies' knowledge, learned knowledge about the behaviour of these fibres and new knowledge gained from small-scale sampling. In this way, a re-evaluation of the hierarchy of materials (previously discussed in 3.3.2) was flexible and adapted to suit the emerging scenarios.

As the amounts of textiles available in this project were limited it was necessary to balance the quantitative data, the aesthetics and the textile integrity. The sampling undertaken was very specific, so that the valuable textiles were not used unnecessarily in pointless sampling, although the sampling



*Figure 57:* Swatches knitted on the Shima Seiki using the grey and black 1/150 tex yarn.

did need to be rigorous enough in order to establish the most favourable results.

#### 4.7.2 Yarn development

Several commercial-sized machine knitting technologies were considered to explore the potential for the commercially spun recycled fibres to be re-animated into knitted textiles. Initial experiments were trialled to determine if the recycled yarns were strong enough to knit in the Shima Seiki SES-SWG Whole Garment machine at AUT's Textile Design Lab. Simple single bed knit swatches were knitted using the grey and black 1/150 tex yarn, developed from waste stream B, to determine if it was a viable solution, through analysing the look, feel and handle of the yarn once knitted. The results were favourable, as the yarn did not break under the tension of the machine and the swatches had a convincing feel, look and handle (refer to Figure 57). The



*Figure 58:* Swatch knitted on the Shima Seiki using a lace pattern.



*Figure 59:* Swatch knitted on the Shima Seiki using a cable pattern.

yarns were also sampled using different knitting techniques, namely, a lace pattern and a cable pattern to determine how the yarn behaved in the Shima Seiki machine (refer to figure 58 and 59). This established how much of an influence the knit pattern could have on the weight and handle of the knit. In addition, it demonstrated the strength and stability of the knitted yarn.

Secondly, to further create textile stability, the Shima Seiki SRY 123 LP inlay machine, also based at the Textile Design Lab at AUT, was used to explore the potential of the double-stranded 2/150 tex black and grey yarn. The machine offered the capability of knitting the finer black 1/150 tex yarn into a textile with a component of the coarser yarn (2/150 tex black and grey), inlaid to create stability (refer to Figure 60). The inlay knitted sample was strong and suppressed the typical stretch characteristics of knitted fabrics. The inlay machine also offered the advantage of



*Figure 60: Swatch knitted on the Shima Seiki SRY 123 LP inlay machine, using the black 1/150 tex yarn the coarser 2/150 tex black and grey yarn.*

developing a textile that behaved like a knit yet looked like a woven.

By determining that the new yarns were capable of being knitted in both the Shima Seiki SRY 123 LP inlay machine and the Shima Seiki SES-SWG Whole Garment machine, this research highlighted future opportunities for designing with recycled fibre yarns. These commercial grade machines offer a vast potential for exploring ways to create increased stability and integrity, through stitch structure. In addition, the Shima Seiki Whole Garment machine can knit complete seamless garments, so that the new yarn would not be contributing to future manufacturing waste.

To further explore the potential of the different yarns, the core spun yarn (from waste stream B) was sampled using hand-knitting techniques. Samples were developed that considered both the integrity of the recycled yarns and their



*Figure 61:* The red core spun yarn was handknitted using a very large 35-millimetre diameter circular needle.

aesthetic. For example, the red core spun merino/ possum yarn was knitted using a very large 35-millimetre diameter circular needle that was specifically manufactured for the purpose. Although the fibres of the yarn were very short and soft the core gave the yarn strength. This meant the yarn could be knitted without breaking. However, the texture and feel of the knit remained soft and pliable (refer to Figure 61).

#### 4.7.3 The development of fibre batts into felt cloth

The textile technology of needle felting was explored as a viable option to reanimate the fibres back into a cloth. The fibres that were carded into batts were locked back together into felted cloth using needle felted machinery, namely, the FeltLOOM® based at the Textile Design Lab at AUT. The FeltLOOM® was designed to felt fibre to fibre and fibre to fabric, specifically of a natural origin such as wool and

alpaca. Although the machine had not previously been used to felt mixed fibre blends or recycled fibres. Techniques were explored to felt together different recycled fibre compositions. For example, the mixed fibre batts carded from waste stream C, comprised many fibre types, such as, polyester, stretch nylons, silk, linen and wool.

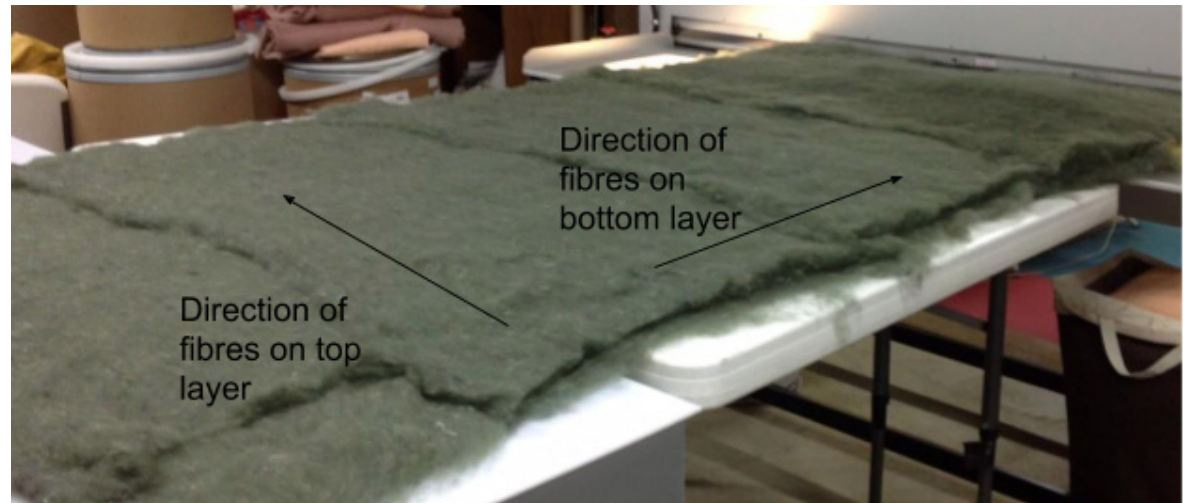
When compared to traditional carded wool batts that have been processed through the FeltLOOM®, the recycled fibre batts appeared to have similarities. The fibres were directionally aligned within the batts, and the fibres seemed to hold together into a sheet (refer to Figures 62 and 63). The initial samples felted together; however, they were thin and weak, so a decision was made to cross hatch the batts and layer several of them together. This method is often undertaken when felting wool, as it increases the stability of the felt. The batts were laid on top of each other with opposing alignments (refer to Figure 64). The



*Figure 62:* The fibres were directionally aligned within the batts and the fibres seemed to hold together into a sheet.



*Figure 63:* In comparison the wool batts are also directionally aligned within the batts.



*Figure 64:* An example of how the batts were cross hatched and layered together.

fabrics developed using this cross-hatched technique were considerably stronger than those with a singular batt, or two batts layered on top of each other, but with fibres lying in the same direction.

Another finding was that the batts that contained at least 15% wool fibres matted together well to form a new felt.



*Figure 65:* Needle felting fibre batts together on the FeltLOOM®.

It was determined that this was because the process of needle felting relies on the natural barbs on the fibre being tangled together as the barbed needle passes up and down through the fibres, locking them together into a felt. Smooth fibres like polyester do not felt very well together as the fibres do not have barbs to catch on the barbed needle. The mixed fibre blends were successfully felted because of the percentage of wool fibres holding the other fibres and aiding



*Figure 66:* Monochromatic colourways from waste stream A layered before being felted.



*Figure 67:* Close-up of the colour change that is revealed on the cut edges of the felt.



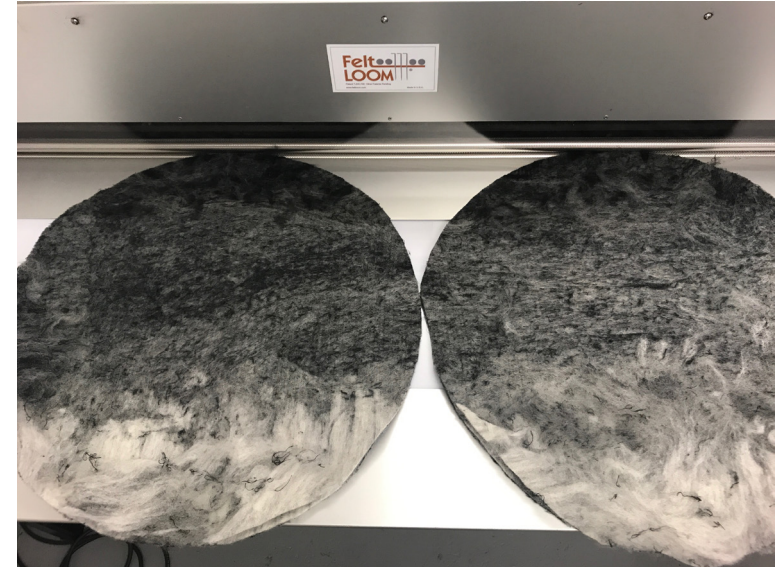
*Figure 68:* The monochromatic colour change is revealed on the cut edges of the felt.

them to lock together (refer to Figure 65).

Layering different coloured fibre batts on top of one another before felting them, also offered a different aesthetic quality to the felted outcome. For example, the different monochromatic colourways developed from waste stream A were layered before being felted (refer to Figure 66).

This resulted in a layered felt fabric where the colour change is revealed on the cut edges of the fabric (refer to Figures 67 and 68).

The FeltLOOM® also offers an opportunity to design without adding to the continuum of waste. The shape of the fibre batt is not limited to a rectangle. For example, you can manipulate the fibres into the shape of the finished design. A round shape can be fed into the rollers as a 2-dimensional circle (refer to Figure 69). The way in which the fibres are laid out in the batt can also inform the surface design of the felt.



*Figure 69: Fibres being shaped into circles before being felted.*

#### 4.8 Chapter conclusion

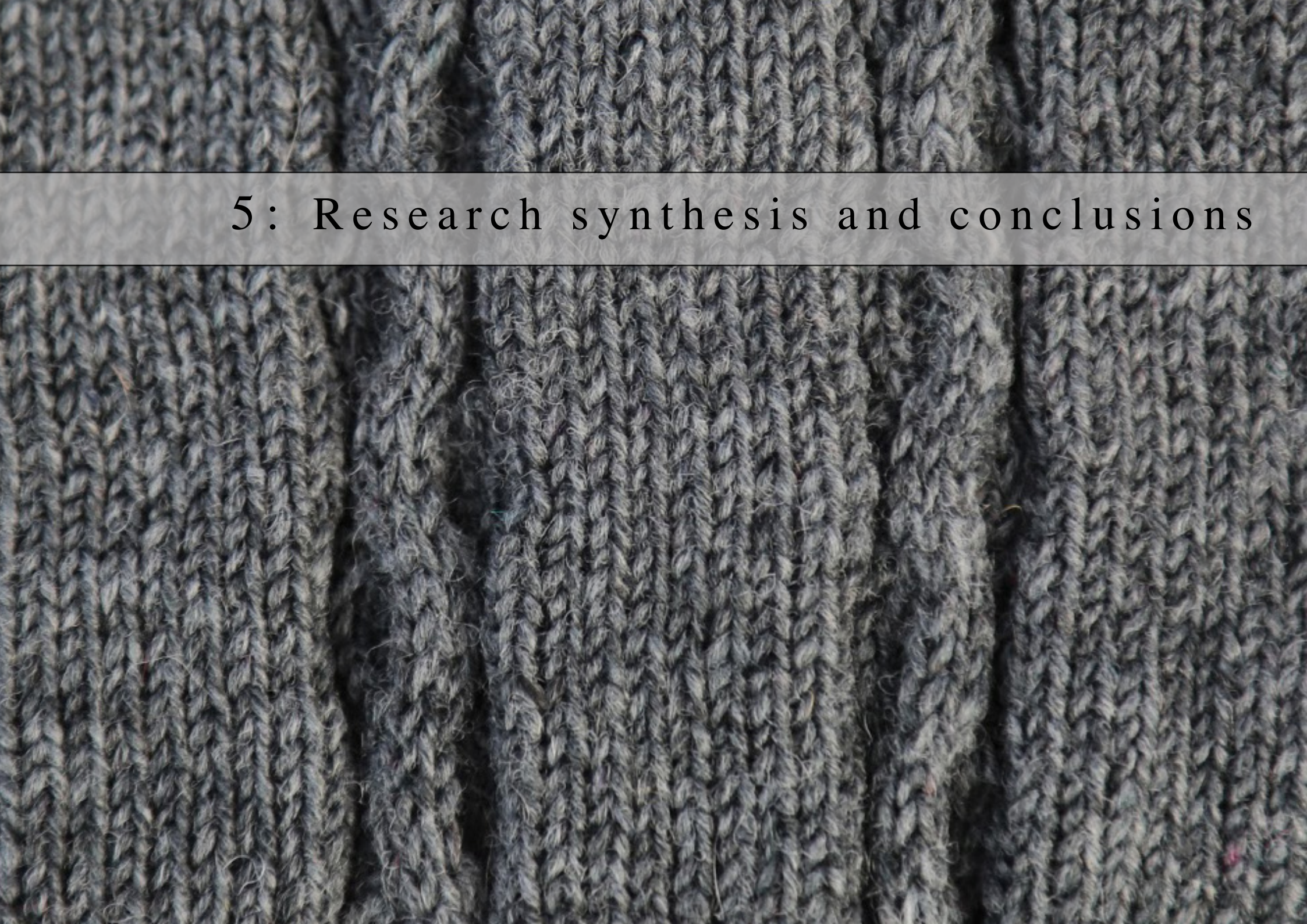
The processes and actions of the research-practice were documented in six main phases. Firstly, the textile waste stream contributors were described and identified as waste streams A, B and C. Next the logistics of collecting and storing this generated waste over a three-year period and across a wide geographical spread, each with individual criteria for availability, volume and collection, were detailed. Then data gathering and mapping methods were described. Different methods were employed at differing times, due to the variables of salvageable textile, colour, fibre content and waste stream flows. Quantitative data accrued factual information, such as weight and typologies, in conjunction with qualitative data like colour categories. The tools used to analyse the data and how this informed decisions in the design phase were outlined.

The disassembly phase was practised simultaneously with the data collection and mapping phase, overlapped with other phases such as fibre experimentation and continued throughout the research. During the disassembly processes non-machinable textiles and componentries were removed, the value of the fibres were assessed, and possible processing scenarios were considered. This pre-processing disassembly phase also informed the development of strategies for local textile waste recycling.

The fibre experimentation phase was conducted throughout the entire project and was a method of testing small quantities of fibre before committing them to commercial processes, so that action research, based on cycles of planning, action, observation and reflection, that also acknowledged the researcher's personal knowledge of fibre blending, and fibre technologies, solved technical and aesthetic problems

that arose.

Lastly, a programme was developed where the generated textile waste, rather than being processed as a homogenised mass, was processed on a case by case basis, thereby acknowledging the original fibres' identities and their potential value. Thus, the fibres were assessed at each processing stage of shredding, opening, carding and spinning. In the last phase of the research practice, the resulting batts and spun yarn were utilised to design new sample textiles of increased value (Appendix C). The materials were reanimated and refutured through the use of traditional and new technologies informed by balancing previously acquired knowledge of the fibres and their intrinsic qualities.



# 5: Research synthesis and conclusions

## 5.1 Introduction

The aim of this project was to re-think and re-value textile waste. The research demonstrates that through engaging physically and cognitively with the threads of unwanted textile waste, it is possible to weave them into reanimated textiles that possess both a new scale of value and a new narrative. The current linear flow of industrial textile waste to landfill was critically assessed in order to identify factors which contributed to undervaluing textile waste and provided an alternative, design led approach to textile waste re-use. Critically examining the specific textile waste streams, including volumes, typology of the materials and the qualities of the fibres led to new knowledge and new understandings about their capabilities. The designer evaluated options for mechanical textile recycling and fibre recovery. This led to the development of a new model for small to medium enterprises to recycle textile waste locally.

This design-centred practice reconnected people, namely, garment manufacturers and textile recyclers with the value of their textiles, maximising recovery opportunities through systems change.

This chapter reviews and analyses the project, synthesises insights and knowledge gained, and draws conclusions from this research. It incorporates both the methodology and design practice that informed the analytical results that contribute to knowledge and offer implications for the future. The research is analysed and summarised through three lenses: sustainable strategies, materials future and design innovation. The sustainable strategies lens examined the strategies used to redirect textile waste and their resulting outcomes. The materials future lens viewed the possibilities of the materials to create change. The design innovation lens looked at solutions through sustainable design practice, so that the scale of the innovation corresponded with the

problem.

## 5.2 Analysis of sustainable strategies

Current fashion manufacturing systems are continually speeding up to match increased consumption rates (Fletcher, 2014). The consequences of ever increasing quantities of textile waste filling landfills is dire (Fraser, 2009; Gordon & Hill, 2015). This project explored a practical approach to change the current linear model from “take, make and waste” (The World Economic Forum, n.d.) into a circular system whereby materials can be diverted from landfill and reanimated into value added materials. Having materials being re-used in a closed loop as a continuum of regeneration allows an extended use of the materials and extracts the maximum value from them. In this way the system can contribute to the circular economy by diverting textile waste from landfill and producing new materials from them. Additionally, the circular system can be repeated

and the materials recycled again and again (refer to figure 70). At present the majority of our clothing is made using predominantly virgin fibres (Ellen MacArthur Foundation, 2017). Although recycling textiles demands 80% less energy than growing or fabricating virgin fibres (Fletcher, 2014), we are experiencing very low levels of engagement with any forms of textile recycling (Ellen MacArthur Foundation, 2017). This causes mounting pressure on non-renewable resources. This research project repositions materials destined for landfill as a valuable resource and a commodity worthy of reclaiming.

The literature confirms that small to medium-sized clothing producers and manufacturers have had the least uptake of implementing sustainable strategies (Global Fashion Agenda, & The Boston Consulting Group, 2017). This factor directly influenced the researcher's decision to engage with small to medium-sized businesses, and to explore sustainable

strategies to recycle their textile waste streams, because their size and structure offers a more flexible and responsive environment for an uptake of new strategies. However, the researcher initially experienced negative responses with regard to the notion of implementing sustainable strategies. The reasons provided by the companies for their negative attitudes related to: the difficulties of working with recycled textiles; the costs involved in the process; and the quality of the textiles produced. Whilst there was a "sense of shame surrounding waste" (Hunting, Gonzales, & Nienhuis, 2018), this had not translated into actioned sustainable change. In addition, this research faced barriers, in the form of entrenched attitudes with regard to recycling commercially sensitive materials, so that concerns for intellectual property were more substantial than concerns for the environment.

Green-washing and fast fashion have led to negative attitudes of distrust and doubt (Charter, 1992, as cited in

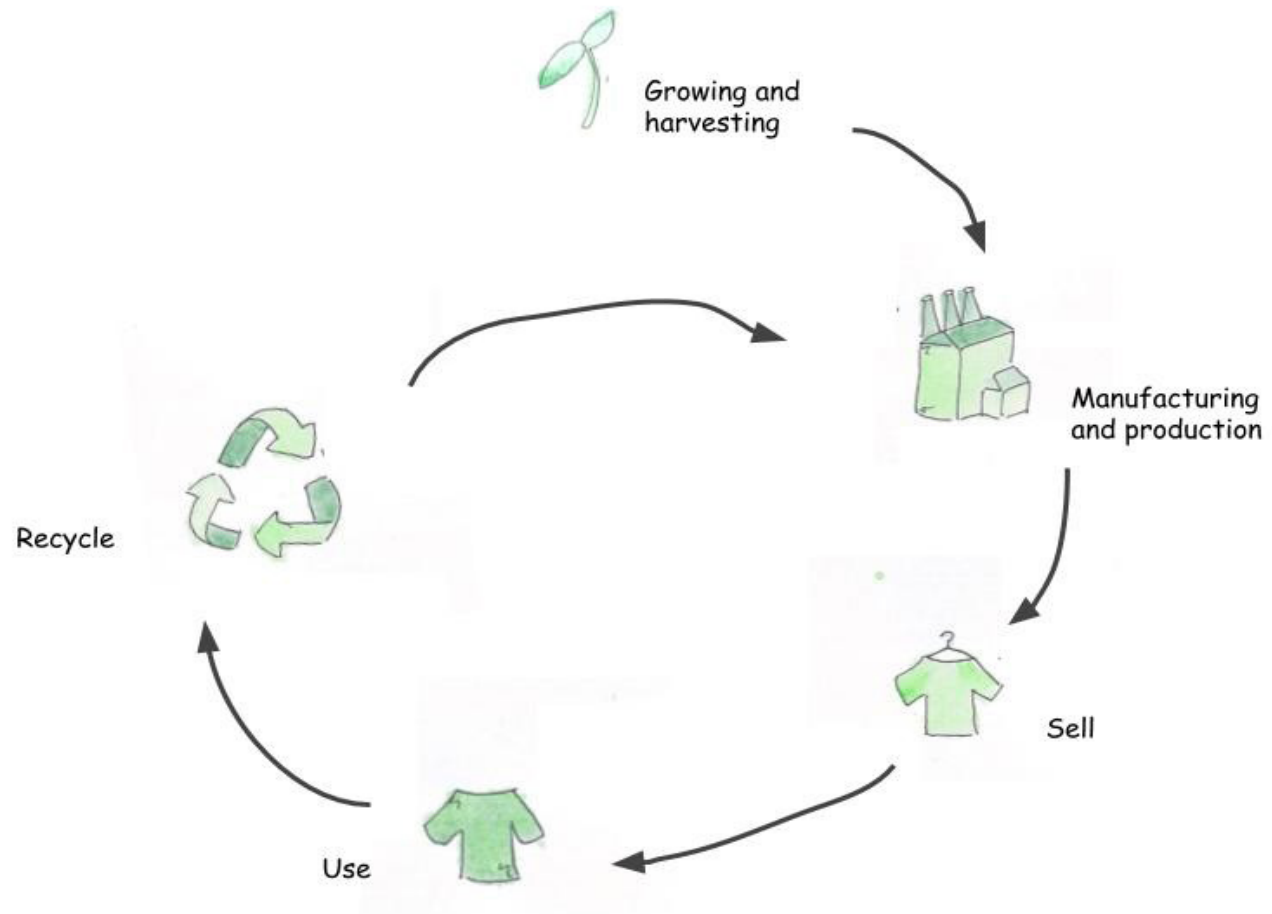


Figure 70: Closed loop circular system.

Cervellon & Wernerfelt). A counter-narrative is necessary to redress negative sustainability messages and to create changed positions (Gillespie, 2013; Tonkinwise, 2011). Patagonia demonstrated that one strategy could be to heroise the garments and the journeys they had undertaken (Gasperini, 2013). This paradigm was extended through this project which focused on heralding the fibres that comprise our clothing. Emphasis was placed on reconnecting people with the value of their fibres to appreciate the past life of the textiles, thereby championing their potential future. In a similar way, this research project recognised that any shift in mindset or practice relied on ‘buy-in’ to sustainable strategies (Senge, 1990). Changing the language surrounding the process of textile recycling influenced the way in which people viewed the fibres. This alternative language strategy afforded the fibres a heroic status, thereby enabling change. This strategy resulted in positive outcomes, namely vendors altering their machinery

and systems to accommodate recycling the textiles for this project. In addition, it changed people’s attitudes towards textile waste and the value of textile recycling.

### 5.3 Analysis of a materials future

This PhD research project aimed to develop and demonstrate a scalable and value-added platform for textile recycling. The project used existing fibre processing machinery in transformative ways with different and unexpected materials. The result of the designer using existing machinery in different ways and working in close physical engagement with the materials, elicited new textile outcomes. These were achieved by the researcher situating herself in the role of a manual labourer to sort, disassemble and reanimate the textile waste. Valuable first-hand knowledge of recycling systems was gained through this process. Physical engagement with the materials

changed the researcher's habitual practice and effectuated a new understanding of the fibres and their incorporeal value, thus challenging the notion that processing large volumes of pipeline recycled textile waste demotes the materials and reduces value. This repositioned the focus of the materials and of this research, so that individual properties of the material were championed, in contrast to mass recycling processes, where identity, colour and materialism are neglected. These developments in understanding textile waste were relative to the issues evident in the prevailing international textile recycling system, that, in its present state, is antiquated, reductive and not sustainable (Hawley, 2006).

Situating this research in the New Zealand context and utilising existing textile technologies challenged the notion that massive infrastructural investment is required to make change. Whilst there is some commercial infrastructure in

Auckland to downcycle textile waste, the system is small and is focused on solutions that degrade the textiles. Recognition of the importance of localised processing and solutions that create value is growing. China recently changed their policy relating to the importation of recyclable materials. This action denies New Zealand access, amongst other countries, to straightforward recycling services. Although this decision is very recent (2017) and the full implications are not yet evident, it is forecast that New Zealand companies that have been selling their waste offshore will now be faced with heavy costs for local disposal. However, a perceived lack of volume of textile waste in New Zealand has meant investment in the necessary infrastructure has not been made. To offer value-added textile waste recycling, investment in specialised textile recycling mills would be needed (Gibson, as cited in Reidy, 2017). In the past, New Zealand had to manage its own waste and as recently as ten years ago, the Ministry for the Environment

records indicate that over 120 million kilograms of textile waste was disposed of in New Zealand landfill annually (Ministry for the Environment, 2007). Taking into account international trends, these figures would have multiplied over the past decade. These factors highlight an expected rise in quantities of textile waste and a lack of available specialised infrastructure to process textile waste in New Zealand.

To enable a better understanding of the complex nature of mixed or blended fibres, this project engaged directly with commercial textile waste streams in New Zealand, providing a tangible framework to investigate possible approaches to recycling mixed fibres. One of the outcomes was the creation of a new fabric that was a 50/50 blend of recycled and virgin materials. This finding enabled the low grade blended fibres that were previously perceived as not recyclable to have an extended life cycle when blended with

virgin wool. Langley et al. (2000) recommended practical research be conducted in this area to overcome some of the complications, supporting the design of this project through a practical approach. The design of the research placed an emphasis on the material and its intrinsic value and potential. The employment of a mixed method approach allowed the characteristics of the fibres and their potential to inform the textile design. The literature supported this strategy, highlighting the difficulties associated with recycling mixed fibres and specifically identifying the lack of processing methods that are available to separate the fibre blends.

#### 5.4 Analysis of design innovation

To build a platform for change, the project engaged both research and practice. By re-designing with waste at the end of its life cycle, the researcher intervened and altered the expected path of several industrial textile waste streams

at both the manufacturing stage of textile production and the post-use phase of clothing. The researcher re-configured sustainable design practice by embracing Fry's (2014) premise of re-directive practice. This translated a theory of design from its current state of "de-futuring" into a mode of practical "re-futuring", where textile waste was considered both a result of a systemic design flaw and a source of raw materials. A primary contribution of this research is a model of a proof of concept that considers textile waste as a resource that can be mechanically processed and transform recycled fibres into valuable new materials.

The lack of recycling initiatives is costing \$500 billion USD a year in lost revenue (Ellen MacArthur Foundation, 2017). To advance textile recycling, we need to create new and innovative recycling systems and improve the methods we use to reprocess the textiles (Ellen MacArthur Foundation, 2017; Langley et al., 2000). The risks associated with the

business of fibre recycling make it a difficult area to operate in and prohibit progress. As the market is continuously changing, the solutions need to be adaptable and flexible, and have the ability to adjust quickly (Walker, 1995).

There were few pre-existing analytical schemes or frameworks to inform the development of the design practice, because most schemes focussed purely on the technical aspects of fibre recycling or processing large homogenised quantities of fibres. This necessitated the development of new approaches, relative to and in response to each phase of the processing. For example, methods were established to gather and record both quantitative and qualitative data for the specific materials unique to this research. Constructive strategies were required and developed to modify vendors' preconceived and negative attitudes towards recycling textiles. In addition, new techniques were created to overcome the limitations

presented by the fibre and machinery. Furthermore, the application of innovative design practices facilitated new thinking about fibre possibilities so that finite resources had the potential to be revalued.

This thesis examined how industrial design practices could become change agents and move from contributing to the problem to become part of providing a solution. The literature revealed that frequently designers do not consider the consequences of their designs or the possible effects these may present for the environment. Rather, design for obsolescence is regarded as acceptable, and the ramifications of the waste generated is not viewed as a responsibility of the designer (Fry, 2014). This research developed a number of possible design strategies that all work towards the end goal of sustainability. While the approaches and characteristics of each strategy had directions that could be useful, either separately or in specific circumstances, they

did not provide a complete solution. Fletcher proposed a more holistic sustainable fashion design concept that she terms a “framework for life” (2014, xvi), which considers not only the technical nature of textiles, but contests the paradigm of fashion. McDonough and Braungart (2013) also propose that a more holistic system is needed, a cradle to cradle cycle, where all waste is considered a food source for another part of the system. While these approaches are admirable and should offer aspiration for designers, the implementation of a complete industrial paradigm shift was beyond the scope of this project. However, some positive, incremental changes in waste collection were noted. For example, the factory where waste stream B was generated instigated a change in the way they managed the collection of textile waste. This meant a change in practice, as they moved from discarding all of their waste into general waste bins destined for the landfill to separating out recyclable textiles. Another progressive change was in the fashion

design studios where waste stream C was generated. The practice of discarding all of their textile waste with other general waste was modified. As part of a sustainable strategy that was subsequently established, textile waste was collected in permanent re-use bins situated in every studio environment.

One of the outcomes from this research project is an increased awareness of the value regarding the choice of virgin fibre used in the manufacturing stage of design. Manufacturers should consider the future value of the fibre type used in the original design process. In this manner, they could maximise the use of waste raw materials so that any future process of recycling would add value. For example, the company producing waste stream A were unaware of the textile content of their gowns or trenchers, and, therefore, did not know the origins of their fibres. Their previous purchasing decisions were financially based with

considerations around quality being limited to the longevity of the garments. However, being aware of the textile recycling possibilities and knowledge surrounding the most valuable fibres in the recycling process, afforded them a position worth considering for future purchasing decisions. This means that they could choose garments that would last longer in their wear phase, be designed with disassembly in mind and choose fibre content, such as wool, that would offer greater opportunities for the recycled textiles. The outcomes of this project may help shape a new mindset towards sustainable design through recognising the value of fibre, both for disassembly and for recyclability.

#### 5.5 Mapping the practice into a decision tree

A mapping method was used to track the flow of textiles as they moved through the emerging system, and form a record of what was successful and what did not work. This mapping method culminated in a decision tree that

enabled an analysis of the project and informed some conclusions. Whilst the decision tree started as a process of documentation, it became an artefact for reflection on practice, rather than a reflection of or in practice. This decision tree mapping provided a visual reference to support the thinking around the behaviour of the textiles, plotted with the capabilities and limitations of the mechanised processes (previously discussed in 3.3.8). This mapping method provided a framework to define the relevant processes and the probabilities of their achievement. It also enabled a visualisation of decision points, where waste moved forward in the system or required thinking in a new way to enable it to be further processed. This highlighted how the researcher needed to draw on accumulated knowledge to find solutions that might have been generated from mechanised processes such as commercial spinning, or handcraft processes, such as hand spinning, in order to gain the best results from the fibres when being recycled. This

mapping method also provides a designer's perspective that overviews and reflects on the whole process, rather than just stages. It presents and conceptualises the process that could inform a design led model of change. It also reveals some of the dynamic complexities that this project handled.

## 5.6 Proposed platform for change

This project established a platform for change to demonstrate that textiles can be recycled at a local level, involving skilled artisans, producers and manufacturers, service providers and designers (refer to Figure 70). The research practice showed it was possible to cultivate new ways of thinking about recycled textiles that focused on the materials and ways to re-value them, based on the fibres' individual potential value. This opened up possibilities for practical changes in existing processes without re-configuring entire systems. For example, to engage waste

stream B in the research, the vendor made a single change in their production line to redirect waste, and they achieved this without slowing down production. An extension of this could be in-house sorting, where the company sorts their own textile waste into relevant colourways at the point of manufacture. Taking into account the scale of their waste stream, this would be a feasible option. In this research the textile waste was processed into new materials as proof of concept prototypes and samples. Operation of this platform outside this research could offer possibilities for companies to engage at different levels. One possible scenario is that companies who buy into the scheme could purchase any recycled materials available within the system, not necessarily purchasing back their own. For example, Fraser Crowe Ltd was a small startup fashion business that approached the researcher during this project looking for sustainable strategies for their textile waste. The company was not able to be considered as a case project for the PhD

research, as the timing of their approach in relation to the project, meant the research was already underway. However, a small boutique fashion house such as theirs would take a considerable amount of time to generate the 200-kilogram minimum waste that the machinery required to shred the textile waste. In addition, it would not be feasible to collect the target weight in aesthetically pleasing colourways. This research develops a system for small, design-based companies to have the possibility to purchase any new textiles developed through the platform, and not necessarily recycled textiles generated from their original waste stream. In this way, what I describe as ‘the kilogramme economy’, where access to textile recycling technologies and systems is prescribed by specified quantities and a limited range of fibre types, would not determine whether a company could viably recycle their own materials. In this way the platform overcomes the limitations around the weight of materials needed to operate the machinery. This would also present

opportunities of blending beneficial waste streams together, so that if a participating company's waste stream was not viable on its own; for example, that it did not contain any natural fibres or the fibre lengths were too short to process

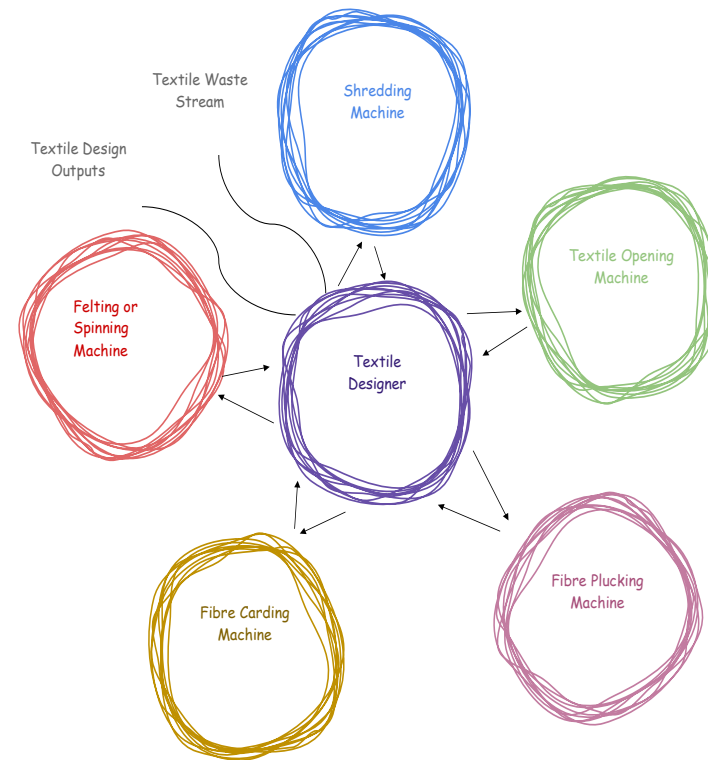


Figure 71: The design-centred system showing how the materials move through different mechanised processes.

alone, another waste stream containing wool or longer fibres could be added. In addition, it could be beneficial for companies to combine their waste streams through this format purposefully to form new material outcomes. Such a hybrid approach, supported by an information system or a broker to enable companies to better collaborate in the combination of different fibre types, warrants further investigation.

A significant strength demonstrated in this recycling platform and inherent in its design is the capability to respond to changes. This designer-centred system requires a designer to lead the process and be responsive. The material outcomes of a designer led system could take a greater priority, as the system would not be aligned with a single manufacturer. The scale of operation can meet viability constraints yet have the ability to be responsive to individual requirements. For example, if a company changed the materials they were manufacturing, or the amount of textile waste generated altered significantly, the system would be

capable of reacting promptly. Such a platform could curate information pertaining to an individual company's waste stream that could highlight their individual potential. This could be beneficial to brand values and offer companies a key point of difference, especially as consumers increasingly challenge brands for sustainable transparency. In addition, through heroing the fibres, an approach utilised in this research with positive outcomes, vendor buy-in could be advanced, so that brands associated with this emerging practice differentiate their products from other companies. This could further enhance their competitiveness, thereby changing perceptions and creating awareness of the value of re-animated fibres.

## 5.7 Contribution to knowledge and future research possibilities

This project collected, processed and reanimated textiles that were destined for landfill. This was achieved in a

manner that was not predicted, and modified the researcher's thinking around recycling textile waste processes. The researcher previously viewed textile waste as supplying an industrial process; however, a changed focus during processing altered its significance, so that the materiality of the raw material was also considered. The designer changed focus to a micro-level and explored the qualities and inherent characteristics of the fibres, rather than maintaining a more removed operational position. This highlighted ways to revalue the actuality of the materials other than solely analysing their technical properties. It contributed to a continuum of new knowledge by generating a different discourse around sustainable textile waste management. It provided tangible building blocks in the form of tabled data and experimental textile development, including new colour stories informed by aesthetics, as well as sensing and visualisation of materials. This demonstrated that the designer's knowledge and fibre understanding, is needed,

through and within this proposed system.

The documentation of this research, primarily through the mechanism of sustainable design practice and supported by this written exegesis, provides a body of work that contributes to knowledge, as it proposes an innovative textile recycling system that could operate in a small and localised manner; also, implementing sustainable strategies that are scalable or repeatable in other situations. The quantitative and qualitative data mapping and the outline of the textile recycling decision tree avail the research findings to other sustainable designers and researchers working within this area. This research could inform future materials design practice both in industry and education. It could alter the business trajectory of a designer practice when considering sustainable applications for used textiles.

The textile recycling decision tree is a mapping method

that provided a framework and an overview, making it a significant contribution to knowledge. It provides a reflection on the whole recycling process, rather than just stages. It presents and conceptualises the process as a system rather than just a step by step process. It also shows some of the dynamic complexity that recycling textile waste has and gives insights into the logic behind decisions that altered the course of materials that were in the system. Also, some of the 'no' answers, such as directing non-shreddable (in this case cotton) textiles to landfill, indicate other areas of textile recycling could be developed further.

The research project could also be used to inform future initiatives to enable New Zealand to achieve waste reduction goals in the future. It is envisaged that the outcomes of the project could be grafted with or onto existing or emerging textile waste management initiatives and offer a fresh perspective on materials knowledge. There is future research

potential in establishing a network sharing knowledge between the suppliers, producers, service providers and artisans, where new sustainable strategies could be trialled and new ways of engaging with sustainability considered. For the scope of this research project, the textile waste recovered from industry was considered a resource, without impedance that working with industry could present. Future research could be undertaken to shift industry perceptions around textile waste recycling, specifically in New Zealand where it has been identified that scale is a problem. As this research demonstrated a changed system that operated with commercial partners, it could be translated into the wider industry. This research could also be expanded by trialling this platform with industry involvement from the providers of the textile waste streams.

It would be advantageous for future research to establish a service platform to provide open access to the machinery

for trialling and processing, as this difficulty and their geographic spread were limitations encountered. This highlights the need for other alternatives to be researched and designed in the future. These are aspects beyond the scope of this project but are areas this research has opened up for other researchers to address.


## 5.8 Conclusions

Sustainment will not occur in a single solution; its pursuit will require many different pathways. In addition, its progression will be associated with attitudinal relationships, such as perceptions, personal value systems and individual connections with the planet. Directional change towards sustainability is required to counter the impact of textile waste on the planet. This research provided such a pathway through new knowledge, insights, re-directing designer practice, transforming tangible commercial textile waste



and utilising existing textile technologies, to hero and re-future the materials.

The synthesis of the PhD project presented here analysed the research through three different lenses: sustainable strategies, materials future and design innovation. This proposed a platform for change offering local, repeatable and scalable options for textile waste. Innovative initiatives provided proof of concept and thereby demonstrated that unwanted threads could be woven into reanimated textiles with both added value and new narratives. Those who would benefit the most from the findings and knowledge generated were considered, ranging from textile design students to industry applications. Future possibilities were suggested that could inform any further initiatives aimed at reducing textile waste in small scalable industries.

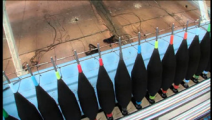

# Appendices

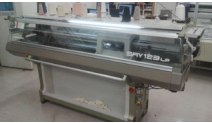






## Appendix A : Mechanised technologies

Machine technology and location	Specifications	Details of process	Image
<p><b>Textile Shredder</b> La Roche Shredder.</p> <p>Textile Products 1971 Ltd. Onehunga, Auckland. NZ</p> <p>Retrieved from <a href="https://www.textile.co.nz/about/">https://www.textile.co.nz/about/</a></p>	<p>The materials are loaded onto a conveyor belt that feeds a machine that has a series of rotating knives which cut the material into small segments.</p>	<p>All of the materials considered recyclable involved in this project were put through this machine as a starting point for the recycling process.</p>	
<p><b>Textile opener</b> LaRoche opener. Textile Products 1971 Ltd. Onehunga, Auckland. NZ</p> <p>Image sourced from; <a href="http://www.macart.com/laroche-opener-%2812038%29~439">http://www.macart.com/laroche-opener-%2812038%29~439</a></p>	<p>The LaRoche opener is a fibre opener that drags fibres onto a single drum that has wires on it. The resulting fibre is then air blown as it exits the machine.</p>	<p>This is a secondary operation to the shredding. All materials that were shredded for this project also passed through this machine.</p>	

<p><b>Haign Carder</b> 1955 Haign Carding Machine. Jumbuck Carding Ltd. Kaukapakapa, Auckland.NZ</p> <p>Image sourced from; <a href="http://www.jumbuck.co.nz/">http://www.jumbuck.co.nz/</a></p>	<p>The function of a carder is to clean and parallelise fibres. A continuous web is formed by the fibres at the end of this process. The main elements of this machine are rotating drums that have saw-tooth wires on them.</p>	<p>Some fibres were carded into sliver on this machine and some into batts</p>	
<p><b>Stone Hedge Carder</b> Lan Mark Farm. Sharpsburg, Kentucky. USA</p> <p>Image retrieved from <a href="http://fibermillingequipment.com/main/?q=cardingmachine">http://fibermillingequipment.com/main/?q=cardingmachine</a></p>	<p>This carder has the same function as the Haign Carder. A key difference is that it has metallic wires on the drums that are not saw tooth.</p>	<p>This carder was used as a primary process before the core spinning process. It was also used to process much finer batts.</p>	
<p><b>Needle felter</b> FeltLOOM® AUT Textile Design Lab. Auckland. NZ</p> <p>Image retrieved from <a href="https://www.feltloom.com/">https://www.feltloom.com/</a></p>	<p>The 66 inch, FeltLOOM® is a needle felting machine with 720 barbed needles, that have a speed controlled punch action, the needles punch through a bed of fibres or fabric and this motion joins the fibres together.</p>	<p>All of the felts developed in this project were processed on this needle felting machine</p>	

<p><b>Yarn Spinning</b> Bigagli B7 Wool Yarns NZ. Lower Hutt, Wellington. NZ</p> <p>Image retrieved from: <a href="https://www.google.co.nz/search?q=bigagli+b7&amp;safe=strict&amp;source=lnms&amp;tbm=isch&amp;sa=X&amp;ved=0ahUKEwjWweru_5naAhVS6bwKHYrDDCQQ_AUICigB&amp;biw=1366&amp;bih=613#imgrc=duyfQS-XNLDziM">https://www.google.co.nz/search?q=bigagli+b7&amp;safe=strict&amp;source=lnms&amp;tbm=isch&amp;sa=X&amp;ved=0ahUKEwjWweru_5naAhVS6bwKHYrDDCQQ_AUICigB&amp;biw=1366&amp;bih=613#imgrc=duyfQS-XNLDziM</a>:</p>	<p>The Bigagli B7 is an automated self acting spinning mule which is manufactured in Italy and is specifically designed for spinning delicate or fine fibre.</p>	<p>The yarn that was commercially spun as part of this project was done on this machine</p>	
<p><b>Knit Machine 14 gauge</b> AUT Textile Design Lab. Auckland. NZ</p> <p>Image sourced from ; <a href="https://tdl.aut.ac.nz/about/knit/#close">https://tdl.aut.ac.nz/about/knit/#close</a></p>	<p>The Shima Seiki NSES 183 Whole Garment machine, 3 dimensionally knits yarn into forms that do not require assembly as the garments are knitted seamlessly.</p>	<p>The commercially spun 1/150 tex yarns were knitted on this machine as well as some handspun samples</p>	

<p><b>Inlay Machine</b>  <b>14 gauge</b>  AUT Textile Design  Lab. Auckland. NZ</p> <p>Image sourced from;  <a href="https://tdl.aut.ac.nz/about/knit/#5">https://tdl.aut.ac.nz/about/knit/#5</a></p>	<p>The Shima Seiki SRY 123 LP inlay machine has the ability to knit fine yarn into textile that has a component of a course yarn being inlaid to create stability and mock woven effects. This machine can also produce technical fabrics if required.</p>	<p>The commercially spun 2/150 tex yarn and the 1/150 tex yarn were knitted on this machine</p>	
<p><b>Knit Machine</b>  <b>8 gauge</b>  AUT Textile Design  Auckland. NZ</p> <p>Image authors own</p>	<p>The Shima Seiki SES - 122-S</p>	<p>The handspun yarns were knitted on this machine</p>	
<p><b>Belfast Mini Mills Rug Yarn Maker</b>  Lan Mark Farm.  Sharpsburg, Kentucky.  USA</p> <p>Image author's own</p>	<p>Fibres are twisted around an existing filament to make a yarn that has two components a sheath which is spun over a core.</p>	<p>This is a modular machine that was placed at the back of the Stone Hedge Carder to produce the core spun yarn</p>	

<p><b>Hand Spinner</b>  Author's own  Donna Cleveland.  Riverhead, Auckland.  NZ</p> <p>Image sourced from ;  <a href="https://www.susanspinner.com/products/majacraft-pioneer">https://www.susanspinner.com/products/majacraft-pioneer</a></p>	<p>This form of spinning is a traditional handcraft technology that is operated by hand and foot where fibres are drawn out and spun together onto a bobbin to produce yarn</p>	<p>This machine was used to test spun yarn samples and develop some yarns that could be handknitted</p>	
<p><b>Platt Carder</b>  1901 Platt Brothers  Carding Machine  Kane Carding.  Dannevirke. NZ</p> <p>Image retrieved from  <a href="http://www.greenacresfibres.co.nz/machines.php">http://www.greenacresfibres.co.nz/machines.php</a></p>	<p>The function of a carder is to clean and parallelise fibres. A continuous web is formed by the fibres at the end of this process.</p>	<p>Some fibres were carded into batts on this machine</p>	

## Appendix B: Colour Library

### Colour Library for Waste Stream B

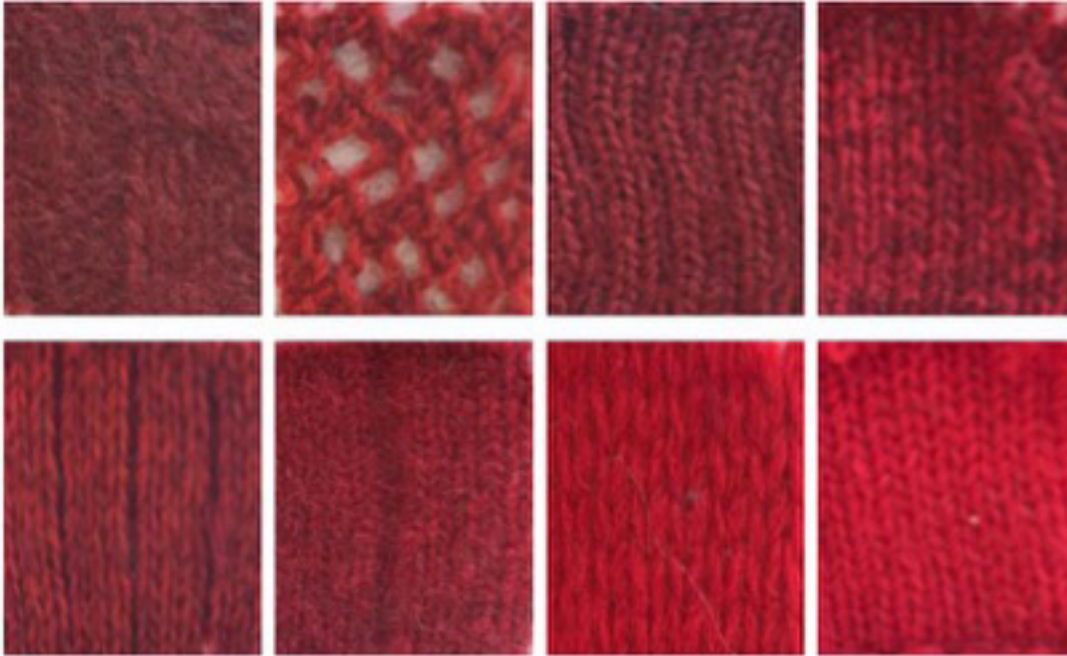
#### Greens



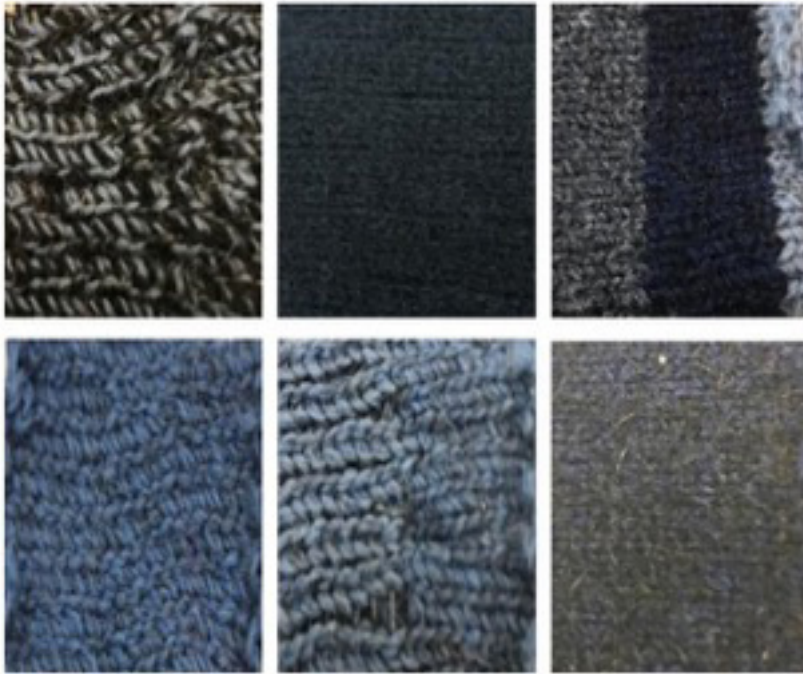
Pinks and purples



Reds



Blues



Whites



Blacks




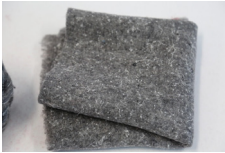


Browns










Greys


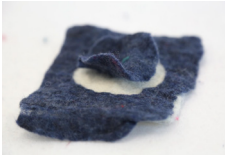


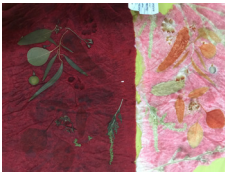


## Appendix C: Textile Design Samples

Waste stream textile was developed from	Textile design application/machine	Picture	Reflections	Possible textile use
B	Inlay machine		Strong knit Looks like a woven	Garments Homewares
C	Feltloom		A bit unstable and weak and fibres fall out	Needs further development
B	Shima knit		The lace pattern is effective and lightens the look and feel of the knit	Garments
B	Shima knit		The cable pattern adds stability to the knit	Garments or soft homewares

B	Feltloom 300g batt		The batts have formed a strong felt, 2 batts layered and cross hatched	Soft furnishings and homewares
C	Shima knit		Handspun yarn knitted on 8 gauge The handspun yarn gives the knit texture	Soft furnishings
A blended with 50% virgin gotland wool	Feltloom		Where the prefelted layers are joined adds an interesting striped aesthetic	Homewares
B	Handknitted		The scale of the yarn and the needle size are effective and the core makes the yarn very strong	Soft furnishings floor rug

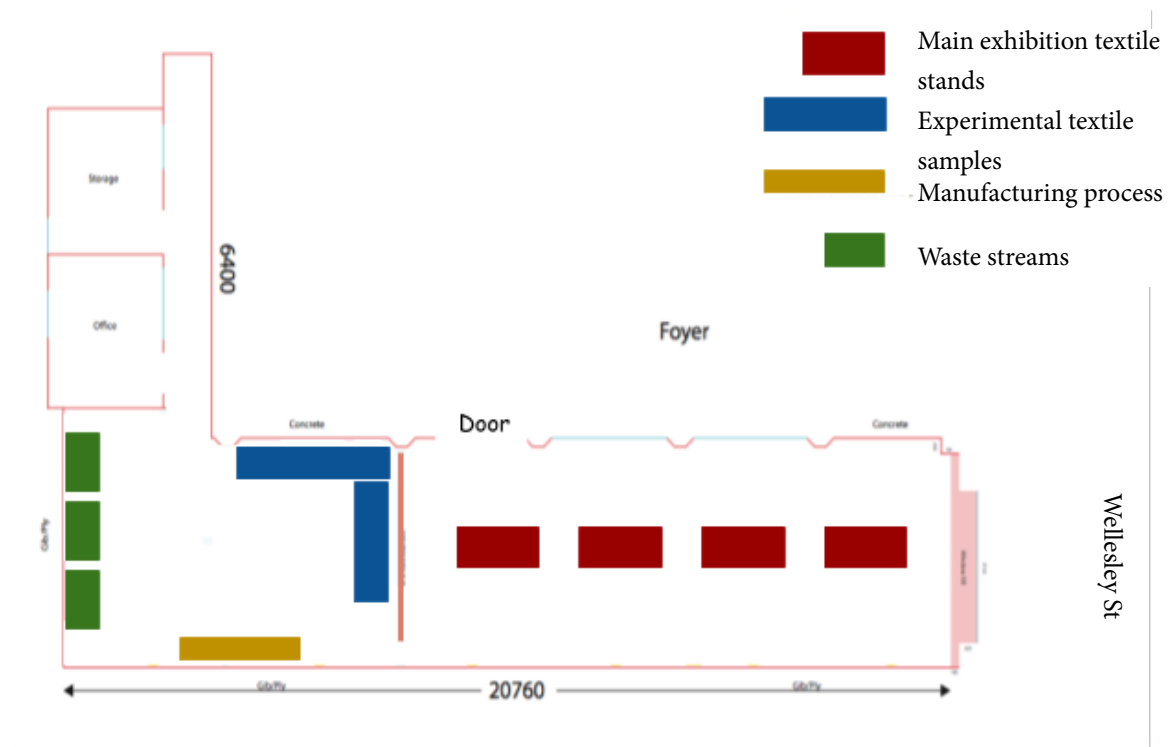
B	Feltloom		The single layer 300 g felt has been smocked giving it a 3 dimensional effect	Soft furnishings Homewares and Garments
A and romney 50% each	Feltloom		2 x 300 gram batts felted and smocked, 3 dimensional effect and is a very strong and dense fabric	Soft furnishings Homewares
C	Feltloom and wet felt		Fibres were felted on feltloom and then wet felted into 3 dimensional shape	Homewares

A,B and C	Feltloom		Small amounts of colour were felted into a pattern similar to paint by numbers	Homewares Soft furnishings
B	Feltloom and wet felted		The possum fibres do not wet felt well, the fibre falls out in the wet felting process	Needs further development
C	Feltloom and digital print		The digital print ran in the washing process so caused some smudging	Needs further development
C	Weaving loom		Weaving offers the handspun yarn a strong fabric	Homewares Soft furnishings
B	Handprinted		Using the felted wool in a botanical dye on silk the red dye coloured the silk fabric and the wool embossed with the leaves	Soft furnishings and garments

B	Feltloom		Wool batts felted onto cork but the cork broke into pieces	Needs further development
B	Feltloom		Wool batts felted onto wood but the wood broke into shards	Needs further development



Appendix D: Exhibition





Transformational Cloth exhibition held at Gallery Three, AUT



Image	Textile description	Making Process
	<p>Content: recycled merino/possum Red colourway</p> <p>3 x batts</p> <p>Total fabric weight 114g per sqm</p>	<p>3 x batts layered cross-hatched directional Felted 15 times on needle felter <math>\frac{3}{4}</math> needle speed <math>\frac{3}{4}</math> roller speed Pressed</p>
	<p>Content: recycled merino/ possum and virgin silk georgette</p> <p>Red colourway White colourway White silk</p> <p>1 batt red 1 batt white</p> <p>Total fabric weight 62g per sqm</p>	<p>1 red batt layered lengthways on virgin silk straight of grain 1 white batt pre-felted and cut into rectangles and placed on virgin silk side</p> <p>Felted 10 times on needle felter <math>\frac{1}{2}</math> needle speed <math>\frac{3}{4}</math> roller speed</p> <p>Wet nuno felted pressed</p>







	<p>Content: recycled merino/possum Pink colourway</p> <p>3 x batts</p> <p>Total fabric weight 114g per sqm</p>	<p>3 x batts layered cross-hatched directional Felted 15 times on needle felter <math>\frac{3}{4}</math> needle speed <math>\frac{3}{4}</math> roller speed Pressed</p>
	<p>Content: recycled merino/possum Red colourway</p> <p>Core Spun yarn</p> <p>Yarn weight 28g per linear meter</p>	<p>Core spun yarn knitted on 35mm hand made needles</p>



Image	Textile description	Making Process
	<p>Content: recycled merino/possum Blue colourway</p> <p>3 x batts</p> <p>Total fabric weight 114g per sqm</p>	<p>3 x batts layered cross-hatched directional Felted 15 times on needle felter <math>\frac{3}{4}</math> needle speed <math>\frac{3}{4}</math> roller speed Pressed</p>
	<p>Content: recycled merino/ possum and virgin silk georgette</p> <p>Blue colourway White colourway White silk</p> <p>1 batt blue 1 batt white</p> <p>Total fabric weight 62g per sqm</p>	<p>1 blue batt layered lengthways on virgin silk straight of grain 1 white batt pre-felted and cut into rectangles and placed on virgin silk side</p> <p>Felted 10 times on needle felter <math>\frac{1}{2}</math> needle speed <math>\frac{3}{4}</math> roller speed</p> <p>Wet nuno felted pressed</p>

	<p>Content: recycled merino/ possum and virgin silk georgette</p> <p>White colourway White silk 1 white batt</p> <p>Total fabric weight 42g per sqm</p>	<p>1 white batt layered lengthways on virgin silk straight of grain</p> <p>Felted 10 times on needle felter ½ needle speed ¾ roller speed</p> <p>Wet nuno felted Pressed</p>
	<p>Content: recycled merino/possum Blue colourway</p> <p>3 x batts</p> <p>Total fabric weight 114g per sqm</p>	<p>3 x batts layered cross-hatched directional</p> <p>Felted 15 times on needle felter ¾ needle speed ¾ roller speed Pressed</p> <p>Top of stool fabric has been hand smocked giving it a 3 dimensional effect</p>







	<p>Content: recycled merino/ possum</p> <p>Blue colourway White colourway</p> <p>1 batt blue 3 batt white</p> <p>Total fabric weight 118g per sqm</p>	<p>3 white batts pre-felted and cut into rectangles and placed on virgin silk side 1 blue batt pre-felted and cut into rectangles placed in herringbone pattern on white prefelt</p> <p>Felted 15 times on needle felter ½ needle speed ½ roller speed</p> <p>Pressed</p>
	<p>Content: recycled mixed fibre content Blue and copper colourway</p> <p>Handspun yarn</p>	<p>Hand spun yarn knitted on 8mm needles</p>



Image	Textile description 	Making Process
	<p>Content: recycled merino/possum Green colourway</p> <p>3 x batts</p> <p>Total fabric weight 114g per sqm</p>	<p>3 x batts layered cross-hatched directional Felted 15 times on needle felter <math>\frac{3}{4}</math> needle speed <math>\frac{3}{4}</math> roller speed Pressed</p>
	<p>Content: recycled merino/possum Green colourway Blue colourway</p> <p>4 x batts</p> <p>Total fabric weight 152g per sqm</p>	<p>4 x batts layered cross-hatched directional 2 Blue and 2 Green Felted 15 times on needle felter <math>\frac{3}{4}</math> needle speed <math>\frac{3}{4}</math> roller speed Pressed</p>
	<p>Content: recycled merino/possum White colourway Green colourway Blue colourway</p> <p>3 x batts Additional circles</p> <p>Total fabric weight 120g per sqm</p>	<p>3 x white batts layered cross-hatched directional Pre Felted once on each side Pre Felted circular dots placed on top Felted 10 times on needle felter <math>\frac{3}{4}</math> needle speed <math>\frac{3}{4}</math> roller speed Pressed</p>






	<p>Content: recycled merino/possum Green colourway Blue colourway</p> <p>2 x batts</p> <p>Total fabric weight 76g per sqm</p>	<p>2 x batts layered cross-hatched directional 1 Blue and 1 Green Felted 15 times on needle felter <math>\frac{3}{4}</math> needle speed <math>\frac{3}{4}</math> roller speed Pressed Die cut into shapes</p>
	<p>Content: recycled merino/possum White colourway Blue colourway</p> <p>4 x batts</p> <p>Total fabric weight 152g per sqm</p>	<p>4 x batts layered cross-hatched directional 2 Blue and 2 White Pre Felted on needle felter <math>\frac{3}{4}</math> needle speed <math>\frac{3}{4}</math> roller speed Wet felted over a plastic shaped resist to form 3 dimensional shape Die cut holes Light fixtures handsewn in place</p>



Image	Textile description	Making Process
	<p>Content: recycled merino/possum Green colourway</p> <p>3 x batts</p> <p>Total fabric weight 114g per sqm</p>	<p>3 x batts layered cross-hatched directional Felted 15 times on needle felter <math>\frac{3}{4}</math> needle speed <math>\frac{3}{4}</math> roller speed Pressed</p>
	<p>Content: recycled mixed content fibre</p> <p>Blue colourway 2 batts</p> <p>Total fabric weight 84g per sqm</p>	<p>2 blue batts layered cross-hatched directional</p> <p>Felted 15 times on needle felter <math>\frac{3}{4}</math> needle speed <math>\frac{3}{4}</math> roller speed</p>
	<p>Content: recycled merino/possum White colourway</p> <p>3 x batts</p> <p>Total fabric weight 114g per sqm</p>	<p>3 x batts layered cross-hatched directional Felted 15 times on needle felter <math>\frac{3}{4}</math> needle speed <math>\frac{3}{4}</math> roller speed Pressed</p>




	<p>Content: recycled mixed content fibre</p> <p>Green colourway White colourway 2 batts</p> <p>Total fabric weight 102g per sqm</p>	<p>3 green batts cross hatched and pre-felted 1 white batt pre-felted and cut into rectangles placed in herringbone pattern on green prefelt</p> <p>Felted 15 times on needle felter ½ needle speed ½ roller speed</p> <p>Pressed</p>
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Image	Textile description	Making Process
	<p>Content: recycled merino/possum Black colourway Grey/Black marl colourway</p> <p>Yarn 2/150 Tex Yarn 1/150 Tex</p>	<p>Black colourway and grey colourway commercially spun into Black 1/150 tex yarn and Grey/Black marl 2/150 tex yarn Both knitted on the Shima Inlay machine (2/150 tex as inlay) Knit steamed</p>
	<p>Content: recycled merino/ possum and virgin silk georgette</p> <p>Black colourway Black silk 1 black batt</p> <p>Total fabric weight 42g per sqm</p>	<p>1 black batt layered lengthways on virgin silk straight of grain</p> <p>Felted 10 times on needle felter ½ needle speed ¾ roller speed</p> <p>Wet nuno felted Pressed</p>

	<p>Content: recycled merino/possum Grey colourway</p> <p>Yarn 1/150 Tex</p>	<p>Grey colourway commercially spun into 1/150 tex yarn Knitted on the Shima Seiki machine Knit steamed</p>
	<p>Content: recycled polyester and wool Black colourway mixed with naturally black and grey virgin Polesworth fibres</p> <p>4 x batts</p> <p>Total fabric weight 132g per sqm</p>	<p>4 x batts layered cross-hatched directional 2 Black and 2 Grey Felted 10 times on needle felter <math>\frac{3}{4}</math> needle speed <math>\frac{3}{4}</math> roller speed Rollers turned off and needled in one area to make dotted pattern Die cut shape and sewn side seams Pressed Leather handles riveted on</p>
	<p>Content: recycled polyester and wool Black colourway mixed with naturally black and grey virgin Gotland fibres</p> <p>4 x batts Total fabric weight 132g per sqm</p>	<p>4 x batts layered cross-hatched directional Black and grey layered by hand to achieve change in colour 2 Black and 2 Grey Felted 15 times on needle felter <math>\frac{3}{4}</math> needle speed <math>\frac{3}{4}</math> roller speed Pressed Die cut shape Sewn together and filled</p>



Image	Textile description	Making Process
	<p>Content: recycled merino/possum Black colourway Grey/Black marl colourway</p> <p>Yarn 2/150 Tex Yarn 1/150 Tex</p>	<p>Black colourway and grey colourway commercially spun into Black 1/150 tex yarn and Grey/Black marl 2/150 tex yarn Both knitted on the Shima Inlay machine (2/150 tex as inlay) Knit steamed</p>
	<p>Content: recycled merino/possum Black colourway</p> <p>Yarn 1/150 Tex</p>	<p>Black colourway commercially spun into 1/150 tex yarn Knitted on the Shima Seiki machine lace pattern Knit steamed</p>
	<p>Content: recycled merino/possum Black colourway Grey colourway</p> <p>4 x batts</p> <p>Total fabric weight 152g per sqm</p>	<p>4 x batts layered cross-hatched directional 2 Black and 2 Grey Felted 15 times on needle felter <math>\frac{3}{4}</math> needle speed <math>\frac{3}{4}</math> roller speed Pressed</p>





	<p>Content: recycled polyester and wool Black colourway mixed with grey virgin Gotland wool fibres</p> <p>4 x batts</p> <p>Total fabric weight 132g per sqm</p>	<p>4 x batts layered cross-hatched directional Felted 15 times on needle felter <math>\frac{3}{4}</math> needle speed <math>\frac{3}{4}</math> roller speed Pressed Die cut shapes Sewn together and filled Tassels from original garment</p>
	<p>Content: recycled merino/possum Black colourway Grey/Black marl colourway</p> <p>Yarn 2/150 Tex Yarn 1/150 Tex</p>	<p>Black colourway and grey colourway commercially spun into Black 1/150 tex yarn and Grey/Black marl 2/150 tex yarn Both knitted on the Shima Inlay machine (2/150 tex as inlay) Knit steamed Sewn into cushion shape and filled</p>



Image	Textile description	Making Process
	<p>Content: recycled merino/ possum Grey colourway White colourway</p> <p>4 x batts</p> <p>Total fabric weight 132g per sqm</p>	<p>4 x batts layered cross-hatched directional 2 White and 2 Grey Felted 15 times on needle felter <math>\frac{3}{4}</math> needle speed <math>\frac{3}{4}</math> roller speed Rollers turned off and needled in one area to make dotted pattern, pattern repeated Pressed</p>
	<p>Content: recycled polyester and wool mixed with grey virgin Gotland wool fibres Black colourway recycled merino/ possum</p> <p>8 x batts</p> <p>Total fabric weight 286g per sqm</p>	<p>4 x black batts layered cross-hatched directional Pre Felted 3 times on needle felter <math>\frac{3}{4}</math> needle speed <math>\frac{3}{4}</math> roller speed 4 grey batts pre-felted and cut into rectangles placed in herringbone pattern on black prefelt Felted 15 times on needle felter <math>\frac{1}{2}</math> needle speed <math>\frac{1}{2}</math> roller speed Pressed</p>







	<p>Content: recycled polyester and wool          Black colourway mixed with grey virgin Gotland wool fibres</p> <p>4 x batts</p> <p>Total fabric weight          132g per sqm</p>	<p>4 x batts layered cross-hatched directional</p> <p>Felted 15 times on needle felter</p> <p><math>\frac{3}{4}</math> needle speed</p> <p><math>\frac{3}{4}</math> roller speed</p> <p>Pressed</p> <p>Die cut shapes</p> <p>Domes added</p>
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Image	Textile description	Making Process
	<p>Content: recycled polyester and wool Black colourway mixed with naturally fawn virgin Polesworth fibres</p> <p>4 x heavy weight batts</p> <p>Total fabric weight 204g per sqm</p>	<p>4 x batts layered cross-hatched directional Felted 15 times on needle felter <math>\frac{3}{4}</math> needle speed <math>\frac{3}{4}</math> roller speed Pressed</p>
	<p>Content: recycled polyester and wool Black colourway mixed with naturally dark brown virgin Polesworth fibres</p> <p>4 x heavy weight batts</p> <p>Total fabric weight 204g per sqm</p>	<p>4 x batts layered cross-hatched directional Felted 15 times on needle felter <math>\frac{3}{4}</math> needle speed <math>\frac{3}{4}</math> roller speed Pressed</p>

	<p>Content: recycled polyester and wool Black colourway mixed with naturally dark brown virgin Polesworth fibres</p> <p>4 x heavy weight batts</p> <p>Total fabric weight 284g per sqm</p>	<p>4 x batts layered cross-hatched directional Felted 15 times on needle felter <math>\frac{3}{4}</math> needle speed <math>\frac{3}{4}</math> roller speed Pressed Fabric has been hand smocked giving it a 3 dimensional effect</p>
	<p>Content: recycled merino/ possum brown colourway mixed with naturally fawn virgin Polesworth fibres</p> <p>4 x heavy weight batts</p> <p>Total fabric weight 204g per sqm</p>	<p>4 x batts layered cross-hatched directional Pre Felted on needle felter <math>\frac{3}{4}</math> needle speed <math>\frac{3}{4}</math> roller speed Wet felted over a plastic shaped resist to form 3 dimensional shape Die cut holes Light fixtures handsewn in place</p>

	<p>Content: recycled polyester and wool          Black colourway mixed with naturally dark brown and fawn virgin Polesworth fibres</p> <p>4 x heavy weight batts</p> <p>Total fabric weight          204g per sqm</p>	<p>4 x batts layered cross-hatched directional          Felted 15 times on needle felter  <math>\frac{3}{4}</math> needle speed  <math>\frac{3}{4}</math> roller speed          Pressed          Die cut shapes          Domes added to baskets</p>
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