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The implications for design and industry are broad. Firstly that while this thesis outlines garment design strategies, and broader – company-wide – approaches that can work to reduce waste in a given context, this research finds that a holistic transformation of the internal design and management processes of the industry is required for them to be successful. In response, theoretical models have been developed which seek to articulate the constraints, roles and actions of design within broader company practices, while contextualising these within the economic system it operates. It is clear that reducing waste will only have a minor positive effect on the environmental outcomes unless we also reduce consumption of raw materials through reducing yield or reducing consumption – ideally both. These findings and models point towards a necessary recalibration of the industry as a whole – small changes are not enough as the existing methods, processes and ethos are deeply embedded, and its agents are resistant to change. The results concur with previous research and conclude that a fundamental shift in thinking is required – one that prioritises a different set of constraints to those the industry and society currently focus on – in order to make the rapid and meaningful change necessary.

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UNIVERSITY OF BORÅS STUDIES IN ARTISTIC RESEARCH NO 29 2019

ZERO WASTE DESIGN THINKING

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THE SWEDISH SCHOOL
OF TEXTILES
UNIVERSITY OF BORÅS

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Licentiate thesis

Cover image: Simplified Zero Waste Design Thinking model

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ABSTRACT

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This research explored methods of eliminating textile waste through utilising zero waste pattern cutting to expand the outcomes possible within industrial contexts and speculates as to the implications for the wider industry and society. Employing an experimental and phenomenological approach, this thesis outlines the testing of known strategies in the context of industry and responds with new emergent strategies to the challenges that arose. A series of interviews were conducted with designers who have applied zero-waste fashion design in an industry context – both large and small scale – to unpack the strategies used and contextualise the difficulties faced. The findings that emerged from the iterative design practice and the experience of working within the field tests inform the surrounding discussions and reflections. This reflection brings into sharp relief the inherent conflicts that exist within the fashion system and has led to the development of a series of theoretical models.

The implications for design and industry are broad. Firstly that while this thesis outlines garment design strategies, and broader – company-wide – approaches that can work to reduce waste in a given context, this research finds that a holistic transformation of the internal design and management processes of the industry is required for them to be successful. In response, theoretical models have been developed which seek to articulate the constraints, roles and actions of design within broader company practices, while contextualising these within the economic system it operates. It is clear that reducing waste will only have a minor positive effect on the environmental outcomes unless we also reduce consumption of raw materials through reducing yield or reducing consumption – ideally both. These findings and models point towards a necessary recalibration of the industry as a whole – small changes are not enough as the existing methods, processes and ethos are deeply embedded, and its agents are resistant to change. The results concur with previous research and conclude that a fundamental shift in thinking is required – one that prioritises a different set of constraints to those the industry and society currently focus on – in order to make the rapid and meaningful change necessary.

CONTENTS

FOREWORD

The 2018 UN climate report (IPCC, 2018) states that we have approximately 12 years to make significant systemic and social changes to all facets of human activity; otherwise we risk catastrophic climate change, leading to ecosystem, financial and social collapse. The fashion and textile industry is a massive, globalised and complex system. In such a system holistic change is difficult – but change we must.

The waste hierarchy, developed from Lansiks Ladder (1978) states that before landfill or incineration, and before recycling, we must first prevent the creation of waste. The fashion industry is responsible for the production of between 55 and 92 million tons (Kerr & Landry, 2017) of waste every year based on 2015 consumption – a figure which is expected to grow significantly as consumption increases. Waste is most often treated as a management problem, and not as a design problem. Zero waste fashion design is concerned with reducing or ideally eliminating textile waste in the production of garments, in my case through the use of zero waste pattern cutting and design techniques. Past research has been to investigate the methods and expressions possible when waste is considered in the context of design. The research outlined in this licentiate sought to apply existing knowledge in the context of the garment industry, and then in the context of non-garment form design – furniture design. The research seeks to provide insights into the opportunities and limitations of zero waste design practice in the context of the current linear economy and speculate as to its function in the proposed circular economy.

When I began my PhD in early 2017, I believed that we could change the system from within by modifying some of the systems and processes used. I worried that it might be unreasonable to expect wholesale systemic change from such a massive, complex and influential industry, and instead, we needed incremental and 'realistic' change that would not frighten industry too much. This licentiate traces my evolution from industry apologist to something a little more radical.

Fig. 1: Zero + One (2016) was a collaboration between McQuillan and One piece garment designer Deb Cumming. In this three piece series (only one is shown here) they collaborated at the intersection of their practices, seeking new expressions and methods. ©Bonnie Beattie

Seeking new methods and aesthetics

I came into this PhD from a background of 15 years exploring zero waste pattern cutting as a design methodology. In 2009 I presented (*Using design practice to negotiate the awkward space between sustainability and fashion consumption,* McQuillan 2009) some of the previous four years of my research into this area, discussing my explorations into possible methods for making fashion without making waste and the mindset required to work effectively in this way.

My early explorations were concerned with finding new methods and expressions. I explored combinations of conventional processes such as the use of standard garment blocks (*Wolf/Sheep*, 2009) and drape processes (*War/Peace*, 2010) shown in Fig. 2. In the *TwinSet* (2011), shown in Fig. 3, and *Twinset: Yield* (2011) I combined multiple garments in a single zero waste pattern in order to better utilise the negative space from one garment pattern for the creation of another. Challenging the locus or origin of design ideas within fashion design was a focus of *VOID* (2012) which explored the idea of tabula rasa, or designing from a 'blank slate'.

Fig. 2: War/Peace (2010) explored the use of two dimensional typographic elements to drive the development of the draped three dimentional form.

FOREWORD

In *Wolf/Sheep* (2009), *War/Peace* (2010) and *Twinset: Yield* (2011), I explored the use of textile print design in combination with zero waste garment design utilising a simultaneous design process. In *MakeUse* (2015), shown Fig. 4, this was extended further, and the collaborative team of graphic, textile and garment designers explored the use of print and digital embroidery to assist the maker in constructing the form and self finish the cut edges.

I collaborated with Julian Roberts and Timo Rissanen in *The Cutting Circle,* to develop new methods at the intersection of our different practices. In *Fashion Thinking – Creative Approaches to the Design Process,* Fiona Dieffenbacher (2013) refers to the generic idea of a fashion design process as methods of "research – sketch – flat pattern/ drape – fabrication – make". In our paper *The Cutting Circle: How Making Challenges Design* (McQuillan, H., Rissanen, T., & Roberts, J. 2013) we discussed our collaborative attempts to challenge how making and design are taught within many fashion contexts, and we began to explore zero waste design as a holistic practice. In *Zero + One* (2016), Deb Cumming and I explored the intersections of our design practices, seeking to apply the unconventional, multi-axis perspective of the body that many one-piece patterns have to find new processes and expressions for zero waste design (see Fig. 1).

I began to explore the intersections of zero-waste practice and how people use their garments – what Dr Kate Fletcher calls the craft of use (2016). In MakeUse (2015) my goal initially was to exploit the opportunities of zero waste in the context of the craft of use, specifically the fact no part of the fabric used to make the garment is lost, and can, therefore, be used to alter or repair itself if desired. Over time the project evolved (2016) to explore the creation of a user-modifiable open source zero waste design system (See appended Paper I for more detail).

In the context of the industry, I have briefly explored the application of zero waste in sportswear for two leading brands in 2012 and 2014, and up-cycling in Space Between with Jennifer Whitty (2012-2014) and I have regularly presented my research to industry audiences. The application of zero waste in the industry is an area that needs more in-depth investigation.

In addition to foundational research, I have taught zero waste design to diverse audiences globally: At Aalto University. (2012), Re:Design, Melbourne, Australia. (2012), Commune, RMIT, Melbourne, Australia. (2012) I explored my initial

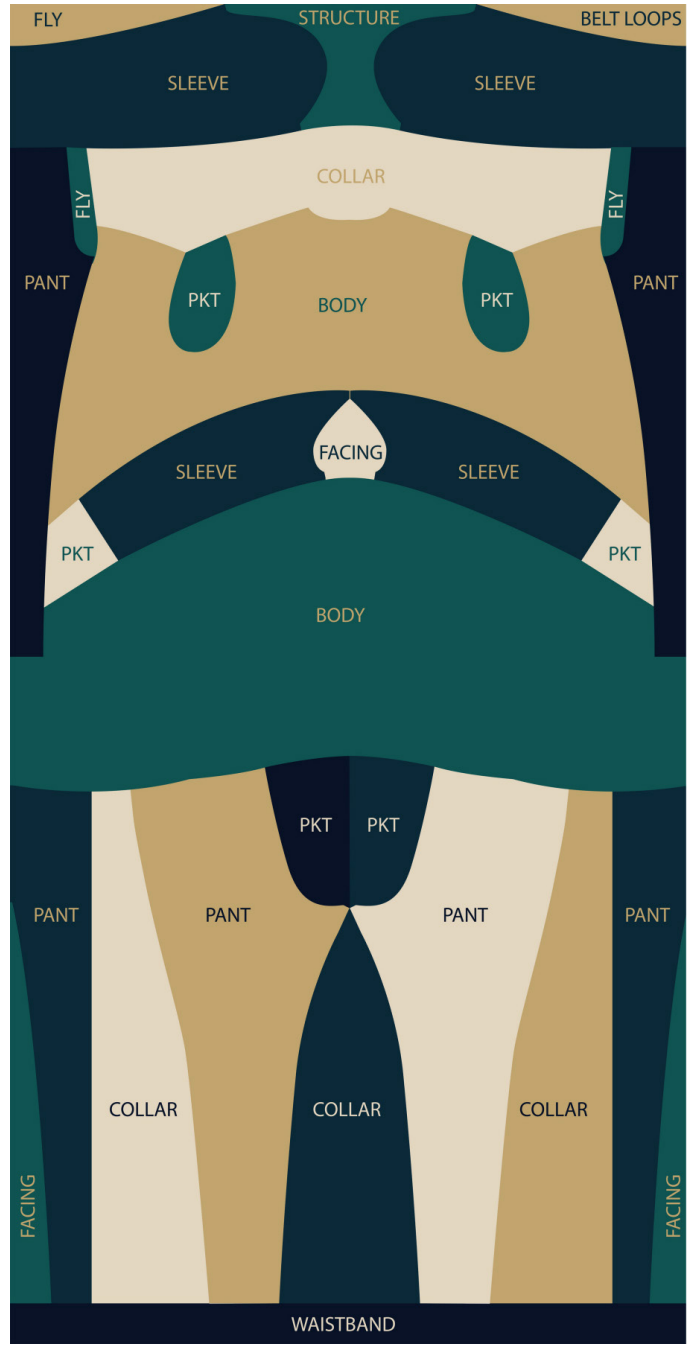


Fig. 3: Twinset two-piece suit (2011) explored the opportunities to be found when embedding two cloely related garments, in this case the jacket and trouser of a mens suit, into a single zero waste pattern.

practices, divided into three approaches called Cut and Drape, Planned Chaos and Geo Cut. Later I developed a more precise step by step method for understanding zero waste design approaches first through Local Wisdom: WGTN. (2014), and later through MakeUse (Fig. 4). This technique was taught at TED MA Masterclass, University of the Arts London (2013 and 2016), and Make/Use Masterclass and Lecture, De Young Museum, Parsons, Swedish School of Textiles, Borås. (2016)

In YIELD: Making fashion without making waste held at The Dowse Art Museum, Wellington and the Textile Art Centre, Brooklyn, New York (2011), Timo Rissanen and myself curated the first exhibition surveying contemporary zero waste practitioners. We worked together again to co-author the first book on the subject Zero Waste Fashion Design (2016). My research has sought to both expand on the methods and expressions possible in the context of zero waste while discussing the broader implications of the practice in the context of the industry and education.

The last 15 years of research in this field has lead me to gain a deep understanding of the methods and processes of zero waste design in a range of contexts. The lack of progress towards the application of these approaches more broadly in education and industry is frustrating. My practice also suggests to me a fundamental difference in this way of working that at times has felt like an unwelcome hindrance. However, it seems that its value might be in this difference; after all, we know that the way the fashion industry currently does things is unsustainable and wasteful. Perhaps a different way of thinking and working, one that places value on a different hierarchy is precisely what is needed.

Fig. 4: The MakeUse (2015) garments shown here are a possible outcome of the user modifiable zero waste design system developed by a collaborative team. Each garment is only a suggestion possible from the design process, a methodology which sought to make zero waste design more accesible. ©Bonnie Beattie.

OUTLINE

This licentiate comprises the first of two related stages of the research undertaken during this PhD. The weaving discussed in Appended Papers II and III (see Appendix) is not discussed here. Instead, this licentiate lays a foundation for a proposed shift in thinking about the role of zero waste design in industry and education.

Following the foreword – which serves to provide the personal research context this licentiate arises from – the text then provides a background to the related fields in which the research operates in, and methods and approaches used to expand upon the field. Through the field tests and interviews, the research seeks a deeper understanding of the issues the industry faces. This licentiate then reflects on the field tests and interviews to begin to conceptualise the value of waste in our current linear economy and speculates as to its place in the proposed circular economy. This reflection leads to the development of a series of theoretical models of zero waste design and finally concludes that for zero waste design to have a positive impact on the industry, it needs to be considered as a way of thinking through design, and not merely a method or process.

Chapter One

This chapter outlines the environmental, economic context the research takes place within while outlining existing research in the field of zero waste design, including academic research, examples in the fashion and furniture industry as well as key directions for investigation such as the nature of constraints and the use of digital software.

Chapter Two

The chapter provides a theoretical and methodological framework for the research outlined in this thesis. The research process is theorised, visualised and described in three subsections. Beginning with experiencing zero waste in the industry, this covers the use of an experimental design methodology in the context of field tests and the phenomenological and analytic approach needed for both the field tests and interviews. Next, the chapter describes the reflection process using an iterative, reflective approach in the context of designerly thinking in practice. Lastly, the research is underpinned by an understanding of design as “future making” and advocates for a transition design approach to aid in the conceptualisation of actions and models for change.

OUTLINE

Chapter Three

This chapter describes three field tests in which waste reduction strategies are applied in the design and marker making processes. It also analyses a series of four interviews with designers who have recently explored zero waste in the industry. The chapter begins by outlining the nature of the field test and how they progressed, and later reflects on the implications each has on design practice in the given context. Interviews were conducted with a range of designers within companies who had attempted zero waste in order to expand on my observations in the field tests.

Chapter Four

This chapter comprises of four interviews with designers who have implemented zero waste strategies successfully in a range of company settings. Their responses are reported and reflected on in order to expand on the observations made in the field tests.

Chapter Five

In this chapter, the value of waste and the relationship between constraints and waste in response to the interviews and field tests is reflected upon. Additionally, the chapter speculates about the role of the designer, and the 'value' of waste in the context of the proposed circular economy, and how the experience in the field tests resulted in a recalibration of the ongoing research.

Chapter Six

This chapter presents a series of theoretical models for zero waste design. The models are proposed as a 'lens' that can be useful when attempting to develop an alternative mindset regarding resource use in the context of product design, development and manufacture. Beginning with the broadest social and environmental contexts, the models allow for an alternative framework for holistic design to develop that considers all the factors that impact on or are informed by design.

Chapter Seven

This chapter concludes this stage of the PhD research, calling for a shift in thinking about the use of zero waste design and sustainability in the industry. It summarises the primary outcome of this research – the establishment of a new lens to view through called Zero Waste Design Thinking. Lastly, it articulates the limitations of the research, areas for further study are proposed, and the proposed trajectory for the continuation of the PhD research is discussed.

List of Publications

Appended papers

I. McQuillan, H. Martin, J., Menzies, G., Bailey, J., Kane, K. and Fox, E., 2018. 'Make / Use: A System for Open Source, Zero Waste Fashion Practice', in *Fashion Practice.* Routledge, pp. 1–27. doi: 10.1080/17569370.2017.1400320.

II. McQuillan, H., 2019. 'Waste, so what ? A reflection on waste and the role of designers in a circular economy.', *Nordic Design Research Journal.* Espoo, Finland, 8(8), pp. 1–9. Available at: http://www.nordes.org/opj/index.php/n13/article/view/485/456.

III. McQuillan, H., 2019. 'Hybrid zero waste design practices. Zero waste pattern cutting for composite garment weaving and its implications', in *The Design Journal,* Taylor and Francis.

Conference presentations

McQuillan, H., 2019. Hybrid Zero Waste Design at *EAD Running with Scissors,* Dundee.

McQuillan, H., 2019. Waste: So what? *At Who Cares? NORDES 2019* Helsinki.

Exhibition

McQuillan, H. and Cumming, D., 2018. Zero + One in *Unmaking Waste*, Australia, 2018

Workshops and presentations

Making space, without waste. Kolding University, Denmark, 2017.
Making space, without waste. Glasgow School of Art, Scotland, 2018.
Zero Waste in industry. Glasgow School of Art, Scotland, 2018.
MakeUse workshop, Queensland University of Technology, 2018.
Zero waste master class, TAFTA, Melbourne, Australia, 2018.

1. BACKGROUND

This chapter outlines the environmental and economic context the research takes place within while outlining existing research in the field of zero waste design. It includes an overview of contemporary academic research in the field, examples of zero waste design in the fashion and furniture industry, as well as key directions for investigation such as the nature of constraints and the use of digital software.

Economic and Environmental Context

Despite the fact humans only account for about 1/10000th of the world's biomass (Bar-On, Phillips. & Milo, 2018), we are impacting on the geological record to such an extent that we are now in a new geological epoch – the Anthropocene (Steffen et al., 2011). The adverse effects of linear resource-extraction-to-waste behaviours are becoming increasingly explicit with extensive biodiversity loss, and climate change tracking for at least a 1.5 degree warming (IPCC, 2018) even if rapid and radical changes to our social, economic and manufacturing systems are made.

For the last century, focus of the economic system has been on encouraging the growth of the production and consumption of products with only a little concern for the broader impacts of extraction and waste. Walter R. Stahel (2018) wrote that "the Industrial Revolution enabled society to overcome scarcities of shelter, food and objects; mass-production turned scarcities first into plenty, then abundance and a plethora of waste". In the linear economy, resources flow primarily in one direction, from the extraction of raw materials (such as water, fibre, minerals, oil, coal), through production, to consumption and finally discarded as waste. The majority of industry's design, production, retail and waste management systems have been developed to fit this linear model. The result in the fashion industry is the vast scale of extraction of raw materials in the form of oil and fibre, wasteful methods of production of garments that are often never purchased, leading finally to an astonishing accumulation of waste.

Stahel (ibid) argues that there has been a preoccupation with "waste management policies instead of efficient resource use and waste prevention", an approach that has seeming led to a limit on the degree of positive change possible within many industries, while also pointing towards the ultimate goal of zero waste design practices. He continues by challenging designers who in the past may have just designed products to primarily meet aesthetic goals, to "consider the duration, mobility and systems-relevance of objects in the CIE, focussing on designing tools, not toys; function, not fashion." This alternative paradigm draws from the seminal work Cradle to Cradle (McDonough and Braungart, 2010) which defines cycles of biological and technical nutrients and began to explore the central ideas of the circular economy.

BACKGROUND

Circular Economy

Geissdoerfer et al. (2017) define the Circular Economy (CE) as a "regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops". The CE definition offered by Giessdoerfer seems to suggest that the minimising of inputs and outputs is 'enough'. The dominant business-led discourse around 'radical' developments such as the circular economy and circular textiles seem to suggest there is little need to modify the behaviour of consumers or challenge growth-centric business models, because it is assumed that technology – such as the development of a 100% recycled circular economy – will prevent climate oblivion. However, research indicates that we need to develop and move rapidly towards more sustainable methods and solutions based on a genuinely circular economy (Tukker and Tischner, 2006; MacArthur, 2013), which does not prioritise growth in consumption (Brooks et al., 2018).

If the CE is fundamentally concerned with imagining an economy made up of products and services without end and without waste – then the very concept of waste is reimagined. Martin Charter in Designing for the Circular Economy (2018) writes that we need to "design and implement new systems that focus on maximising materials value in the system for the longest time period, where waste is 'designed out' from the beginning". Charter points to another perspective of CE which is relevant to this research, that it potentially turns the traditional 'waste hierarchy' on its head. In the CE it seems that resource consumption over time is most important, rather than waste management. Charter goes on to argue that from an infrastructure perspective we require a two-pronged approach – "focus on 'zero waste' and maximising value in the system over time". He identifies that this will mean "significant process re-engineering; (...) requiring product and behavioural changes on a major scale." Profound holistic transformation is required. In the context of zero waste design where the goals have primarily been to reduce waste, and not necessarily reduce resource use, this mirrors Rissanen's assertion that zero waste design is not enough (2013).

Hope that a CE focused on recycling will solve our problems, without the need for a holistic change is commonly held by industry and citizens alike. Fellner et al. (2017) and Brooks, et al. (2018), argue that these simplistic notions – even if a theoretical 100% recapture of materials is achieved – are flawed. The 2017 study by Fellner et al. examined what level of greenhouse gas (GHG) emissions reduction we might expect if we recycled 100% of the materials used across a wide range of industries: plastic, aggregates, iron, steel, aluminium and paper/board. They found that even with a theoretical (and impossible) 100% recapture and recycling rates it would only generate a 1.6% reduction in GHG emissions. This is because the industries examined already recycle at relatively high rates, the materials are often in permanent (or near permanent) use, so material throughput is low, and growth is still very high, so replacing new with recycled material will not come close to meeting the increase in demand. The report concludes that growth in material use needs to flatten and stabilise.

One reason increases in efficiency and material recapture are 'not enough' is because it often actually increases production and consumption, as the raw materials saved through efficiency become drivers for growth – a phenomenon called the 'rebound effect'. Grosse (2011) argues that "what we call economic growth is the long history of the diversion of efficiency gains into production increases." There seems to exist a hope for a circular economy whereby a perpetually expanding market is fed by ever decreasing raw material consumption, therefore removing the need to limit growth. It seems clear, however, that without limits to growth it is likely that our longed-for closed circular economy will instead manifest as an ever-expanding spiral economy.

In Kate Raworth's Doughnut Economics (2017), the fundamental problem with our obsession with growth is laid bare. She conceptualises all human existence as successfully functioning between a "social foundation" and an "ecological ceiling" and demonstrates how our obsession with economic growth within a linear economy has led us to transgress both. She argues that we treat GDP and the pursuit of growth as essential truths, when in fact they are relatively recent additions to our understanding of economics. She advocates for a genuinely circular model seeking to 'thrive in balance' in the 'doughnut' between our ecological ceiling and social foundation. Raworth was a contributor to the Circularity Gap (de Wit et al., 2019) which reports on a world which is only 9% circular, and this figure is in a negative trend. There is much left to be done.

The allure of the Circular Fashion Economy

Due to its wastefulness, size and complexity, the fashion industry has often been the focus of research into enabling the circular economy. From the position of raw materials, systems and design outcomes, garments are a particularly problematic case for material circularity (Charter, 2018). This is due to the mixing of biologi-

cal and technical materials (through mixed fibres such as cotton and elastane, and the use of metal or plastic trims) in individual products making fibre recycling challenging to do without the reduction of quality (Peters, G. et al. 2018), and automated recycling almost impossible. Researchers Rebecca Earley and Kate Goldsworthy have been exploring concepts of circularity in the fashion and textiles space for many years (Goldsworthy and Telfer, 2012; Earley and Goldsworthy, 2015; Earley, 2017; Goldsworthy, 2017), first in their work with Textile Environment Design and later in its incarnation at Centre for Circular Textiles.

The fashion industry itself seems very interested in ideas of the circular economy. H&M says that they aim to "become 100% circular" (H&M Group Sustainability Report 2017), by exploring solutions that create a close-loop for textiles, where "unwanted clothes can be recycled into new ones" (Ellen MacArthur Foundation, 2019). Other large companies such as Burberry, Gap Inc and Nike have similar goals and with H&M are all members of the Make Fashion Circular organisation (formerly known as the Circular Fibres Initiative) which seeks to invest in technological solutions to fibre recycling. Perhaps unsurprisingly, there is little discussion in these industry contexts on the way growth limits the effectiveness of a circular economy.

The circular economic model embraced by industry is critiqued by Brooks et al. (2017) who argue that by focussing on closed-loop recycling, these businesses actually "privilege the status quo and technological change." They argue that such "optimistic" solutions to the challenges facing us indicate adherence to the notion of a "good Anthropocene," whereby it is imagined we adapt and prosper in human-centered, "utopian eco-modernist systems". Brooks et al. write that the focus of environmentalists, on the other hand, has been to encourage us to change our consumption habits – buy less, pay more. However, "because fundamentally changing consumption patterns represents a threat to one of the logics that underpins capitalism: the need for the market to grow and economic activity to ever expand or face crisis" this is a strategy which has so far failed to gain much traction.

According to the United Nations Sustainable Development Goals (SDGs, 2015), CE is relevant to a number of the 17 goals, e.g. Goal 12 – Responsible Consumption and Production. A vital pillar of the circular economy asks that we design-out waste, but the focus of this has tended to occur in the product use stage and through enabling recycling. There is little drive to design out manufacturing waste beyond what is already done automatically by computer software (primarily though marker-making software) because space is not provided for it to be fully explored in the deeply embedded systems and methods for cut and sew construction.

Fig. 5: Garment factory line, workers wear colour coded uniforms based on what section they work in.

Zero waste design

Research in the field of zero waste design has been located primarily in the fashion context. Unlike the majority of fashion design practice – where the goal is primarily to introduce a difference (Hallnäs, 2009) – zero waste fashion design could be seen as a practice concerned with solving a problem. When engaging with the zero waste redesign of an existing garment – we know its overall desired form, but we strive to achieve something similar without making so much waste – so the design problem is the waste. Aside from my own investigations (see Foreword), research has primarily focussed on decoding the actions of the zero waste designer/pattern-cutter to identify design methodology (Rissanen, 2005, 2010, 2013; Lumsden, 2010; Gwilt and Rissanen, 2011; Niinimaki, 2013; Townsend and Mills, 2013; Carrico and Kim, 2014), the relevance of zero waste fashion design to sustainability goals such as timelessness and waste elimination (Rissanen, 2011; Niinimaki, 2013) and implications when teaching (Noronha Valle and Assis, 2018). In response to the climate crisis and the associated waste problem, zero waste design cannot only eliminate material waste but can also reduce the yield (volume of resources required) for a given design. However, while it can contribute to the reduction of industry waste and resource use, eminent zero waste fashion designer and researcher Timo Rissanen (2013, p. 160) states, "Zero-waste fashion design is not 'good' in and of itself," going on to say that we need to examine the system it exists within as a whole in order to make meaningful change. Beyond initial explorations which have occurred, such as in MakeUse (version 1: 2015, and version 2: 2018) and Rissanen's Endurance Shirt (2011), further research needs to explore this fundamental challenge, asking what the current problems are, and what can we do to redesign manufacturing and related systems (as in APOC shown Fig. 6) as a whole.

Fig. 6: APOC by Issey Miyake 2009. Not all APOC pieces were zero waste, however all demonstrate a direct relationship to fabric. © 2019. Digital image, The Museum of Modern Art, New York/Scala, Florence.

Zero waste in the fashion industry

Current examples of zero waste design methods applied in the industry have primarily been within small scale fashion business. Brands such as womenswear brand Study NY and swimwear brand Emroce (see the interview in Chapter 3) exemplify the kind of small companies who make zero waste a core aspect of their business. Their small scale enables them to overcome many of the issues of scale that exist in the larger globalised fashion industry, particularly the impact that hierarchical design systems have in large companies. Eckert & Stacey (2003)observe that for knitwear companies, there is a difference "in how much effort they put into particular activities (…) the more upmarket companies invest more money in the design process, and designers have better opportunities to do research" (ibid. p. 19). This points towards a demarcation that is visible in the application of zero waste in the industry – outside of small companies, examples tend to be within a larger research-intensive company, and manifest at small scale as a one-off garment or capsule collection. Companies which explore zero waste within the context of a one-off garment often only ever develop it to a prototype and do not put it into production, such as David Telfer's 2012 project for Northface – Argentari Jacket. In 2017 COS developed a limited edition collection exploring waste reduction (though not zero waste) through patterncutting for their 10th-anniversary celebrations. The copy associated with the collection included explanations of the relationship between design elements, garment proportions and fabric width – "With the shape of the hem determining the shape of the sleeve heads, the design of this cotton poplin shirt dress uses up any surplus fabric to show the geometric potential of a single length of fabric" – giving insight into their design process. COS Creative Director Karin Gustaffson said at the time "Each look was created like a jigsaw puzzle. The shape was decided based on how best to use the entire width of the fabric so there was no waste. It was a new challenge for us." (in Flanagan, N., 2017). The collection was produced at scale and was available across their stores and online; however, it was only a one-off production. In 2016 German company Hess-Natur developed a zero waste collection with Carolina Carrera based around coats and had a broader zero waste capsule collection between 2016-2017 (see interview). Today only the one zero waste skirt (Fig. 7) is available for purchase suggesting zero waste is not an ongoing design strategy for the company. As with many of the proposed solutions for sustainable or circular fashion, companies seem to be searching for a 'drop-in' solution that does not require significant change to their process. The swapping of one fibre for another is relatively more straightforward than the readjustment of entire supply chains.

Constraints and Zero Waste Design

An understanding of the impact of constraints on design practice is useful when considering zero waste design practice. The most apparent constraint in zero waste design is the width of the fabric and the goal to eliminate waste. Lawson (2006) explored the relationship between the internal and external constraints in design, and the notion of 'decisive constraints' was explored by Mose Biskjaer and Halskov (2014). They write, "we have noticed that certain intentional creative moves that seem counterintuitive or even unwise… in fact turn out to be related to the attainment of radically new solutions." This experience of intentionally choosing constraints leading to innovation is one that I have experienced in my zero waste work regularly. Mose Biskjaer and Halskov attribute two features to the type of decisive constraints that lead to innovation, which are that they are "…rooted in radical decision-making by going against easy and common creative choices as solution alternatives, and they accelerate the design process by pushing it forward in the form of an unexpected leap."(2014, p. 28).

While it is clear that constraints as a methodology can function as a way to generate innovation, it seems there is something else at play in industry's difficulty in implementing zero waste to a larger scale. From an academic 'outsiders' perspective, it seems there is a mismatch between the collaborative and holistic design practices that we knew were needed to develop zero waste designs successfully and the hierarchical, siloed nature of the majority of large scale industry. In a 2017 report by the Global Fashion Agenda (GFA) (Kerr and Landry, 2017) industry workers identified the following barriers to sustainability; short-term thinking, siloed roles, resistance to collaboration, lack of company resources, among others. Contemporary industries tend to have complex supply chains, with materials sourced globally, and critical actions and decisions made independently of others, often in different buildings, cities or countries, using different languages. How can we negotiate the various forces at play in the development of a design when a holistic approach is needed.

Fig. 7: Hess-Natur skirt developed in 2017, still in production at time of publication. ©Hess-Natur

BACKGROUND

Digital 3D design for zero waste fashion practice

One possible emerging aid in the implementation of zero waste design in the industry is the use of 3D modelling technology such as that offered by companies such as Lectra, CLO3D and Optitex. Digital 3D software enables for the simultaneous design of 2D zero waste pattern and the resulting 3D form. This action used to take place primarily in the mind of the designer until constructed in some form as a sample or toile. In the past I have used paper maquettes to do this initial testing, a method that while inexpensive did not adequately convey the material quality of the design. In industry, the relationship between drawing/specification and pattern/sample is relatively linear and one-directional, however, because in zero waste design the pattern is the design and they have a symbiotic relationship, the application of a reciprocal design method to a primarily linear design system is likely to be problematic. Therefore it is proposed that the use of digital 3D software to augment and visualise this relationship could enable the more straightforward application of zero waste design methods into the industry.

Upon learning about CLO3D, it became immediately apparent that this software had the potential to transform my design practice. I began by exploring the application of the software to garment patterns I already knew worked and was able to see how rapidly I was able to generate new design variations from this – a process that in the past would have taken many days now took only a few minutes. Once I began to master the use of the software I explored its use as a method of design genesis in addition to design modification.

In Zero + One (McQuillan and Cumming, 2018)I first developed a draped torso form according to Rickard Lindqvist's Kinetic Garment Construction theories and inputted this into CLO3D to evolve into a zero waste coat (Fig. 9). The use of the software enabled me to see in real time what impact my actions on the 2D pattern had on the 3D form. Rather than having to undergo a time-intensive physical iterative process of alteration/ sample/ alteration/ sample, this occurred entirely digitally and very rapidly. The advantages of this for the speed-obsessed industry were clear. The design of zero waste products that had previously been a risky, time and material consuming process could now be explored with surety, relatively quickly and with minimal material use. This assertion is backed by French zero waste fashion designer Mylène L'Orguilloux who states on her website that the use of 3D software such as CLO3D has enabled her to generate and transform her own zero waste design process rapidly.

Fig. 8: Zero + One digital prototype exploring the intersections of one piece garment cutting and zero waste design methods. With digital 3D tools it is possible to rapidly test design variations for zero waste garments.

The additional benefit of utilising digital prototyping and design tools such as CLO3D is that it can significantly reduce the use of materials for design and sampling. It can replace many of the initial sampling processes and speed up translation from idea to accurate form without the need for cutting cloth.

Zero waste furniture

Outside of the fashion industry, there has been some exploration of zero waste design. Within furniture design most investigation in this field has been within the context of sheet material, probably because unlike sheet material, other industrial manufacturing methods are inherently low waste already (rotational moulding for example). An interesting example is the Four Brothers chair series (Fig. 12) by Seungji Mun. This series of four chairs are similar – like brothers – and are cut from the same dimensioned sheet of ply-wood. The chairs featured in a window display across a range of COS stores to promote their 10th-anniversary collection (which was zero waste). Following a similar approach is the series “inspired by the ingenuity, resourcefulness and values of the Occupy Movement” by furniture company FN. All pieces are produced using Plywood and CNC manufacturing, and the efficiency is listed on the items page in their online shop. New Zealand Furniture designer Glen Catchpool explored a more curvilinear form with his Pare Chair, in which he used sheet material, but thin, moldable veneer rather than relatively inflexible ply. The waste from offcuts is used to grow the mycelium in the space between the veneer layers, allowing him to produce a more complex and curved form.

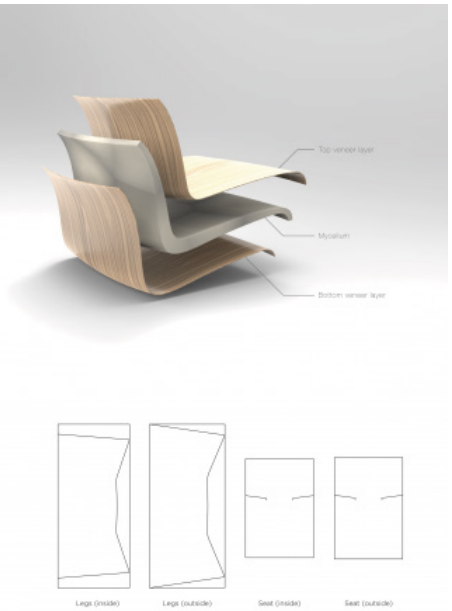


Fig. 9: Pare Chair construction and pattern detail by Glenn Catchpool ©Glenn Catchpool

Two key differences for furniture design that makes zero waste strategies simpler is that there are inter-nationally standardised material sheet sizes, and grading (needing to produce different sizes for the same design) is often not required. Additionally, the relatively slower pace of change (compared to the fashion industry) in the furniture industry means this is a field which has great potential for further zero waste research, and perhaps there are approaches we can build on.

Fig. 10: Chair by FN ©Ken Landauer;

So, what now?

It is clear there is a need for a deeper, applied understanding of the opportunities and limitations of zero waste design practice in the context of industry and how we can educate to enable change. This research seeks to challenge thinking around what zero waste practice can teach us – to question the how and why of garment design, and interrogate some of the commercial industries responses to the environmental crisis we find ourselves in. The research outlined in this licentiate aims to explore new methods and implications of eliminating textile waste from the production of clothing at the pre-consumer stage, specifically through zero waste pattern cutting and design practices. By applying existing knowledge in this area in an identified industry context, it is proposed that new methods and guidelines can be developed to assist the broader application of these waste elimination and reduction approaches.

2. APPROACH AND METHODS

The chapter provides a theoretical and methodological framework for the research outlined in this thesis. The research program for this PhD as a whole takes the form of reflective practice (Schön 1983) as advocated by Kolb (1984) of experience, reflection, conceptualisation and active experimentation. This licentiate traverses the experience reflection and conceptualisation phases.

The research process is theorised, visualised and described in three subsections. Beginning with experiencing zero waste in the industry, this covers the use of an experimental design methodology in the context of field tests and the phenomenological and analytic approach needed for both the field tests and interviews. Next, the chapter describes the reflection process using an iterative, reflective approach in the context of designerly thinking in practice. Lastly, the research is underpinned by an understanding of design as 'future making' and advocates for a transition design approach to aid in the conceptualisation of actions and models for change.

Aim

This experimental practised based design research (Frayling, Koskinen et al. 2008) began by establishing a broad research program (Binder & Redstrom 2006) which aimed to explore new methods and implications of eliminating textile waste from the production of clothing at the pre-consumer stage, specifically through zero waste pattern cutting and design practices. This research sought to apply existing knowledge in this area in an industry context, and develop new methods and guidelines to assist the broader application of these waste elimination and reduction approaches (see Fig. 11 on the following page). However, as the research progressed through the field tests, it became clearer that the research cannot merely be concerned with designing objects or forms, but should also design the systems that this practice operates within.

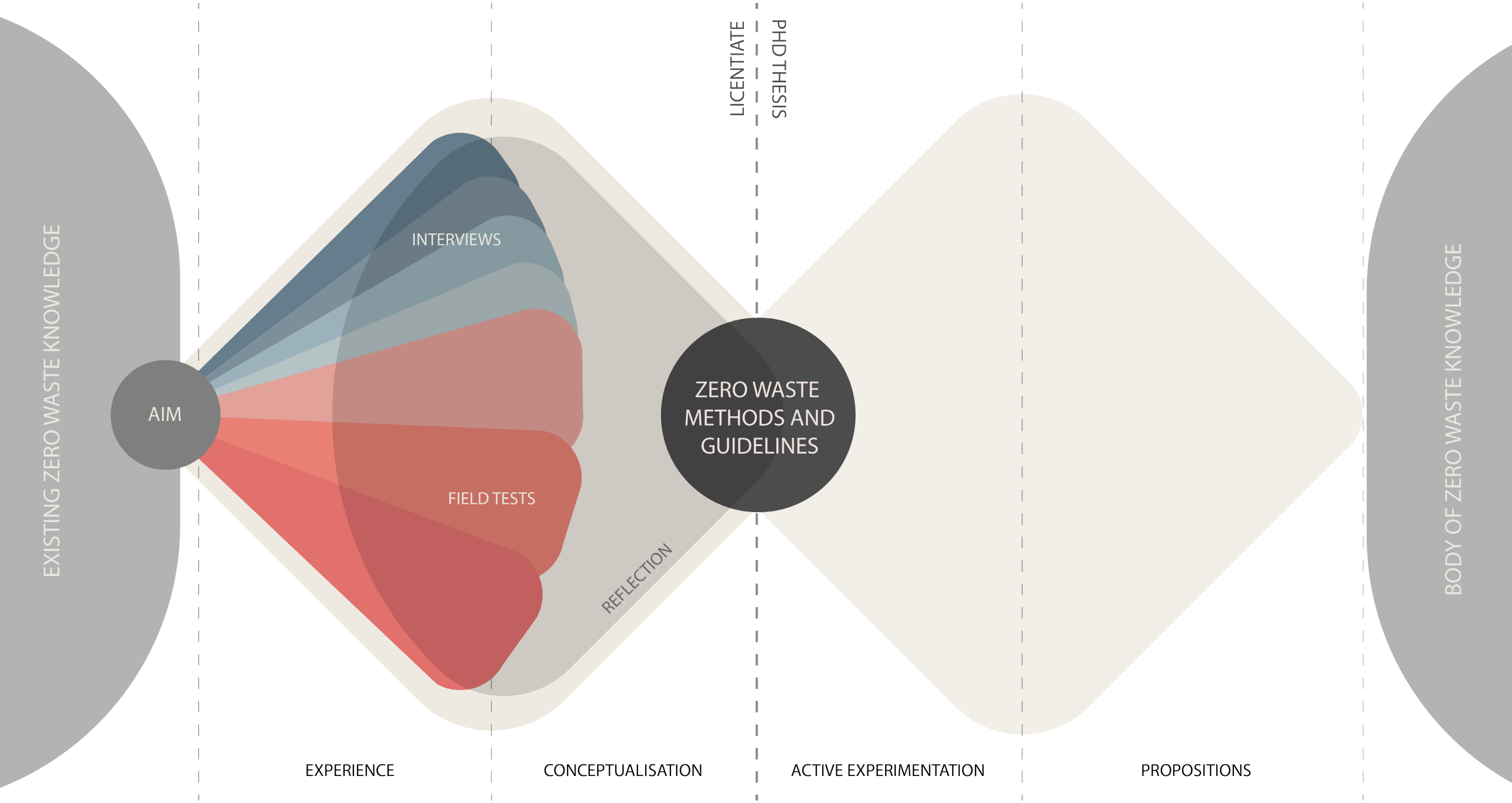


Fig. 11: The initial plan for this research sought to expand on the lack of research into the application of zero waste methods in indsutry. It was imagined that through expe-rimenation in the field, and reflection and articulation of the experience, findings could outline suitable methods and provide guidelines for both industry and future research in the field. This model is developed from the "double diamond" design development process (British Design Council, 2005)

APPROACH AND METHODS

Experiencing zero waste design in the industry

As the majority of academic research in the field of zero waste design practice has occurred in the developmental and theoretical realm, it was important that part of this research sought to apply zero waste practices within a contemporary industry context. Field tests were planned in order to apply previous research 'in the field'. The goal was to experiment with developing zero waste garments within defined industry contexts and report of their progression through the design and production phases so that others may learn from this. The field test context was predefined and controlled by the company. Existing research has already established that when attempting zero waste as an independent researcher, without the existing constraints of an existing design process within an existing company then successful zero waste outcomes can be developed (see Foreword and Background); however, the majority of the fashion industry is not set up or even open to this kind of approach. As outlined in the Background section the kinds of approaches attempted by industry are primarily one-off garments or 'capsule collections' that sit somewhat outside of the existing model – this research seeks to know to what extent zero waste design can be applied within existing industry frameworks and what can be learnt from this experience.

The beginning of this research involved two field tests, of different durations and goals, both within large garment companies which have sizable globalised supply chains. The original intention was to develop 'successful' products within these companies so that these successes could be reported on in this Licentiate so others – be they designers, companies or researchers – might learn from the experience. The third field test was a collaboration in a field outside of the fashion industry in order to understand both the fashion industry and zero waste practice in comparison to a related but contrasted field. Interviews were conducted to gain insight into other designers experience in this field of study.

Experimental Design

Koskinen et al. (2008) describe a design experiment as "pieces of design carried out as a part of a research effort", and clarify that in this process design work is research – the two are inseparable. Furthermore, they describe the Lab, Field and Gallery contexts that design experimentation occurs within. This research is primarily situated in the Field context, which is defined as that which places design practice and outcomes into a "naturalistic setting", however for this research, the field is not society as a whole – the field is the ecology of the company, and to a lesser extent broader industry.

There has been only limited research of the methods utilised by companies when attempting zero waste design. Gathering sufficient empirical data about these methods for comparison is problematic, in part due to the reluctance of companies to share details about processes that can potentially give them a competitive advantage, or embarrass them at their failure, and also due to the small sample size that would be possible even if the information was fully accessible. So employing an experimental design methodology within the identified field has enabled a variety of methods to be tested in order to gain insight into what might be successful.

Products, methods and processes are not the only outcomes of design experiments. As Friedman (2003, p. 521) argues, it is the designers "interpretation and understanding of experience that leads to knowledge. Knowledge emerges from critical inquiry." Combining skills as a designer with a critical perspective on the field enables theoretical models to be built out of the design experiments and surrounding reflection.

APPROACH AND METHODS

Taking a phenomenological perspective

Phenomenology describes experience, and it is always needed when qualitative methods are used. It allows researchers to deal with the realities of the world and identify weaknesses in data gathering. Phenomenology seeks to identify patterns of subjective experience. Hermeneutic phenomenology states that the relationship between event and person will impact on the meaning that is formed and in the context of this research this is the perspective taken.

Field tests and interviews

It is important that when designing research which takes a phenomenological approach, to acknowledge it is impossible to entirely distance oneself from the findings and observations as the researcher is in effect part of the research itself. When reporting on the experience and process of the field tests, I will often use the first person perspective to make explicit that this is my personal experience and reflections of the experiments. This approach has weaknesses, such as the inability to describe both unique experiences and make generalisations – I must be careful about what I conclude from this methodological approach. However, my first-hand experience in the context allows for detailed insights to be gained.

To enable the research to expand somewhat more broadly from the personal observations gained in the field tests, a series of text-based interviews were conducted with designers who have worked to progress zero waste collections or garments through a design and production process. A thematic content analysis method was employed to thematically code the information in the interviews and observations from the field tests. According to Braun & Clarke (2006) a theme “captures something important about the data in relation to the research question, and represents some level of patterned response or meaning within the data set.” In the field tests and interviews, similar themes emerged again and again, and this coding informed the development of the reflections and theoretical models.

Reflection on the implications

Reflection occurs at all stages of the design program. In the field tests, the experience and outcomes are reflected on in order to develop and report on possible solutions, while also planning subsequent design actions and conceptual moves. Throughout every stage of the experimental design work, reflection on the outcomes and implications enables a deeper understanding of the process and outcomes, and what it may mean concerning both the design and the context in which it is situated. A crucial moment of reflection occurs through the interviews, which were undertaken after the field tests, and sought to understand the context within which the field tests operated while providing more significant insights into potential strategies. The interviews were then analysed alongside the field tests and both were used to develop the zero waste design models.

Reflective Practice

This research program utilises experimentation as a core of the design practice. “In its most generic sense, to experiment is to act in order to see what the action leads to” (Schön 1984). Hannula et al. (2005) advocate that design research should be able to communicate “where [the research] is coming from, where it stands at this precise moment, and where it wants to go”. In action, this reflective practice took the form of design practice within the field tests followed by broader speculation of the future of the fashion industry in response to the experience in the field tests, and the development of the theoretical models to articulate these observations.

Iterative design practice

In the context of all three field tests, and through the reflection on these and development of the theoretical models, a non-linear iterative design practice occurred. The progressions from experience, to reflection to action, was not always straightforward or clear, and sometimes many months passed between insights. Additionally, all field tests were collaborative, a factor that leads to a greater depth of understanding but also, therefore, more problems needing to be solved.

APPROACH AND METHODS

Designerly Thinking in Practice

Johansson-Sköldberg & Woodilla, (2013) suggests a combination of Schön, Buchanan, Lawson and Cross's thoughts on design thinking could provide a structure that places "'designerly thinking in practice' in contrast to the rationalised, systematic study of design by Simon, and the meaning-creation of Krippendorff's hermeneutic approach". In the development of the theoretical models, this research takes an approach similar to Buchanan's (1992) use of "placements" and to examine the nature of the problems and constraints. Buchanan defines placements as "the quasi-subject matter of design thinking, from which the designer fashions a working hypothesis suited to special circumstances". In the case of this licentiate, the placement is 'zero waste design'.

In *How Designers Think: The Design Process Demystified* (1980), Bryan Lawson wrote about External and Internal constraints in design. There are established sets of acceptable or desirable constraints for fashion design which while they vary from designer to company to project, are consistent in that they do not usually include consideration of material waste. In fact, it would generally be considered an undesirable constraint. The existence of these constraints is explicit in zero waste design, and so Lawson and Cross's "focus on the designer's specific awareness and abilities" enables the perspective as a designer practising within the constraints of zero waste to uniquely inform a way of seeing and thinking about the industry.

The fashion industry can be conceived as a series of interconnected problems, with an enormous economic and environmental burden, multiple, differing opinions and incomplete or contradictory knowledge. This is a conception that Rittel et al. (1973) and Buchanan (ibid) define as meeting the definition of a "wicked problem". As Buchanan wrote, "the activities of design thinking are easily forgotten or are reduced to the kind of product that is finally produced. The problem for designers is to conceive and plan what does not yet exist, and this occurs in the context of the indeterminacy of wicked problems, before the final result is known." This precarious and future looking approach is taken up more specifically in the conceptualisation phase from the perspective of Future Making and Transition Design.

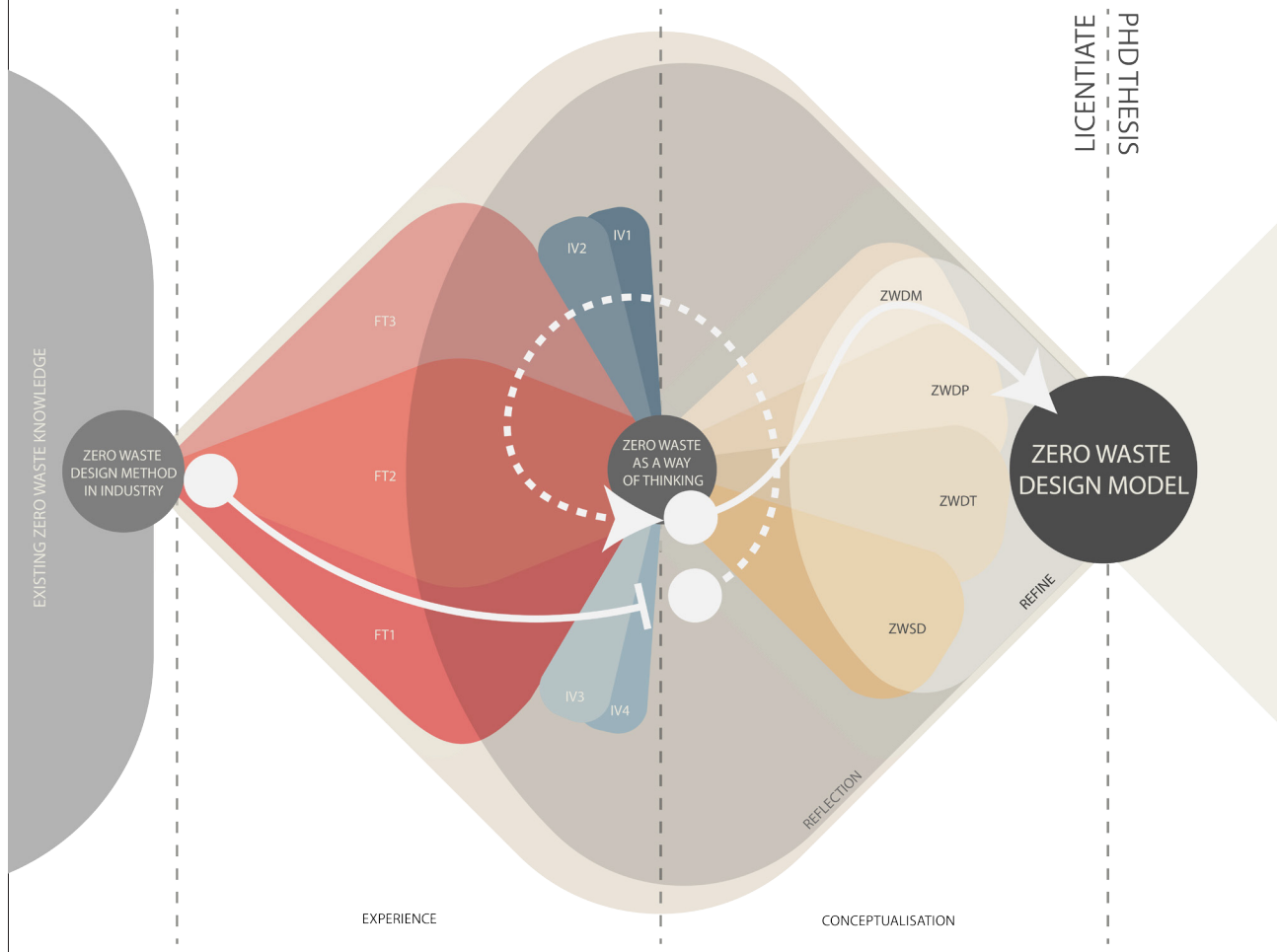


Fig. 12: The trajectory of the research was far less linear than originally concieved as the field tests revealed significant road blocks to the successful implimentation of zero waste design methods as a 'drop-in' model. Despite the linear way it is outlined in the text, experience, reflection and conceptualisation did not occur entirely linearly and was not always orderly. Often my experience in the design program felt confusing and messy, while at other times I felt clear headed – only to then question my actions and fundamental beliefs. Operating in this uncertain space is an essential part of the design program as we need to make ourselves uncomfortable to find the exciting stuff.

APPROACH AND METHODS

Conceptualisation

In the conceptualisation stage of the design program, this research sought to express the findings as conceptual or theoretical models to provoke a shift in thinking about the role of zero waste in industry and the lens through which sustainability is viewed in the fashion industry and education.

Thinking through design

Zero Waste Design Thinking in this context means something like "thinking about the industry/problem/system through zero waste design". It proposes zero waste design thinking as a lens through which to view a system or company, which enforces a holistic way of thinking. It probably most closely aligns with Buchanan's (1992) understanding of design as (ill-defined) problem solving, but also draws from Schön's 'reflective practice', Lawsons (1980) 'external and internal constraints' and Cross's (2011) 'designerly ways of knowing'. This research agrees with Tim Marshall (2014) who takes the view that design cannot act in isolation of the complex social, economic, and environmental issues that envelope it. Furthermore, this research exists (as perhaps all design should) in a precarious, and political space (Fry, 2010) – our current situation demands that we "confront an unavoidable choice: we either support the status quo or we chose a path of change" (Fry, 2010, pg 1). This tension is the context in which this research is undertaken.

Future Making and Transition Design

Simon (1969) argues that design is about changing existing situations into preferred ones, or "how things ought to be". He argues that "design and design research share with engineering a fundamental interest in focusing on the world as it could be, on the imagination and realisation of possible futures, as well as on the disclosure of new worlds" (in Grand and Wiedmer, 2010). Yelavich and Adams (2014) propose that design can facilitate a process of "Future-Making", and that this process would be inherently social and profoundly political. It locates design and its effects within issues of social justice, environmental health, political agency, education, and the right to pleasure and play, far beyond and with more profound impacts than the merely aesthetic.

Expanding on ideas encapsulated in Future Making, Transition Design as conceptualized by Irwin et al (Irwin, 2015; Irwin, Kossoff and Tonkinwise, 2015) provides a framework in four parts that provides clear intent and purpose for design that cares in the 21st century: vision, theories of change, mindset/posture, and new ways of designing. It imagines a design world where designers could apply the deep understanding of the "interconnectedness of social, economic, and natural systems" that is needed for addressing the complex issues we are facing.

Up to the phase of the research discussed in this licentiate, future making and transition design methodological approaches help to identify the areas for which change is required, and how they may intersect with my "specific awareness and abilities" (Johansson-Sköldberg et al. 2013).

3. WASTE IN THE FIELD

This chapter describes three field tests in which waste reduction strategies are applied in the design and marker making processes. The chapter begins by outlining the nature of the field tests and how they progressed, and later reflects on the implications each has on design practice in the given context. The first two field tests are anonymous; the brand of the company involved is not essential; however, the context they operate in is. Additionally the observations cannot be generalised, but they do provide potential insight into the issues and roadblocks which are likely to occur within these contexts. The first two field tests are embedded in the conventional fashion design system, and the experiments for them have a relatively narrow aesthetic framework, and the research intervenes from an 'outsiders' perspective – someone not initially familiar with the internal processes and systems of the particular content. The third field test explores zero waste design processes outside of the fashion industry in order to compare the issues that arise and learn more about what aspects may be unique to the fashion industry and which are unique to zero waste design.

The goal leading into these field tests was to develop successful zero waste garments for the companies and, in Field Test 2, to see the design through the entire design, production and retail process in order to report on the research findings so that other researchers, designers and companies might learn from it. While this occurred to some extent, the reality was entirely different.

All three field tests were acts of collaboration, between the researcher and marker-makers, designers, technical designers, garment technicians, financial managers, and many others. The iterative design process responded not only to the aesthetics or functional implications of the product but also to unexpected factors such as the way trade agreements, or cutting machinery may impact on possible problems and their solutions.

Field Test 1: Low price, high street brand

The first field test was of short duration, lasting only two days. A sizeable fast fashion company (referred from here on as FT1) asked me to work with a group of their freelance marker-makers to reduce waste in their markers. FT1 are known for their efforts to reduce the negative impacts of their garments; however, they are a brand with high product turn over, where low-cost garments are the vast majority of their offering.

The zero waste design workshops I deliver are usually very hands-on to provide participants with a tacit understanding of the opportunities and limitations of zero waste fashion/pattern design – it usually involves planning, designing and making a zero waste garment, or modifying an existing design to meet similar goals. The participants in this field test do not usually design garments or make patterns; they either adjust patterns for fit or make mini markers using provided patterns and marker making software. This was identified as a problem for the proposed workshop in the context of the company as for zero waste design, the marker is the pattern – they are not separate. While there are strategies to use that can make a marker more efficient, it usually impacts on the pattern itself. So, if the pattern cannot be modified at all, it is not possible to make a zero waste design, or even to reduce the waste it makes.

Marker-making is where the majority of attempts to reduce waste in production take place, and companies and designers commonly view zero waste as a design/marker-making exercise. A marker-maker takes the provided garment pattern and works with specialised marker making software to achieve the most efficient layout of the pattern of fabric for production. They are rarely allowed to make changes to the design, though they can sometimes make suggestions to the design team aimed at improving yield. Furthermore, most marker making software is excellent at generating the most efficient marker possible for a given pattern, but the problem is that the pattern is not designed to be highly efficient. It is designed to make the design as specified, and efficiency is rarely specified. It was clear that a significant shift in process and understanding was required. Nevertheless it was decided the project should continue – while allowing a small range of design and pattern modifications for a specified design – in order to test possible improvements and outcomes within this tight framework.

The garment specification (Fig. 13), pattern and existing marker (Fig. 14) were provided, and an example (Fig. 15, 16) was developed to show them before the workshop began.

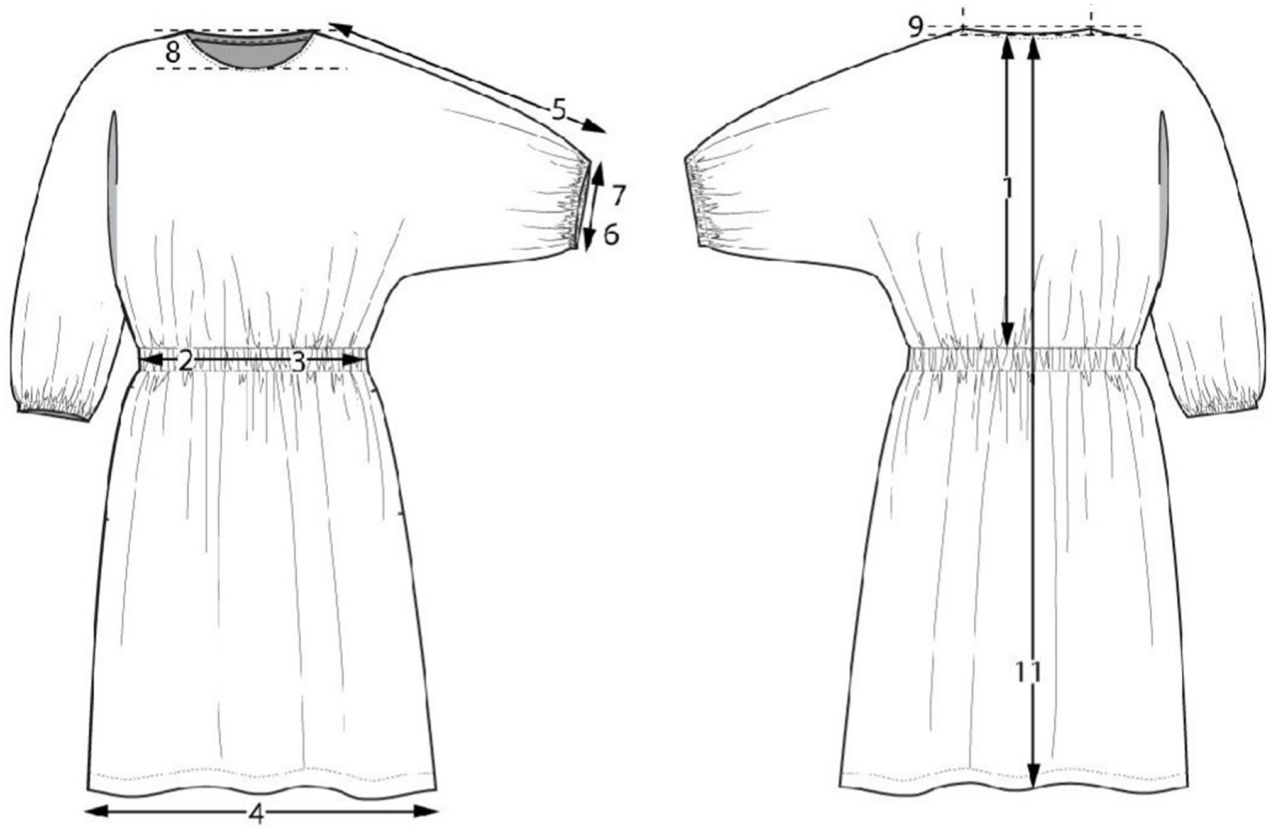


Fig. 13: Specification drawing of proposed design for development as provided by FT1. A simple design was chosen with relatively high yield and waste.

WASTE IN THE FIELD

Aim

The stated aim provided by the company was to raise awareness around zero waste and waste in general, to train the suppliers' pattern/marker makers so they could produce more efficient 'mini-markers'. They hoped to reduce their waste on 1-2 styles which were already shipped, in order to share the findings in broader company meetings and try to get more focus and attention on the issue.

Teams of marker-makers worked on an existing dress design, which had a predetermined fabric choice and relatively high yield and waste percentage. Garment selection was based on a style they were currently producing a marker for; therefore the design was considered already established.

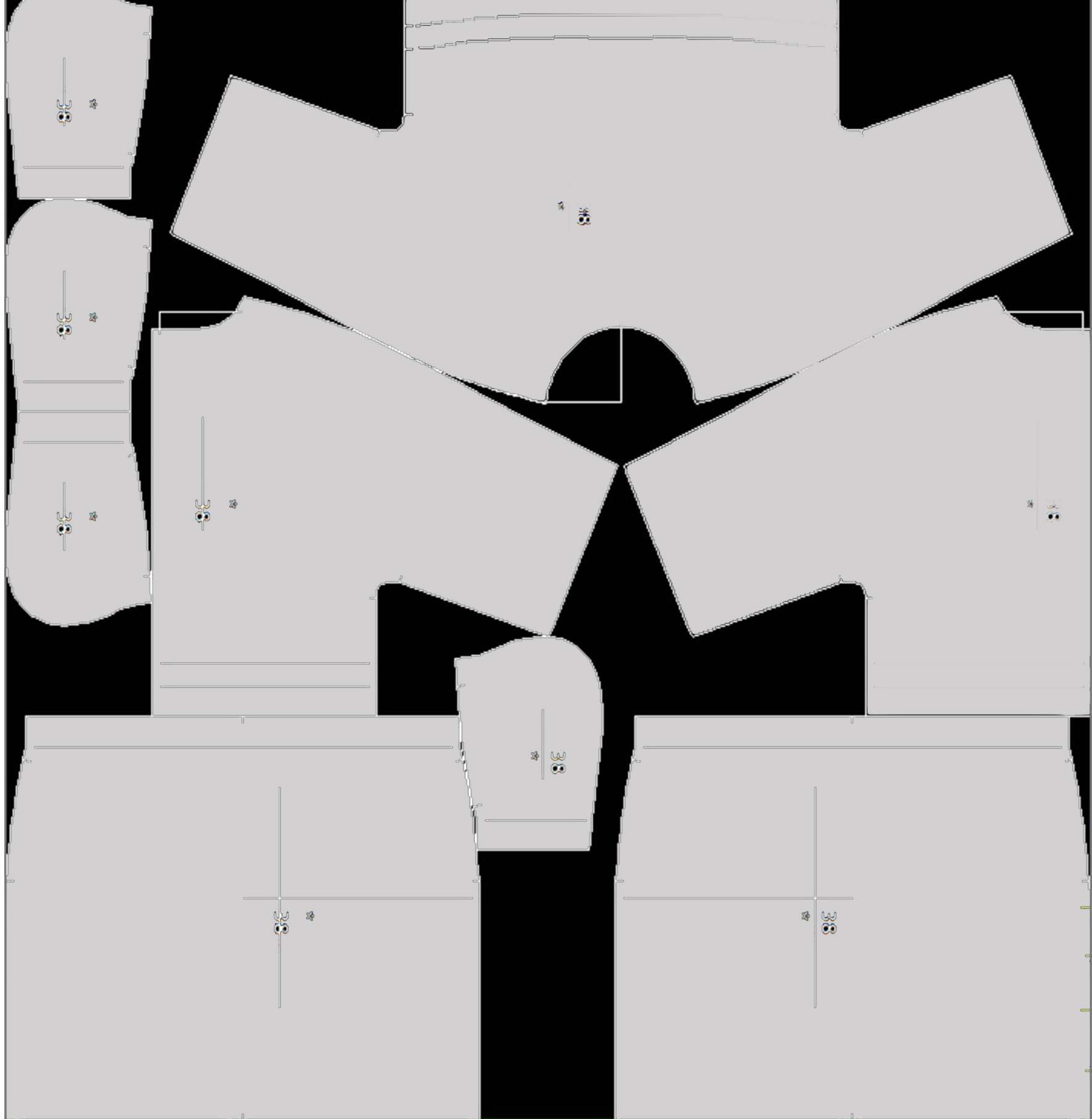


Fig. 14: This image shows the garment pattern (for the specification shown in Fig. 13) placed in a production marker. Waste is approximately 25%

Process

The staff involved in the workshop did not use 3D software in their work; therefore a paper design method was utilised to explore possible outcomes.

The field test followed the following outline over two days: Beginning with a lecture introducing zero waste, including a discussion exploring industry application, in particular how it relates to the design and production process within FT1, such as grading, marker-making and flexibility (or lack of) within their processes. The importance of managing complexity in construction was discussed, as when taking an existing garment and reducing its waste, this can easily lead to more seams or more elaborate construction sequences. The discussion served to highlight the things that were needed to be known before starting – from what are the 'fixed' aspects of the design (in this instance almost everything), to what is the size of the cutting table.

The workshop explored the modification of existing designs in order to be less wasteful by demonstrating how to translate a conventional dress into a zero/low waste version, first with an external example and then using the companies own design (see Fig. 16). Then the participants explored a range of the MakeUse patterns, in order for them to gain an understanding of zero waste patterns in paper. Zero waste design techniques were demonstrated

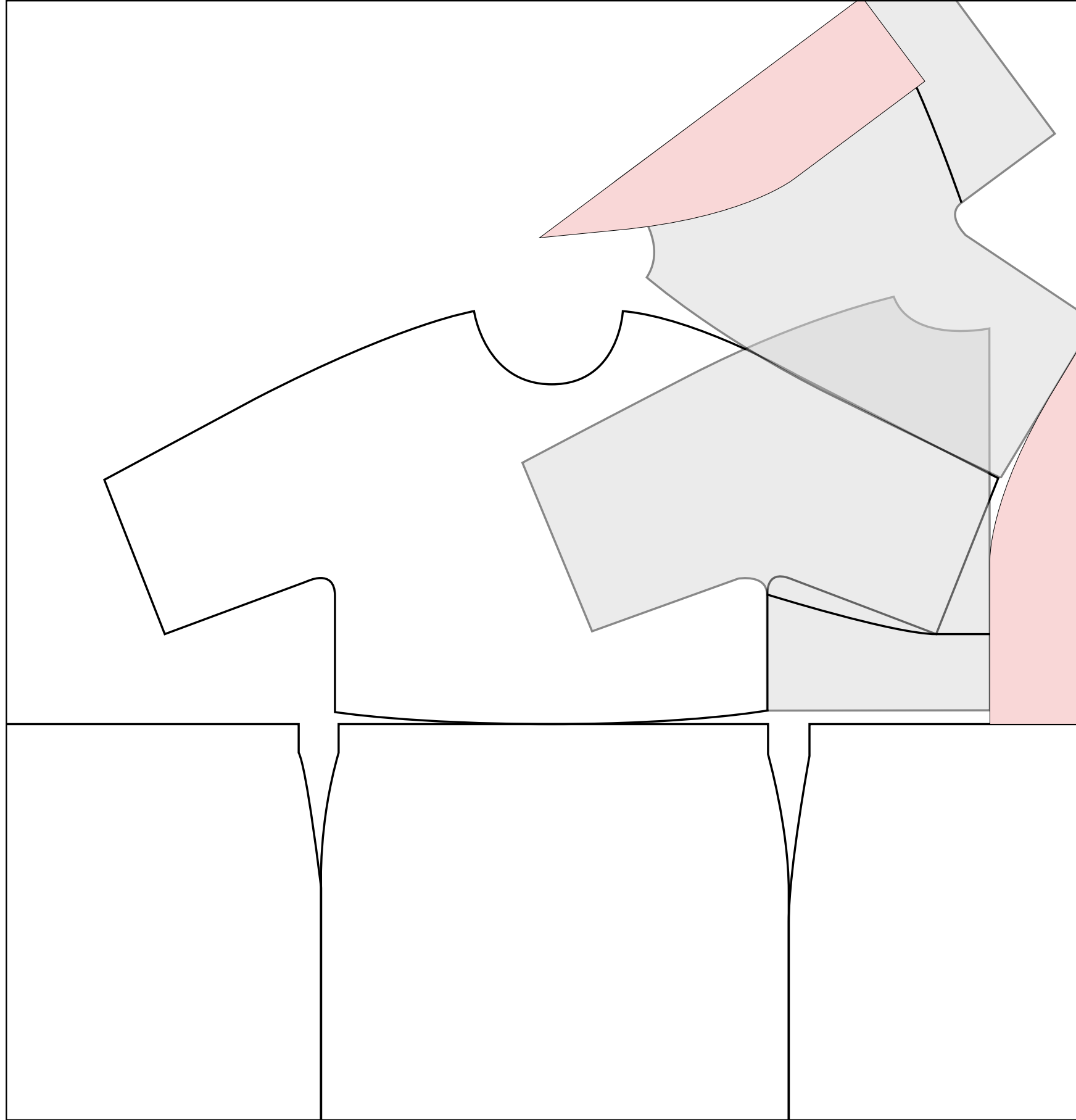


Fig. 15: This image shows part of the initial planning for modifying the dress design in order to reduce yield. Zero waste was not an objective as the design brief was much too narrow – the design was only allowed to change in a minimal way.

that were seen as useful based on the requirements of the existing design – for example, the design had a kimono sleeve, so the kimono based MakeUse tops were demonstrated. Then the participants moved on to the MakeUse modifiable zero waste grid system and the use of blocks or existing patterns for zero waste design.

The main collaborative exercise involved proposing small changes to the provided garment design in order to improve garment yield and reduce waste dramatically. The kinds of changes allowable by FT1 were limited to a small selection of alternative seam placements, without change of silhouette or critical details. Methods were attempted such as seam transferral (eliminating a seam in one location by moving it to another) to balance the modification of pattern for efficiency without changing the silhouette or adding to the overall seam numbers. In this context three different possible outcomes were developed, one of which reduced yield for the planned style by 26%, by adding a single seam.

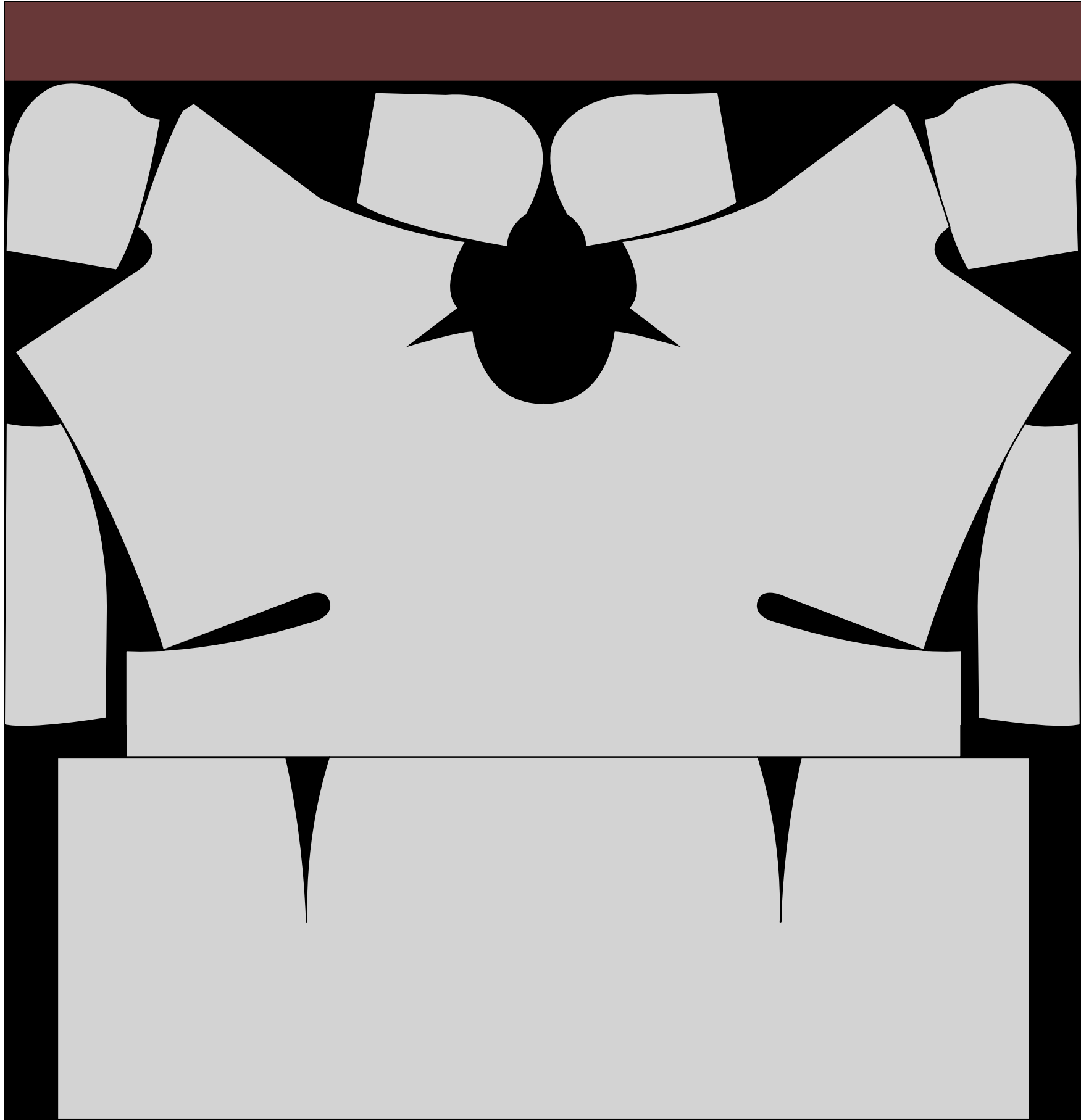


Fig. 16: The resulting pattern from initial experimentation with pattern manipulation within the defined guidelines. As only one seam was allowed to be added, to enable the reduction of yield this example eliminated seams elsewhere – the shoulder and side seams. The manipulation modified the grainline for some pieces. The yield was reduced in this example by approximately 10%, The dark red section at the top shows the difference between the original yield and the new. The black is waste.

Outcome

Each of the modified garments and resulting markers were costed by FT1; however, the company indicated they would not have chosen to implement the changes, as the savings made on material yield, though considered extremely significant in the context of the fashion industry, were outweighed by the extra cost of additional sewing seams – because their cloth was so inexpensive.

Two months later I saw the original style we had worked on in the window of a local store.

Initial reflection

My immediate reflections on this field test began from when the company asked me to work with their marker makers and it became clear they had no influence over the design decisions being made. This choice of participants indicated to me that there was a misunderstanding of the realities of what causes waste in a marker. As most marker makers use extremely effective software to assist them, this stage of the design and production process is already optimised for maximum efficiency. The issue lies now in the way the garment pattern is constructed, which is entirely determined by the garment design.

Fig. 17: A speculative pattern layout for FT1 dress that would significantly reduce yield and waste. This approach would require a redesign, and much more complex sewing. In the context of the brand this is not feasible. Dark red area on right shows reduction in yield from original. Black is waste.

Field Test 2: High price outdoor brand

The second field test was of much longer duration and for a very different garment brand – a large sustainable outdoor brand (referred to as FT2). This field test took place in two phases, beginning with a workshop and a brief exploration of one possible zero waste approach for a single garment in a single size, which was never meant for production. This workshop and garment exploration was followed by an extended second phase aimed at developing a 'high efficiency' garment for both men's and women's styles, in a full size-range for production. A vital aspect of this field test was the use of the digital 3D software, CLO3D. The software enabled the development of zero/low waste designs and digital prototypes to proceed despite thousands of kilometres separating me from the remainder of the design and technical team.

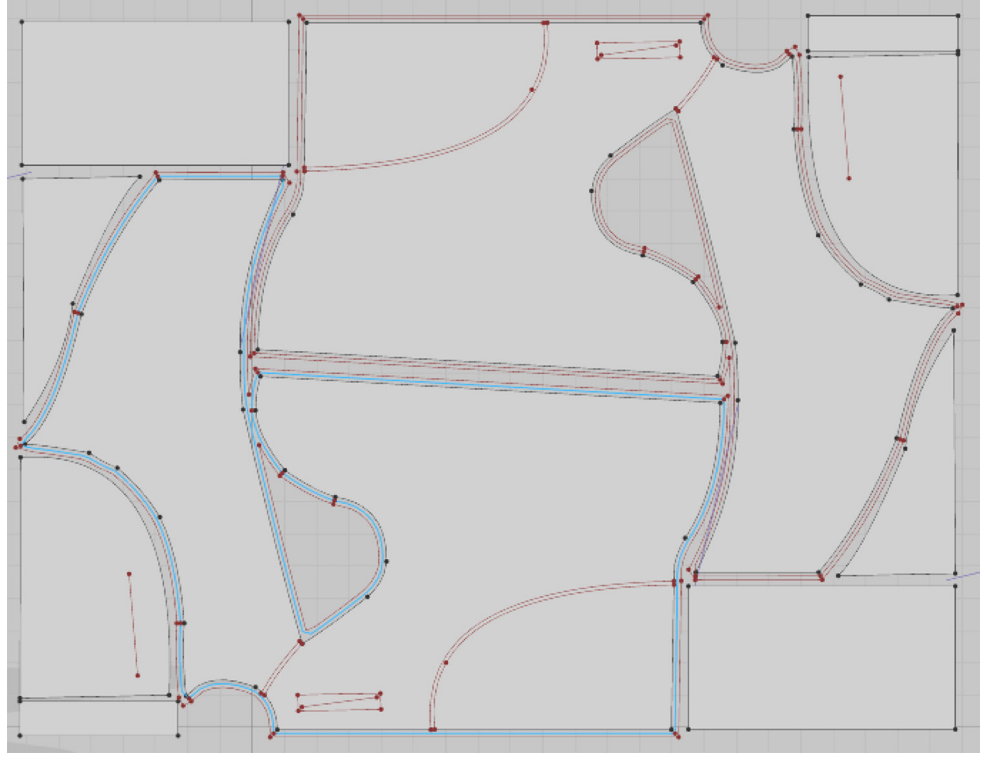
Phase 1: Feasibility test

Aim and process

In 2016 I led a zero-waste design workshop with product departments at FT2 and in preparation for the workshop, I was asked to redesign an iconic mid-layer fleece jacket using zero-waste design principles to demonstrate to the team what may be possible. Working from the current pattern, measurement chart, and sketches, I design a fleece jacket with different seam lines particularly in the sleeve, but maintaining the same fit as the existing fleece jacket, and achieving almost no waste. A physical sample was never created during my design process due to the tight timeframe but the 3D software I used reduced the need for this.

Outcome

This design was presented to the product team while hosting the zero waste design workshop. Team members designed and constructed garments in FT2's R&D centre during my visit and the outcomes were presented to all designers at the end of the week. When discussing the garment shown in Fig. 19, changes to seam placement, such as moving seams slightly for reasons of function, taste or aesthetics were suggested, however, when making these changes, both large and small, efficiency and yield returned close to the original. After learning so much during the workshop and initial design development, staff at FT2 continued work in this field on their own, making small improvements to high volume styles.



Zero waste redesign of men's style for Phase 1 of FT2.

Fig. 18 shows the zero waste pattern. The pattern was developed using some of the key concepts proposed by Rickard Linquist in his PhD, but adapted for a zero waste concept.

Fig. 19 shows digital prototype of garment that the pattern generates. FT2 determined that the design lines deviated too strongly from the original design it is interpreted from, however saw potential in the experiment.

Phase 2: High efficiency project

Aim

After working on these improvements as a result of Phase 1, the team decided to embark on another project with me, this time redesigning a men's and women's technical fleece mid-layer. The goal regarding waste minimisation was for what they called 'high efficiency' – 92% efficient use of materials, instead of the usual 80-85%. The project began as 'off calendar' meaning it would have a long development period with no specific production date, acknowledging the particular challenges this type of project development faced.

The decision to seek high efficiency and not zero waste was based on the understanding of the limitations their existing production model would likely impose upon the outcome. The fabric width is fixed after all, and if you wish to grade a garment conventionally it will take up more room. Strategies such as rotating pattern pieces 90 degrees to allow for growth in the lengthwise direction were not desired due to shading and difference in fabric stretch. The patterns needed to maintain aesthetic between sizes, so designing the marker for each size where the pattern and garment design is slightly different would also not be desirable. The high technical requirements for their products means that aesthetic outcomes in response to seeking to reduce waste which did not meet performance or fit goals would not be acceptable. So a (still very high) goal of 92% was established. The design of the garments needed to fit the same as the current style, using the same fabric, but initially the remainder of the design was relatively open.

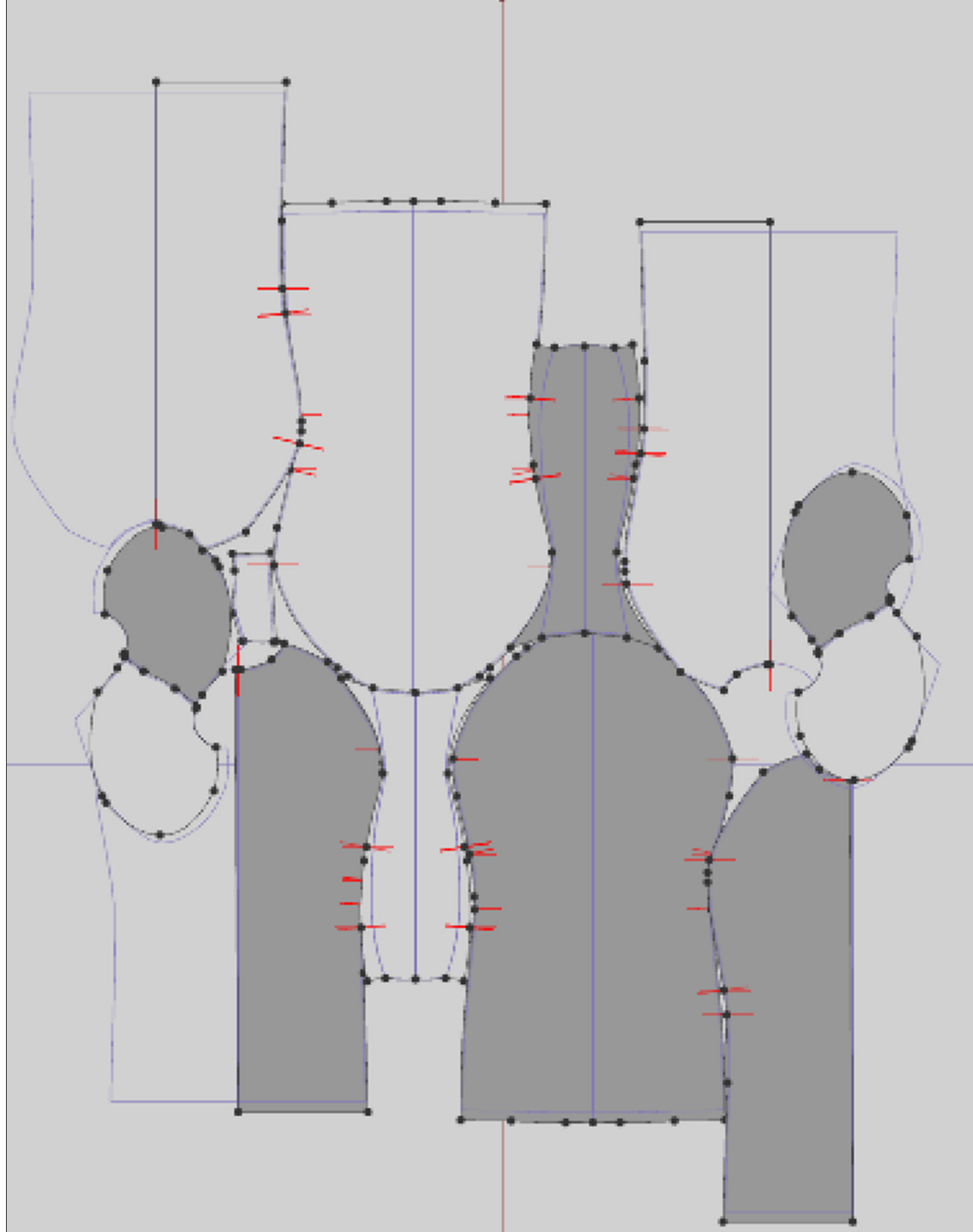


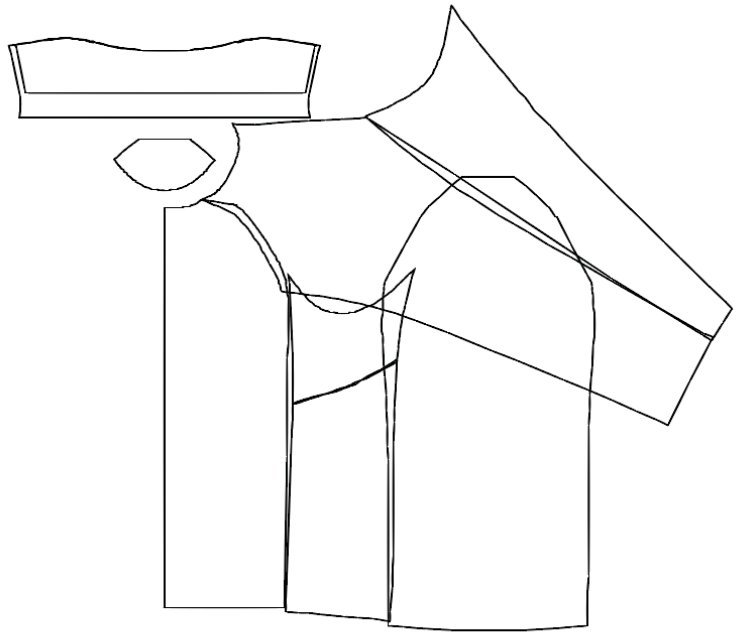
Fig. 20. Using the provided garment patterns in CLO3D, potential layouts were developed. Here the pattern pieces are 'nested' to visualised the negative space created with minimal pattern manipulation.

Process

The design process was as follows. In Sweden, I would design a possible solution utilising CLO3D – in which I was able to digitally construct a prototype made with an aesthetic and material behaviour scan of the fabric of the design, and on the brands male and female digital fit models. I did this using the existing pattern for the garments, and I also had access to the base block or pattern this was developed from, as well as size charts, garment samples and specifications of the existing design.

Method: Designing the marker

Initially, my design approach was that I would design the patterns to interlock in a specific way, effectively designing the marker. I would send these patterns (which formed a set marker) to a technical designer at FT2 who would grade them, and place them in the marker using their marker making software. This process confirmed that the approach of designing an exact layout for the marker would mean that once graded the yield and waste would be the same or worse than the original. Alternative grading approaches which may mitigate this were proposed and rejected by FT2 due to difficulty maintaining consistency of fit and aesthetic across sizes.



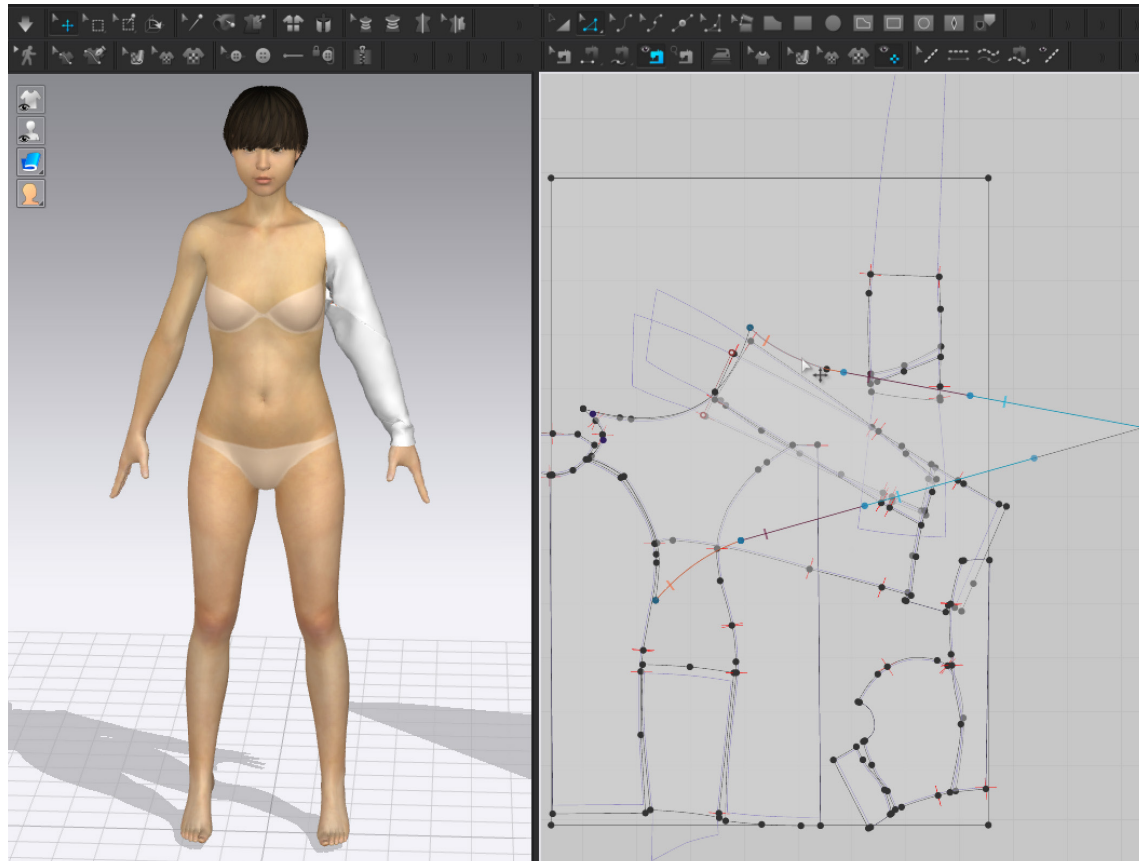


Fig. 21 and 22. Using the provided garment patterns in CLO3D, potential layouts were developed. In this case the whole marker is designed, and the overlapping pieces lead the development of the pattern and resulting design lines.

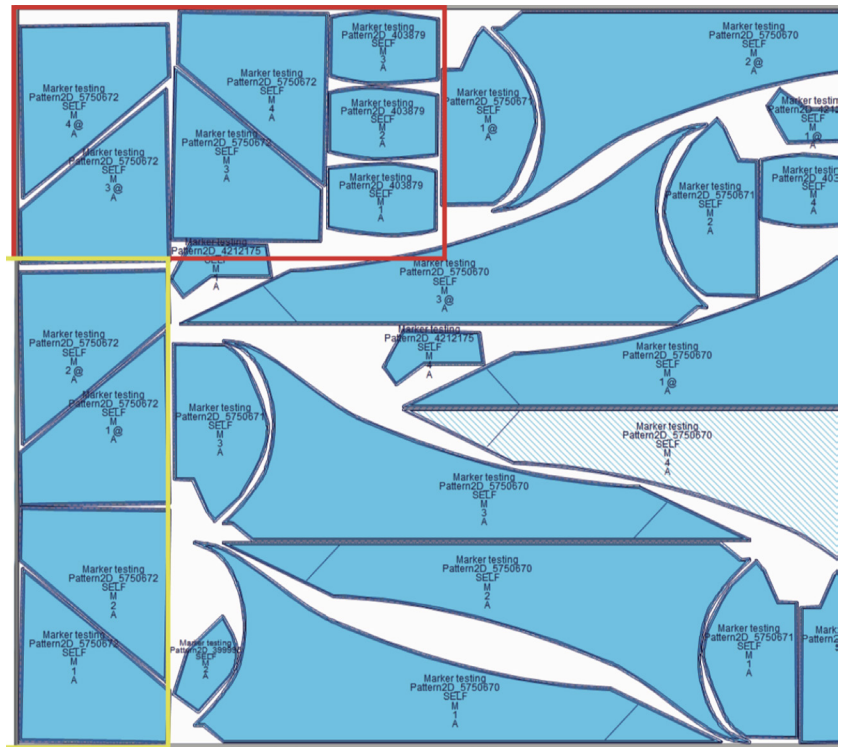


Fig. 23: Early on the effectiveness of designing groups of patterns to nest with each other was clear (divided marker). The fabric is always rectangular, so units of patterns that nest perfectly with each other need to be designed, with complementary angles, and in a range of sizes to best fill the gaps. This allows for efficiency to be maintained even after grading.

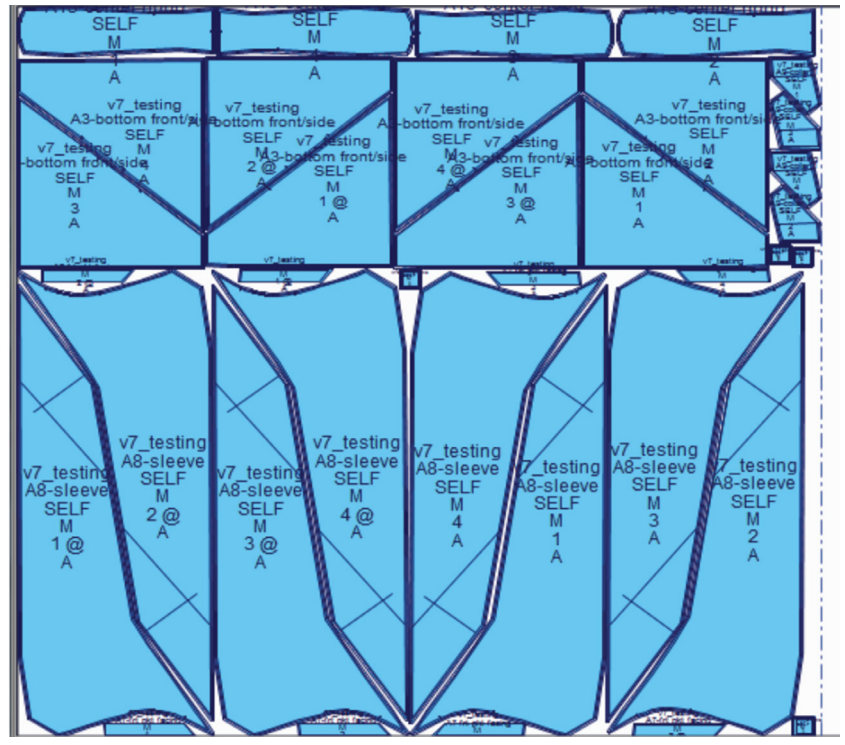


Fig. 24: The triangular sleeve pattern piece changes in small ways from the first design to the second, but this leads to a significantly more efficient design because the pieces can now nest closely together. This nesting approach means that pattern pieces dont have to be rectangles, so long as they make somethng close to a rectangle then the layout is likely to be more efficient.

Method: Designing a mixed marker

The notion of designing a mixed marker in a predetermined arrangement of sizes was suggested as I knew that it had been successful in other contexts (also see interviews with Tess Whitfort and Mary Beth McDermott). Mixed markers are commonly used in industry and usually combine sizes of the same style garments into a single marker. However, in a conventional mixed marker, the exact configuration or ratio of sizes is not predetermined, and instead responnds to the specific order numbers for different sizes. FT2 was not willing to attempt this as it could lead to a mismatch between demand and what is produced (which would be wasteful)

Method: Design a divided marker

Next, I attempted a method where the body and sleeve was spatially divided on the marker, and each were designed as rectangular units (see Fig. 24). In this approach, the body pattern pieces would nest with other body pieces, and the sleeve and hood would nest with other sleeve and hood pieces. Effectively designing internal partial markers that are rectangular and can be puzzled together to make a more efficient layout.

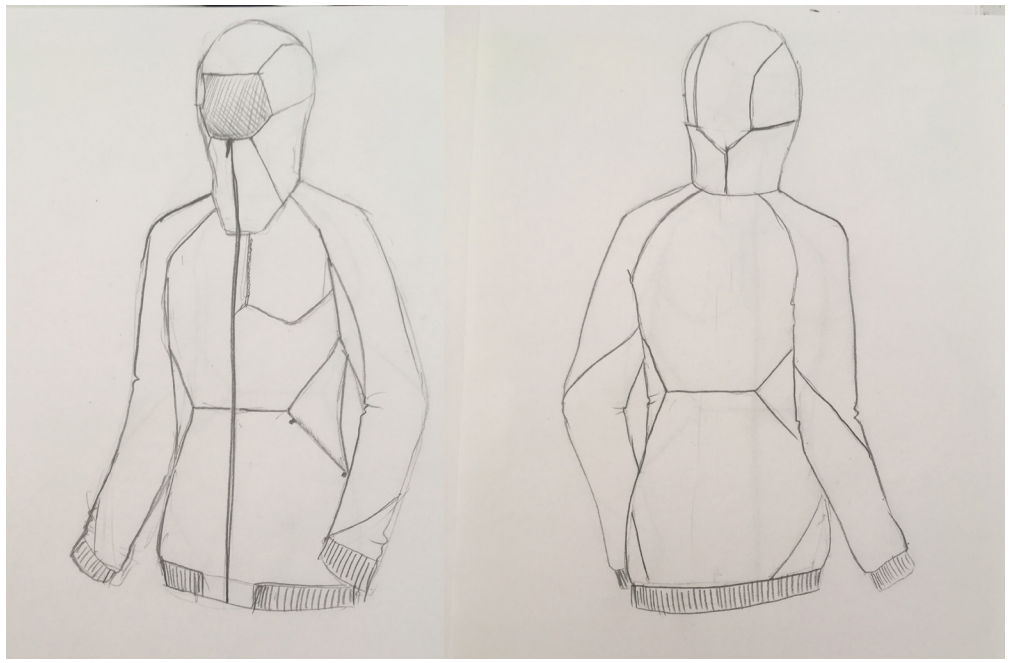


Fig. 25: While i do not often sketch to design this sketch was generated in order to propose the hexagonal method i thought may work with the brand goals.

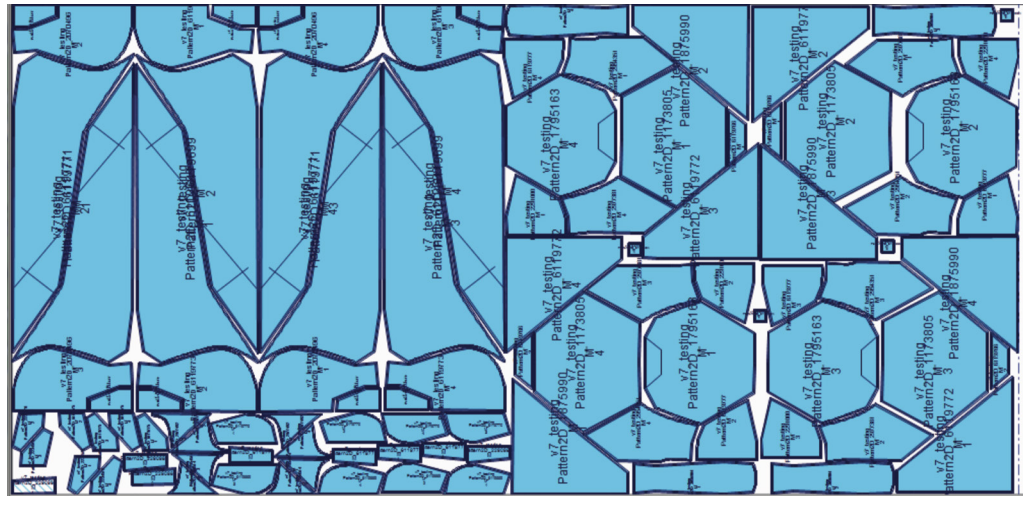


Fig. 26: Hexagonal pattern layout, this achieved about 87% efficiency

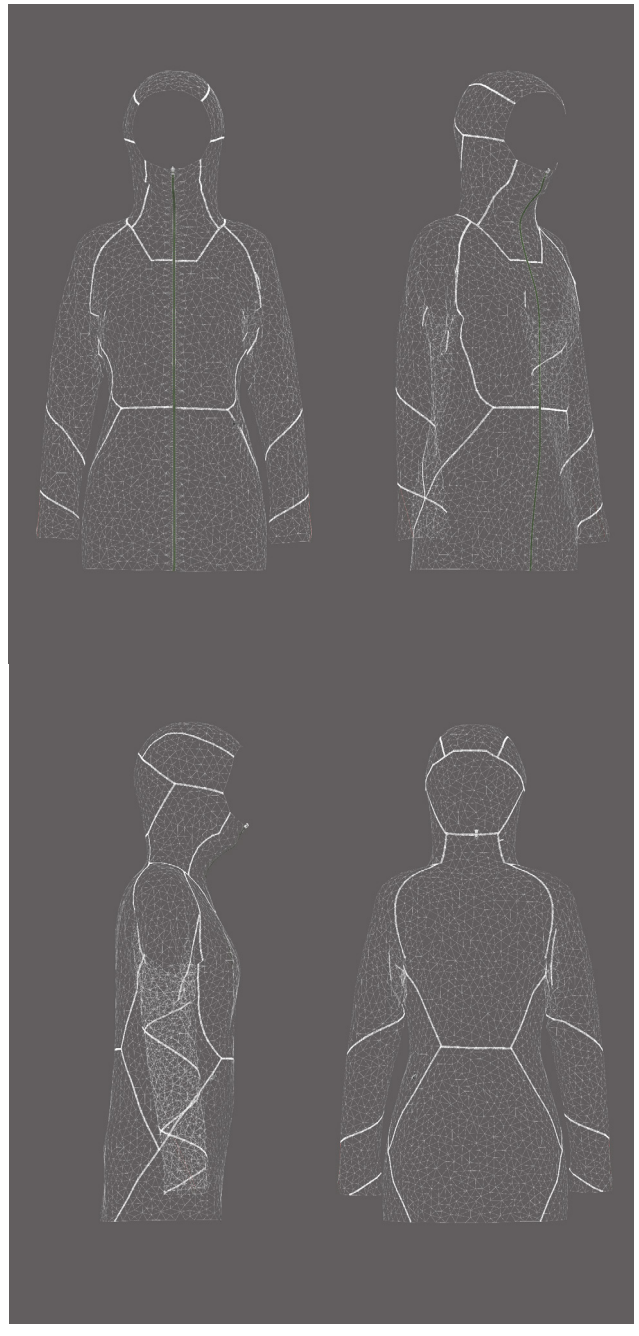


Fig. 27: The resulting 3D render of the hexagonal approach. The relationship between the sketch (left) and the resulting pattern render is close. This I believe is the result of the 3D software that enables the designer to see the impact of their pattern decisions on the 3D form as they progress.

I attempted this method with a range of design lines; for example, I began using hexagonal pattern pieces, referencing a significant design element commonly used by FT2. I speculated that the hexagonal angles would enable the pieces to slide by one another, theoretically allowing the pieces to make room for larger pieces while closing and filling gaps in smaller sizes. I tested this approach, and the result is shown in Fig. 25, 26 and 27.

The results were assessed by the line manager and its design lines were considered too different from the original so suggestions were made to change the exact placement of seams, which was actioned, and yield and waste returned to the original figures or worse. This iterative process continued back and forward for many months, with shifting explicit and implicit constraints (to expand upon Lawsons (2006) internal and external constraints) playing an ever-increasing role in the decisions made.

Constraints

The longer the process continued, the more constraints were placed on the design both from the wider design team in the company and from the factory. For example, the factory required a buffer (Fig. 28) between pattern pieces of 6mm in order to cut notches to assist in the construction, immediately generating about 3-6% waste (depending on the number of seams and pieces) which seemed unavoidable. From the company, there was an ever increasing list of design elements that could not be changed that were not there at the beginning. I believe this was because at the beginning the design team at FT2 were not able to fully articulate the core of the design – it is a classic piece; they know it implicitly. However, when working with an external designer, they needed to be explicit, or at least allow for time to fill in the missing information. FT2 seemed to require the design to be fundamentally different while staying almost exactly the same. It was at this time that the project was moved to be 'on calendar', significantly reducing the time available to develop successful solutions.

Despite the challenges presented through constraints, both the designs progressed satisfactorily enough that FT2 arranged for the design, technical design team, and me to travel to one of their factories for a week of intensive collaborative work. We were to finalise details and to work with the factory to troubleshoot some of the more unconventional design elements of the garment, with a deadline of the end of the week.

At the factory, we were able to develop successful outcomes much more rapidly. We were able to quickly establish methods and outcomes of methods which did not work for the specific context, issues arose and were rapidly addressed because we could ask each other, or the factory floor directly.

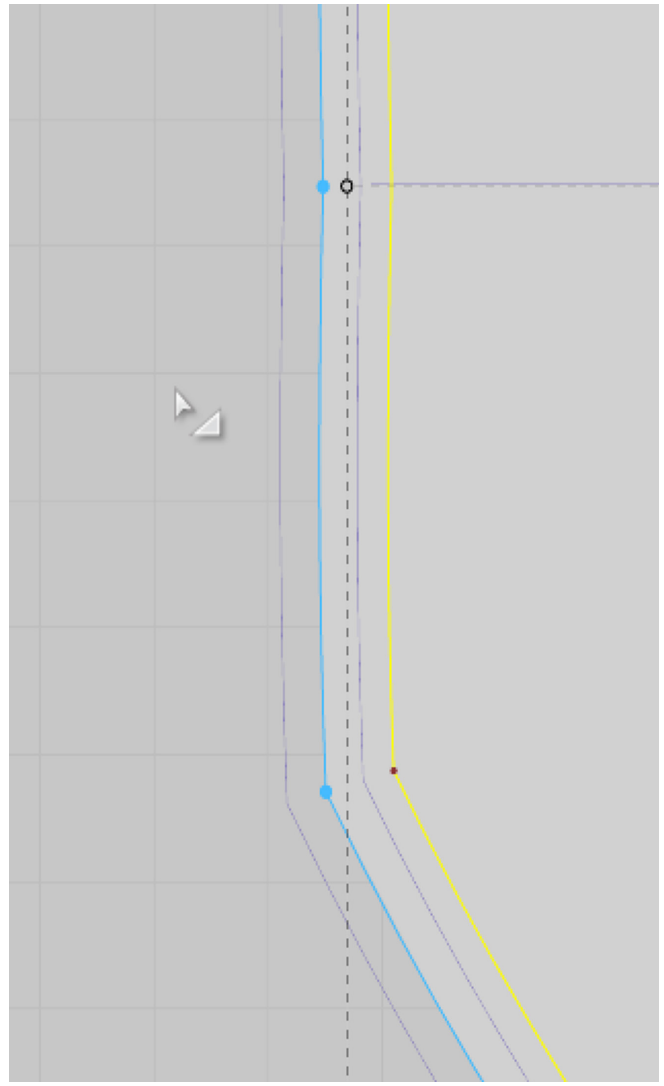


Fig. 28: 6mm buffer between pattern pieces leads to an automatic generation of waste and design limitations brought about by the reduction in surface area available. Yellow line is sewing line (6mm seam), bright blue is cutting line and black line is the 3mm buffer added to each piece, generating a 6mm buffer between piece.

Method: Designing a flexible marker/garment design system

The team and I approached the design of the garments at the factory utilising a method developed from the Divided Marker approach. Borrowing from Rissanens (2013) “hierarchy of garment elements”, each garment is designed to be comprised of pattern pieces which have the following features.

1. The garment pattern pieces were separated into large, medium and small sizes. For example, the front and back body of the garment were the largest pieces that could not be divided further due to functional and aesthetic goals. Other large pieces such as the sleeve were determined to be able to be divided further based on the functional and aesthetic goals. The sleeve cuff, side body and hood pieces were provisionally determined to be small or medium sized.

2. These large existing garment pattern shapes were manipulated so that they achieved a 2D form which was as close to a rectangle as possible, without changing the resulting fit. In the case of the front body, the seams were manipulated so that the front of the hood grew out of the front neck and filled in the space where the neckline was. The shoulder seam was moved so that it now ended perpendicular to the grainline and therefore made a form very close to a rectangle (see Fig. 29)

3. The small and medium pattern pieces nest together to form mini-rectangular shapes, and with the large rectangular pattern pieces enable all the various pattern pieces to fit together with improved efficiency.

The main area of difficulty was in the hood for both men’s and women’s styles as they had a very specific desired fit, as well as a precise placement of design lines. This meant that modifying the design of the hood was not desired. As a consequence, this is the area of the design that is most wasteful. If one of either the fit or the design lines could have been move flexible, then a more efficient hood could have been achieved.

Fig. 29: An example marker showing the large, medium and small pattern pieces nesting into rectangular-like forms within the marker. The large pattern piece marked at the top is the front body which has been modified to better fill the space. The medium pieces make part of the sleeve. Difficult pieces include the hood (bottom blue piece) which remains largely unchanged from the original

When not designing is designing

It seemed our presence at the factory enabled questions to be asked about some of the processes and practices considered standard. The buffer between pattern pieces was questioned again – we examined how the cutting machine worked, how the notches were made and the software used to apply them to the pattern to see if we could reduce the buffer and therefore reduce the waste. At first, the factory was adamant it could not be changed, however at our insistence they asked their cutting technicians to test it, and discovered they would be able to cut with half the buffer. This new finding could be applied across hundreds of styles and many different companies. From a design perspective, we could reduce the buffer between pattern pieces (Fig. 30), which made more space in the marker for the design. This experience outlines an example of how zero waste design enforces a holistic way of thinking that can impact on practices outside of design, which can then feedback into design practices.

Outcome

This kind of at-factory design had never taken place in the company before, and in a short space of time, a significant amount of work and related breakthroughs were achieved. The outcome of this week was a sample of both the men's and women's technical garments, maintaining the fit of the original design, in a full-size range, able to be manufactured, with a lower yield than the original. This package was then critiqued by the remainder of the design team back in the USA, where they suggested further small changes to the aesthetic and fit of the design, which the factory actioned, and these returned the yield and waste percentages only marginally improved on what it was initially.

The company proceeded with this version of the garment, and it became available for purchase from April 2019.

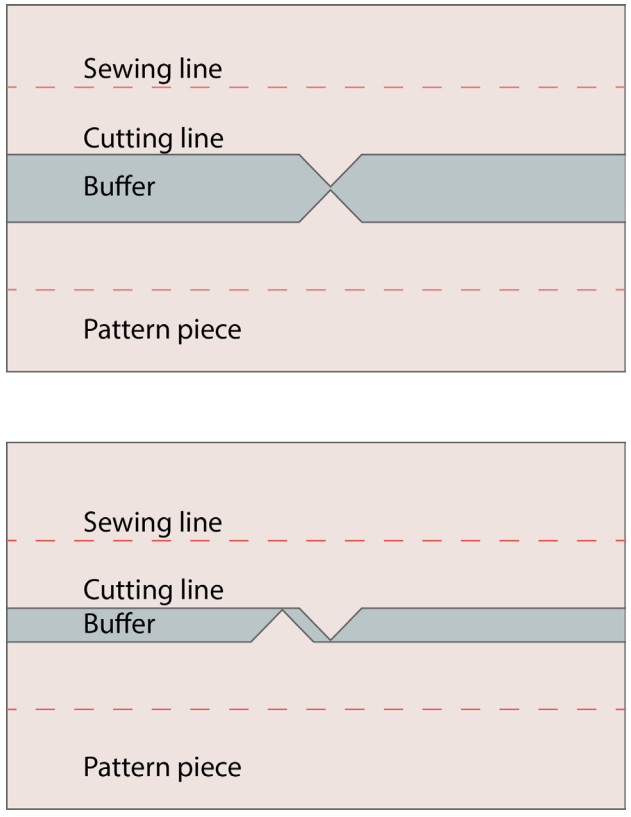


Fig. 30

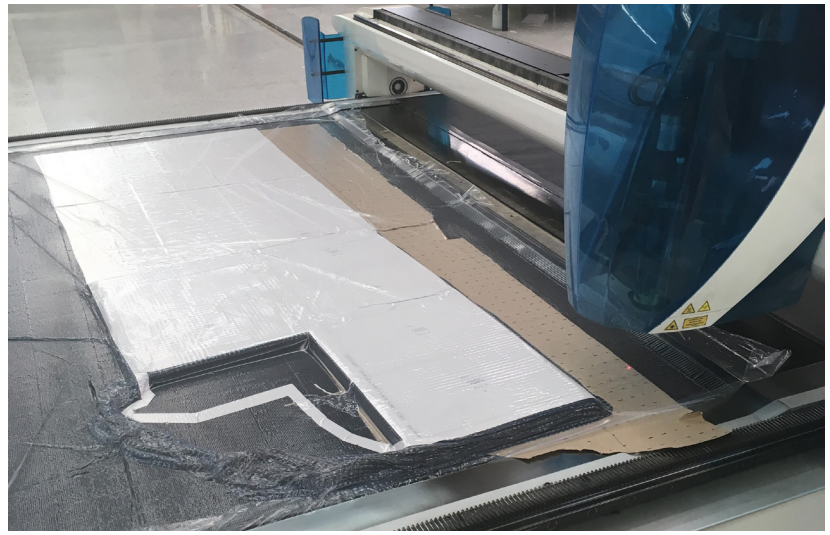


Fig. 31

Fig. 32

Fig. 30, 31 and 32: The 6mm buffer was thought to be required because of the cutting machine needing room to turn sharp corners when cutting external notches for sewing knitwear. Testing (shown Fig. 33 and 34) demonstrated we only need a 3mm buffer in total (Fig. 32)

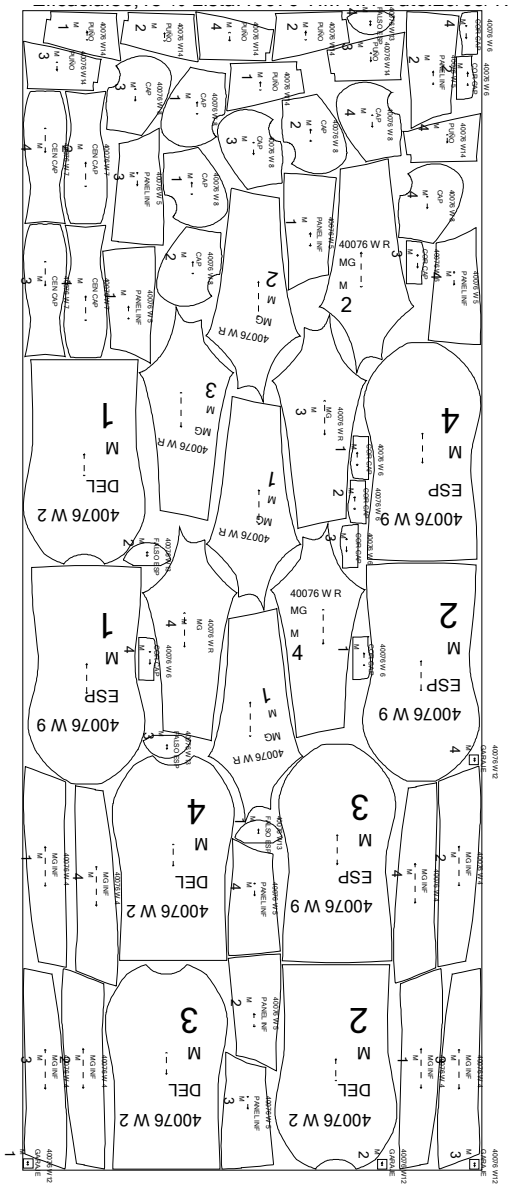


Fig. 33: Original Marker: 83.13%

The complex relationship between hierarchy, constraints and processes is clear. Here are the markers taken from various stages of the development of the garment shown in Fig. 37. The design went through multiple iterations to where its efficiency reached an improvement of 4%: a 22% reduction of waste (Fig. 35). After which the design was evaluated by the regular design team who were not involved in the high efficiency project and the efficiency reverted close to where it started (Fig. 36).

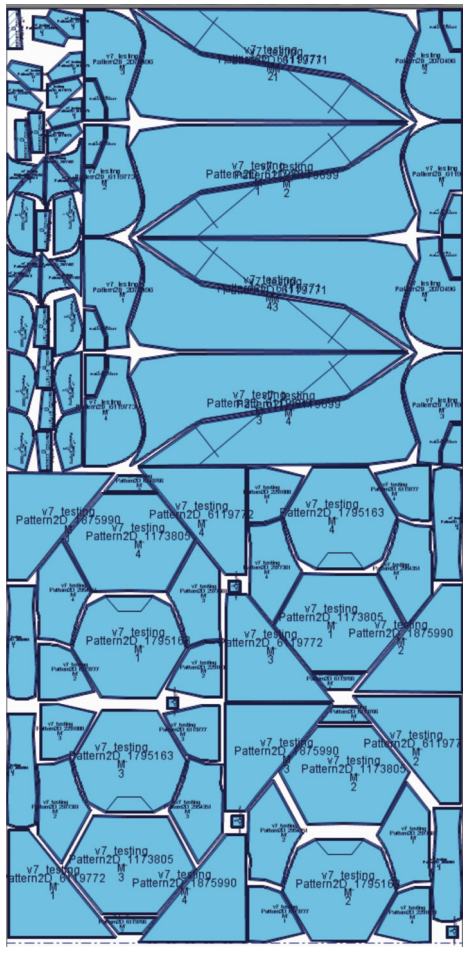


Fig. 34: Best prototype pre-factory, utilising sliding hexagon method and nesting as squares: 87%

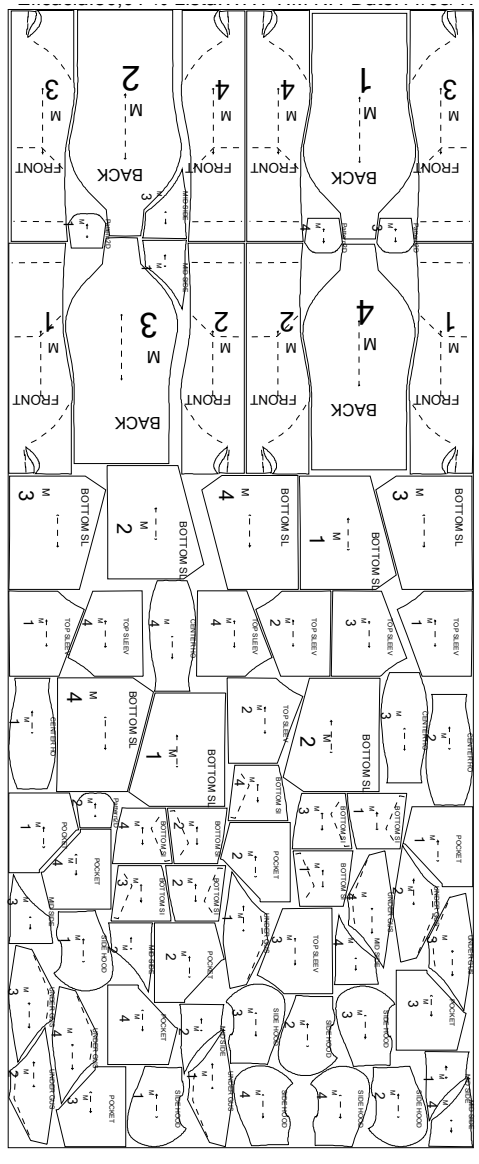


Fig. 35: Factory prototype, waist band in different fabrication so yield is reduced for main body: 86.01%

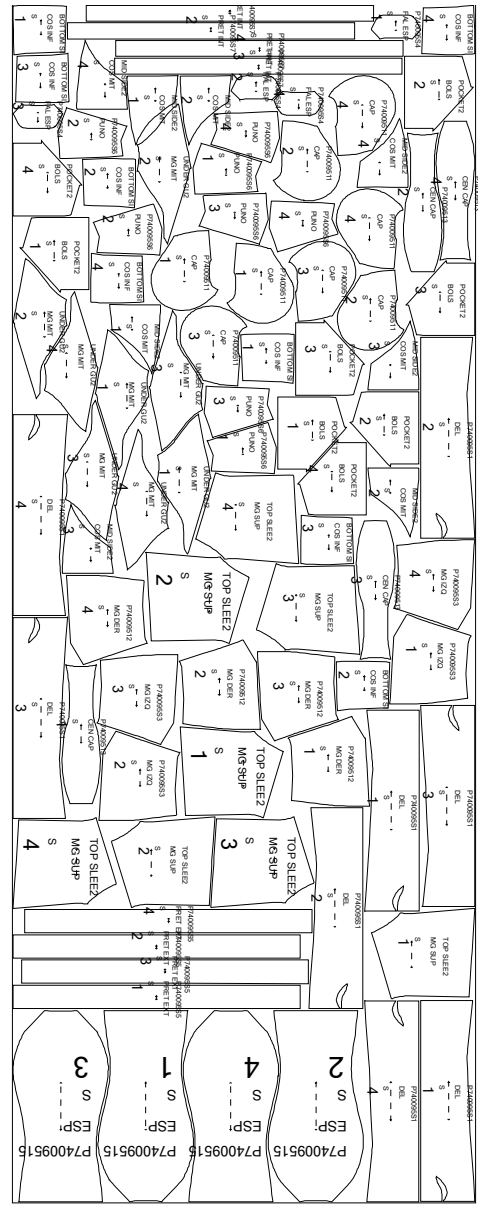


Fig. 36: Adjusted after design feedback: 83.35%

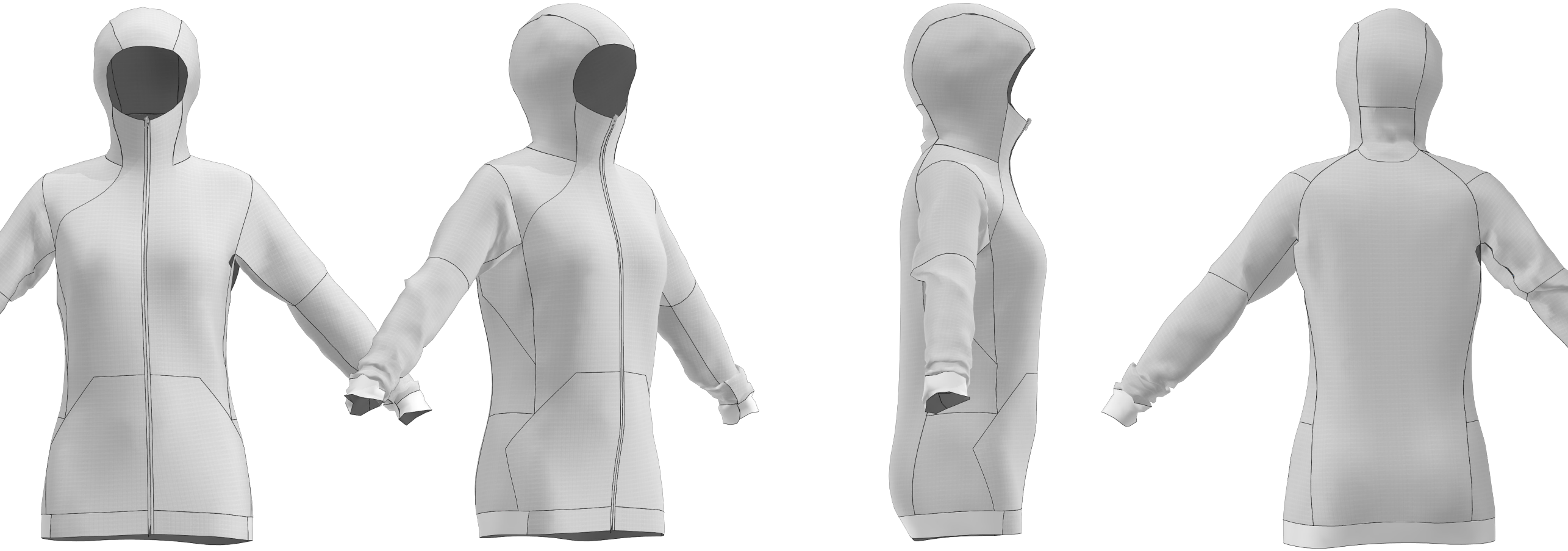


Fig. 37: The women's digital prototype (shown above as developed at factory) achieved 86% efficiency. The right shoulder area shows the construction of the garment – there is no raglan seam. The left shoulder shows a 'fake' cover stitched raglan seam line. This was a compromise between yield/efficiency and aesthetics.

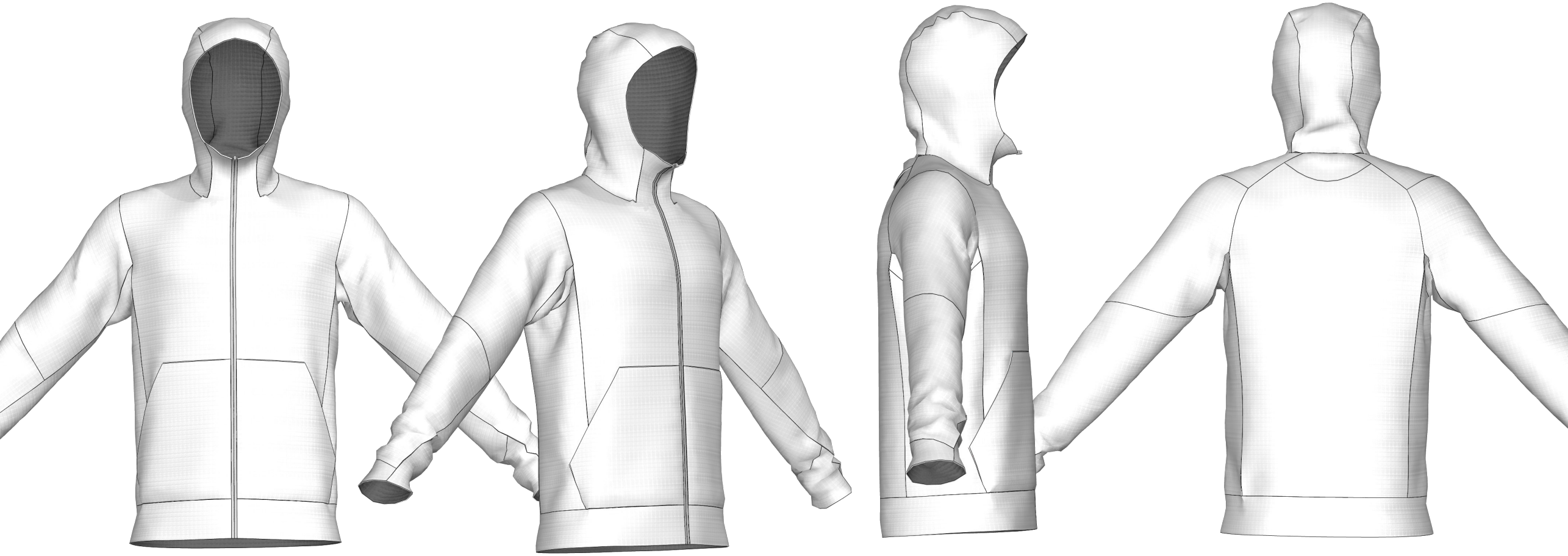


Fig. 38: The men's garment at conclusion of the factory collaboration (shown above) achieved 86% efficiency. The same underlying construction is used for the men's style as for the womens, however the 'fake' raglan seam used on the women's style was not specified here due to the desired 'masculine' line that the underlying construction offered. The sleeve construction is different between women's and men's style in this iteration, however it was later changed to both have the same construction as the men's style.

WASTE IN THE FIELD

Initial reflections

The construction of the garment was unconventional, and so detailed construction sequences were provided to people on the factory sewing line, and we worked through these with the factory line manager to ensure that what we hoped to achieve was possible with the equipment available and the skill of the staff. It was necessary, in these interactions that we trusted each other and learnt from each others understanding of design and construction in order to achieve a successful outcome. If this process had occurred earlier in the process this research proposes it would have saved a significant amount of time.

I have suggested to the company that a blending of different manufacturing methods they already use in their products might be a good step forward, such as the use of fully fashion knitting in combination with high-efficiency cut and sew (Fig. 39). This approach would enable the specific shaping required in areas that are wasteful in 'cut and sew' (such as the hood) to be instead produced using a lower waste method of production, further reducing waste overall for the product.

Another key realisation in my experience of this field test was that many of the actions undertaken by me should be actioned instead by software. Often I found myself moving seams incrementally back and forward in order to balance the needs of efficiency and fit, and I feel these actions could inform a new hybrid design/marker maker software that makes changes within specified limits and generates possible lower waste outcomes within these variables.

Interview

An interview was conducted with one of the design team who was extensively involved in FT2 in order to discuss if any aspects were missed in the reflection process at the time of the field tests. Often this was because there were many decisions made which the researcher (as someone not working at the company) was not privy to. The questions asked are the same as asked in the Interview chapter in order to enable comparison.

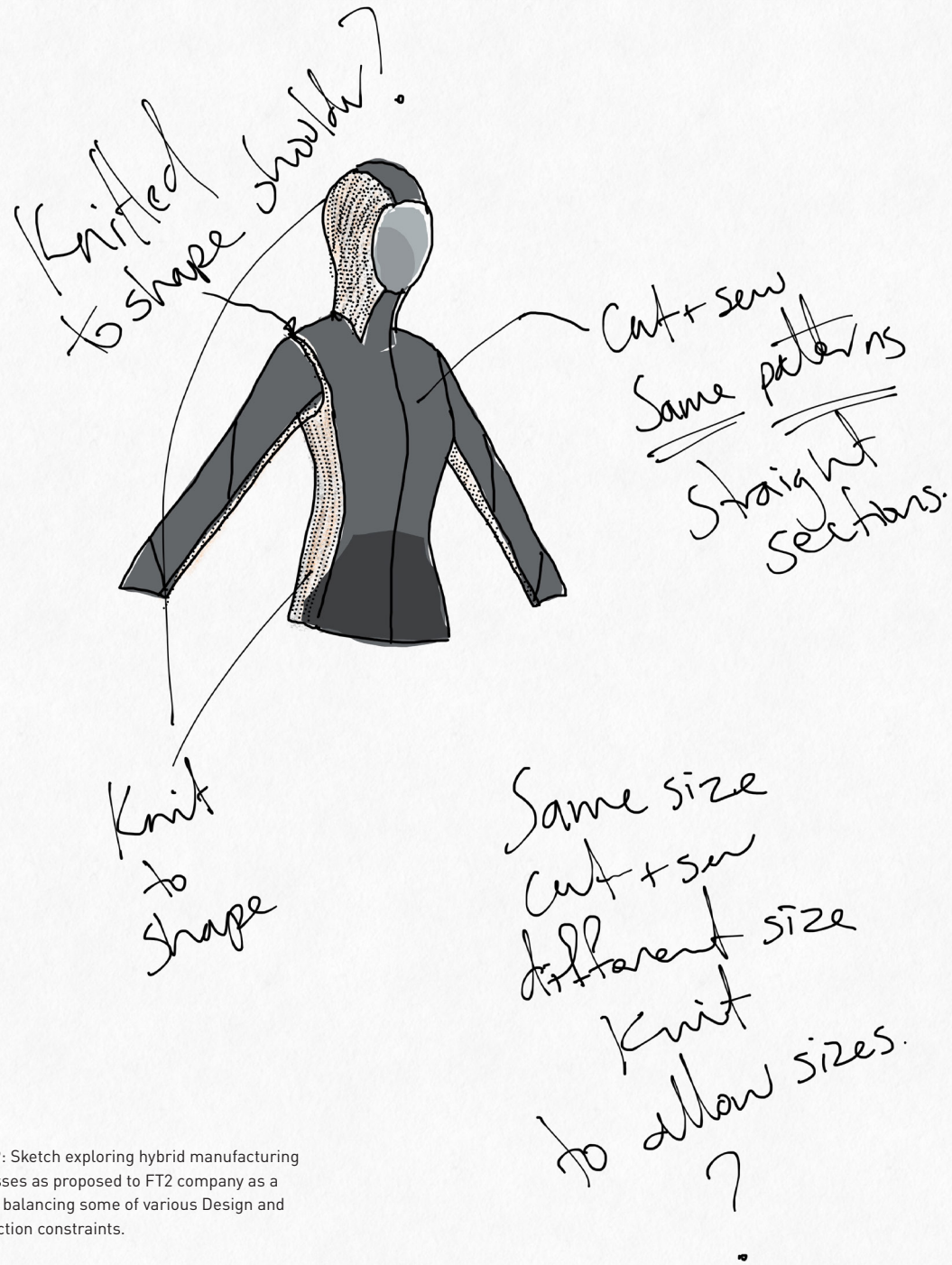


Fig. 39: Sketch exploring hybrid manufacturing processes as proposed to FT2 company as a way of balancing some of various Design and Production constraints.

WASTE IN THE FIELD

This interview is conducted with the technical designer at FT2 who proposed the waste reduction project to the remainder of their team.

Q. How did the concept for the zero waste project begin?

I attended a free workshop given by Holly McQuillan at a college campus in California. Excited by the idea of bring zero waste design to scale, I brought the material and Holly and Timo's [Rissanen] book [Zero Waste Fashion Design] back to work and designers picked up on the excitement as well so we brought Holly down for a weeklong workshop with our product teams. Over the week participants explored different methods of achieving zero waste and gained an appreciation for how difficult this task is, especially to scale for a range of sizes and using multiple fabric widths.

MOTIVATION

PEOPLE

Q. Relationship between initial design, zero waste pattern, sampling and final outcome – What was the work flow like?

As described in FT2

Q. How did you approach the design process regarding things such as fabric width, was fabric selected first for example?

Fabric was selected first. We felt it would be a waste of time to try to design something with less waste without knowing fabric width.

FABRIC

Q. In terms of goals what were the main concerns for the design? Was there a hierarchy (was fit more important than 100% zero waste for example), did the hierarchy change over time, in what way?

Fit and function override everything else. If it doesn't fit then no one will buy it / keep it and it will go to landfill anyway – what a

BRAND GOALS

PRODUCT

waste that would be! Design aesthetic was also a high priority for similar reasons – if it's not beautiful, no one will want to wear it… again, wasted time and resources!

Q. How was this managed with the fitting process for example?

PEOPLE

In one project we let the design and product teams make all fit and design comments, and rather than just sending those to the factory, we also gave these comments to the internal patternmaker to interpret the end results desired by the designer –slimmer though the waist, or more smaller hood fit, or longer sleeve length for example. The internal patternmaker could think through multiple ways to solve the issue rather than simply adding to the sleeve length at the end of the sleeve. It was imperative that we have the design team express all of their needs for fit, function, and design from the beginning so that we didn't get to the end with a product that no one wanted to sell.

PEOPLE

Q. Was the product designed to 'replace' an existing one in your line, or designed as a completely new offering?

PRODUCT

Replace existing

Q. How do you think this may have impacted on the design process?

PRODUCT

It's definitely harder since there's already a customer following of the current product, you can't compromise any of the existing features for the sake of waste reduction. We would be open to using a new fabric for a completely new zero waste design.

FABRIC

Q. Was it important the design met goals regarding yield (did you make comparison to similar products) or was the focus on achieving zero waste and a particular fit and design aesthetic.

WASTE IN THE FIELD

Yield is important in every product due to waste and cost. The focus on these projects were on achieving a higher efficiency rate/ less waste. Reducing yield was also a goal – both for cost and material resources. Is it really that much better to achieve zero waste if you increased yield/ material production in order to achieve this?

RESOURCE USE GOALS

Q. Were the cost/price point goals the same for the zero waste garments as for regular pieces?

Yes

Q. Did you design the whole marker, or pieces that would work together (simple geometric shapes for instance)? If you designed whole markers, how did you approach grading?

We have tried both ways – geometric shapes that will work together as well as looking at the existing marker and modifying the most problematic pieces. We never got to the point of achieving exceptionally less waste than current in the base size so have not explored this.

DESIGN METHOD

PRODUCT

Q. What size range did you work with? Were all sizes zero waste?

It would have been alpha sizing, or SM / ML size grouping had we gotten this far. None were zero waste

GRADING

Q. How did machinists deal with any complex pattern forms, sewing difficulty, new methods of construction? Was this a consideration in the design process?

We had to make very detailed, color coded sewing sequence instructions for the factory to be able to sew the complex shapes. Sewing sequence was considered in the design process, utilizing 3D to mock up a design in some cases, and sewing actual mock

PEOPLE

PLANT

PLANT: SOFTWARE

PEOPLE

ups when 3D was not available. We learned to bring the factory partners (sewers) into the conversation earlier than normal to help ensure that our designs would be feasible in production.

Q. What were the main issues you faced when designing the garment, from management, design and manufacturing etc?

TIME

Time and manufacturing alignment. If we had ample time to explore design lines and involved the factory from the beginning stages I think we could be successful in at least getting to 95% in the base size for a top/ jacket (and pants, but pants are already closer to this target in some cases). It comes down to this being a side project for a few people when it would need the time commitment of a full-time person. Working with the manufacturer proved to be challenging over email – we had much more success when we went there and worked together in person. I believe you need a team of people working on this type of project, including someone from the factory, who is invested in researching what's possible.

PEOPLE

PEOPLE

Q. Do you apply any of the things you learned in this process in ongoing garments or collections – In what way has zero waste endured in the company, would the company do it again?

We are more aware of the marker yields in production, especially for our higher volume styles. There is interest in continuing to work on these projects and we continue to explore as time and bandwidth allows for all departments involved.

PRODUCT

MOTIVATION

Summary of fashion industry field tests

These field tests aimed to explore new methods and implications of eliminating textile waste from the production of clothing at the pre-consumer stage, specifically through zero waste pattern cutting and design practices. This stage of the research sought to apply existing knowledge in this area in a fashion industry context, and develop new methods and guidelines to assist the broader application of these waste elimination and reduction approaches.

In terms of what the research aimed for at the outset, neither of these field tests were considered a 'success' at the time. While methods and implications are part of the findings, it was imagined that there would be manufactured products which demonstrated the success of zero waste design approaches in the context of industry, and this licentiate would be able to report on these as success stories.

Field Test 1 revealed a relationship between fabric cost and the percieved value of applying waste reduction strategies, something that raises questions about the motivations for waste reduction in the context of that field test. Methods were applied and were successful at significantly reducing the yield and waste for a given style, however broader considerations regarding the cost of manufacture rendered these improvements financially meaningless, and therefore undesirable.

Field Test 2 uncovers the impact of hierarchy between people involved in the design process, but also between the various design variables and constraints that drive the development of any project. Again methods were applied somewhat successfully, even given the increasingly tightened constraints, however, the improvements were reversed through an established hierarchical design development process which is not expected to consider waste or yield in the decisions they made.

Is it you or me? Zero waste methods outside of the fashion industry

Parallel to FT1 and FT2 a collaborative zero waste project outside of the garment context was explored. The goal of this was to compare the processes similarities and differences in terms of design practice, particularly any limitations and expectations to see if any insight can be gained from considering zero waste design practice in a broader 3D form giving context.

This research speculated that there exists a similarity between industrial design practices and zero waste design – that zero waste design seeks to solve a problem, as opposed to only seeking aesthetic differences (Hallnäs 2009). This research sought to test if this similarity existed, so it could be exploited in the future to enable more accessible application of zero waste in some sections of the fashion industry which are more similar to industrial design (such as outdoor sportswear, which more heavily invests in the development of their products than high street fashion).

Field Test 3: H/E Chair

H/E Chair is a prototype of a collaborative chair design undertaken by myself and furniture designer Emma Fox. Emma is based in New Zealand undertaking her PhD through Lund University and is exploring new propositions for flat pack furniture using circular and composite materials currently focused on the use of textiles to further develop and improve the field. I am in Sweden, and my goal with this collaboration is to explore zero waste design in a non-garment context. Due to distance, much of our design process occurred via the internet utilising social media platforms such as Facebook and Instagram, as well as Skype and Messenger.

Aim

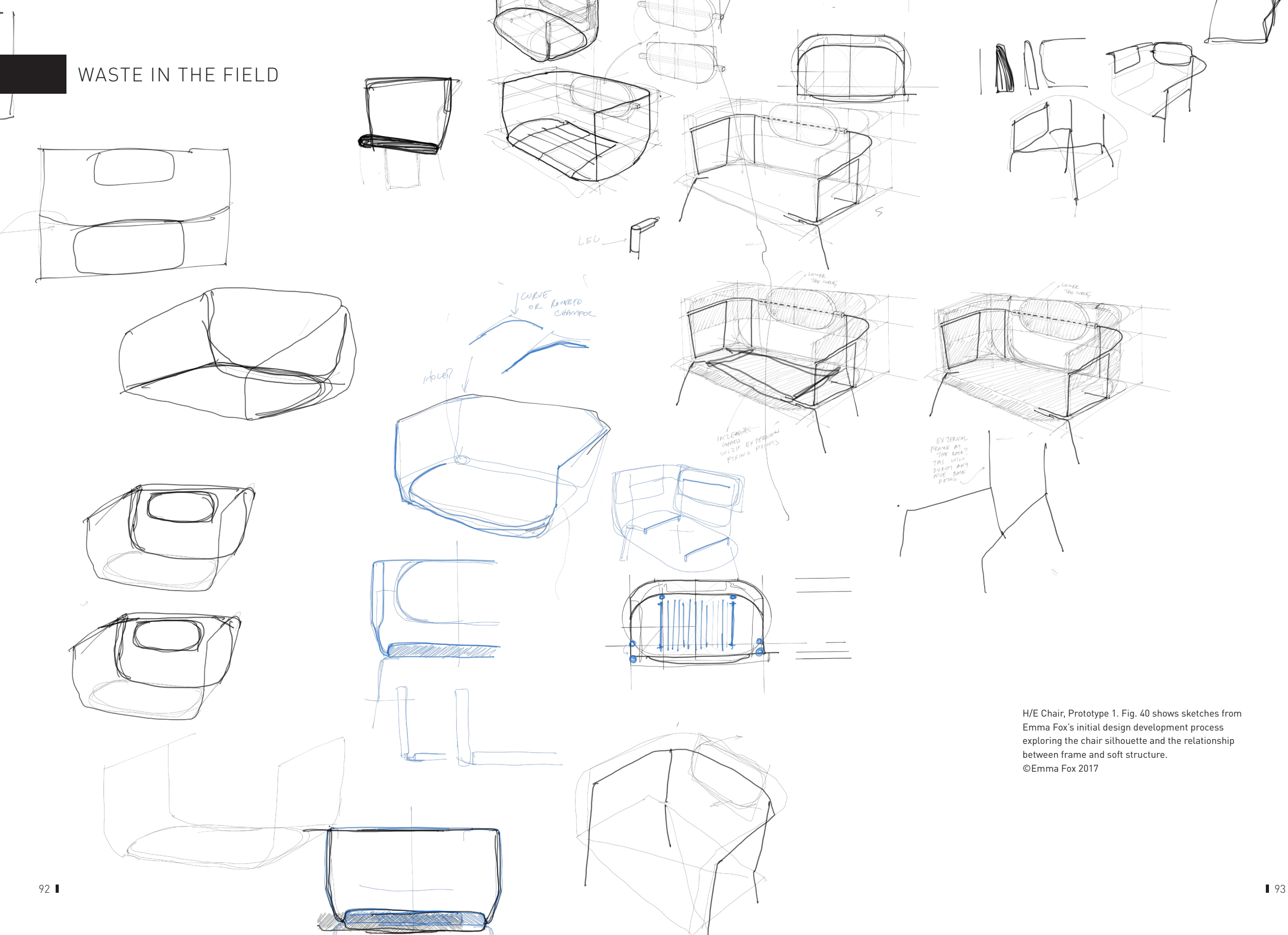
We aimed to explore the use of zero waste pattern cutting in the context of flatpack furniture design. The majority of zero waste furniture has been explored using hard sheet materials such as plywood (see Background chapter), so this experiment aimed to explore processes which combined soft and hard materials.

I treated the design of the chair in the following way. The frame of the chair is like the body, except that we can control the design and construction of the chair frame whereas the shape and form of the human body are relatively consistent. I viewed the upholstery of the chair as I do the garment – I was 'dressing' the chair frame (body). This conceptualisation aided me in comparing the design processes I usually use with how I designed for the chair, allowing me to gain a different understanding of my preconceptions about how I design for the body.

Process

We decided on the type of chair it would be, a 'shell chair' which is a typology that does not typically follow flat-pack design principles, likened to those made famous by Charles and Ray Eames and Robin Day in materials like fibreglass or thermoformed plastic. We made a shared folder on Instagram of the kind of aesthetic we were interested in pursuing in order to establish a shared understanding of the overall goals. From this starting point, Emma sketched her initial ideas for the chair proportions and dimensions, while I developed form studies in paper exploring the chair. Emma was reluctant to provide dimensional starting points for me to work with, and because I usually worked with a body/frame as a starting point, I felt like I needed her to provide this for me. However, in furniture design there is no established body/frame – you design it yourself although there are some conventions which are commonly adhered to. Early on there was uncertainty about the possible relationship between frame and upholstery, and these relative to fabric width. With garment design the designer can start with an established garment size and type; however, these constraints for a chair are less clearly fixed. So where do we start?

Emma began by exploring the proportion and size of the chair and expressed difficulty in dealing with the relationship between various requirements of the design. She expressed tension between aesthetics relating to curves and volumes, functional aspects in terms of flat packing the frame, and concerning fit and the pattern making. Emma seemed to seek to determine details of the design early on and was reluctant to send me anything unresolved. She asked me how much detail I needed before proceeding with the zero waste pattern cutting aspect of the design, and I told her that the less exact the details are, the easier it will be. I wrote, "it's very hard (like FT2 hard) to achieve an exact design unless zero waste has been there from the start." I was concerned she was talking about the specifics of curve details before I had seen any details about proportion and overall scale which for zero waste usually relate directly to fabric width. Additionally, she seemed to be seeking to determine the fabric pattern without working from the fabric width. I wrote: "Maybe you've considered it, but I haven't seen what you've been doing except for sketches, which don't have a relationship to fabric width." It was clear that we were miscommunicating key elements of each other's design processes essential to the projects success.



H/E Chair, Prototype 1. Fig. 40 shows sketches from Emma Fox's initial design development process exploring the chair silhouette and the relationship between frame and soft structure.
©Emma Fox 2017

WASTE IN THE FIELD

H/E Chair, Prototype 1. Fig. 41 and 42 show sketches from Emma Fox's frame construction development process. When i first saw these I was concerned as the frame proportions had no relationship to the fabric width and the aim was to integrate the development of both.
Fig. 43 shows final frame design, finished before the soft structure was developed at all.

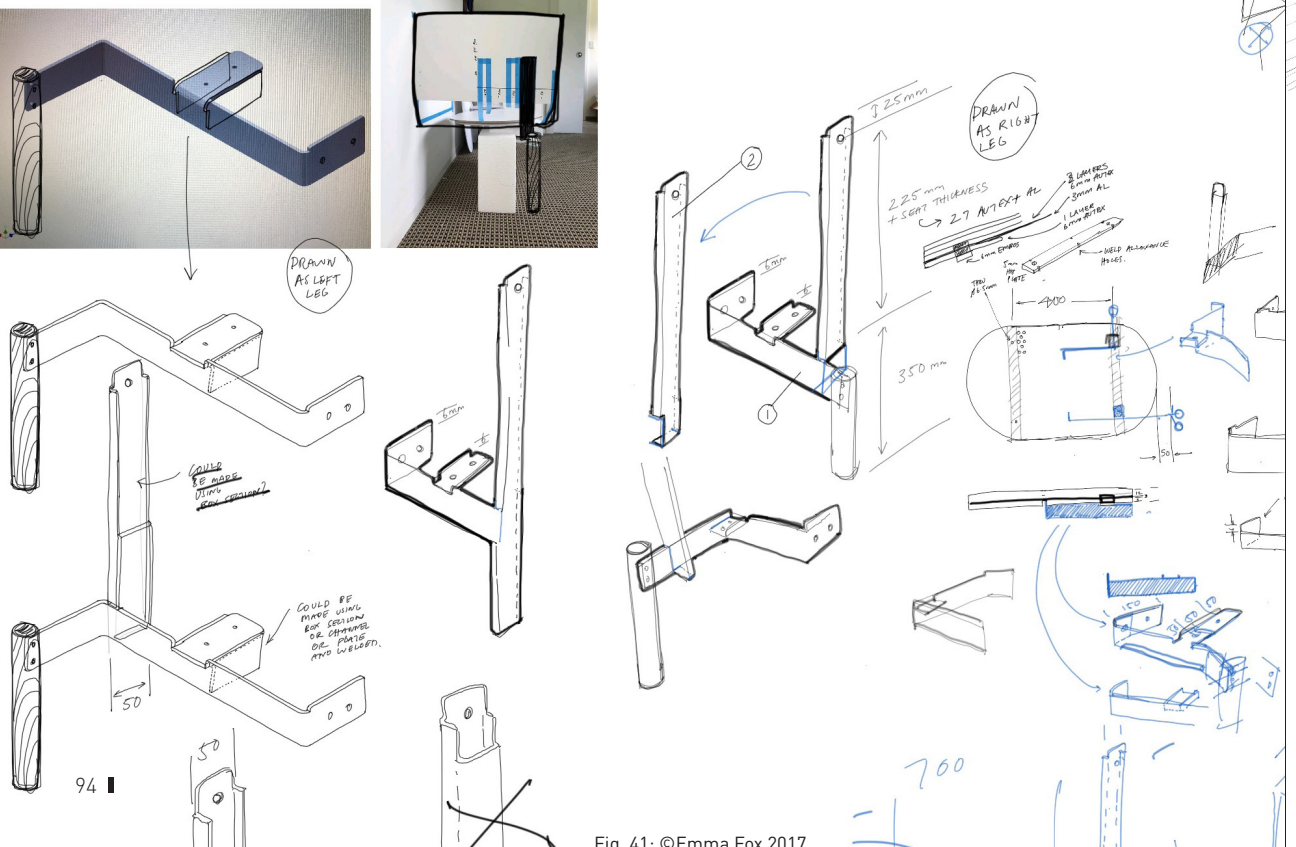


Fig. 41: ©Emma Fox 2017

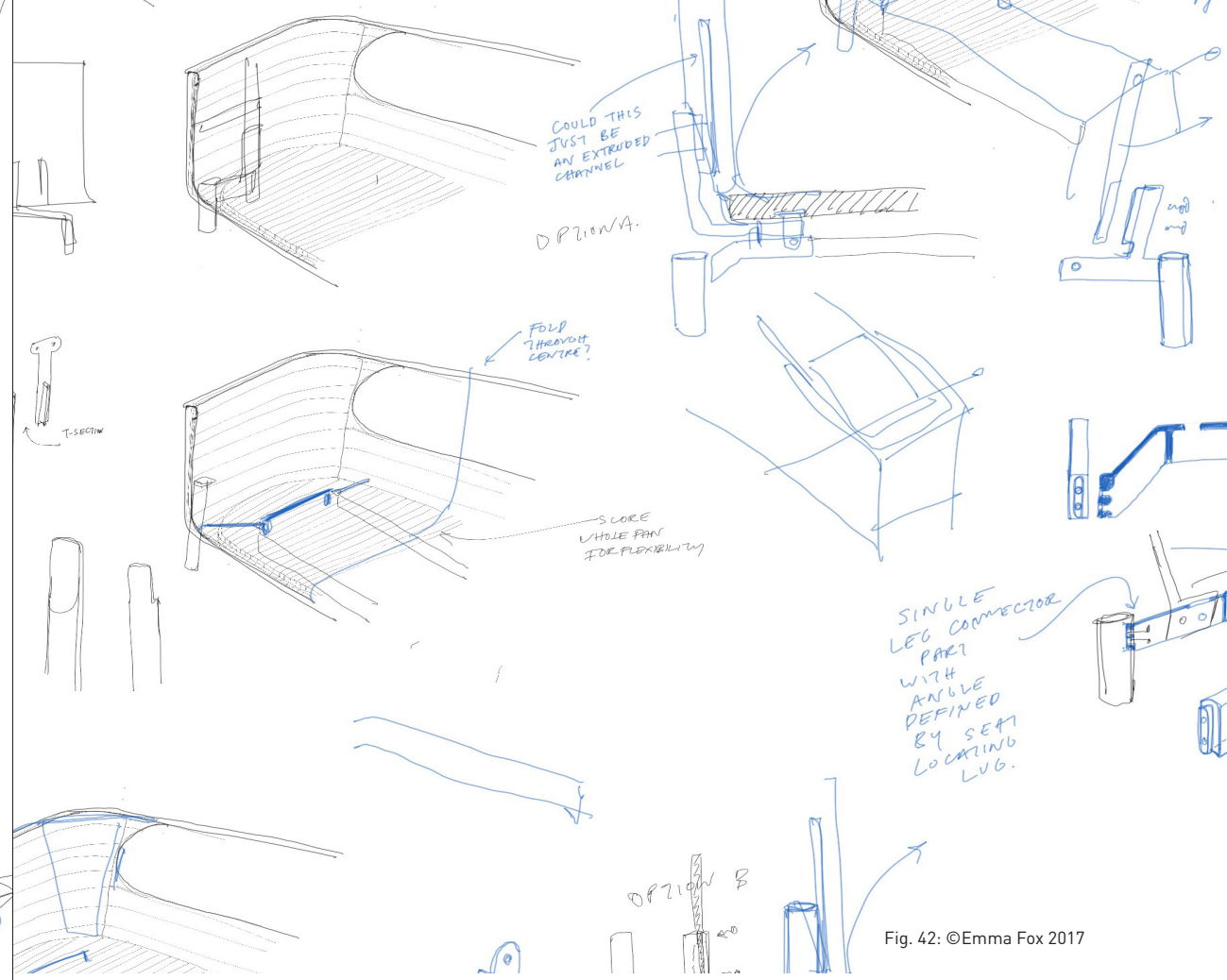


Fig. 42: ©Emma Fox 2017

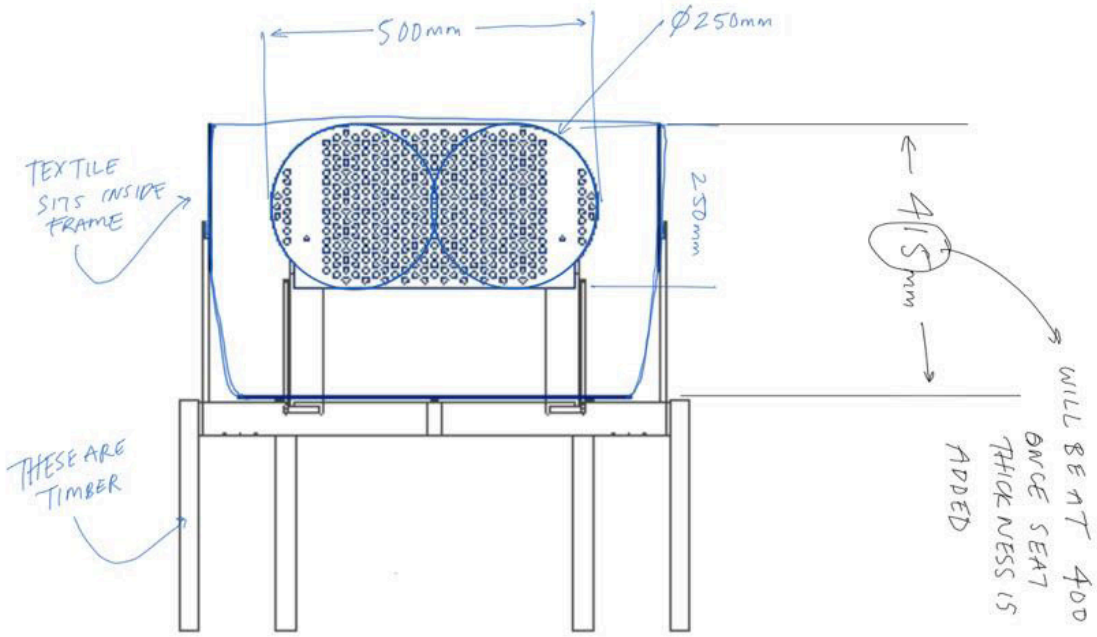


Fig. 43 ©Emma Fox 2017

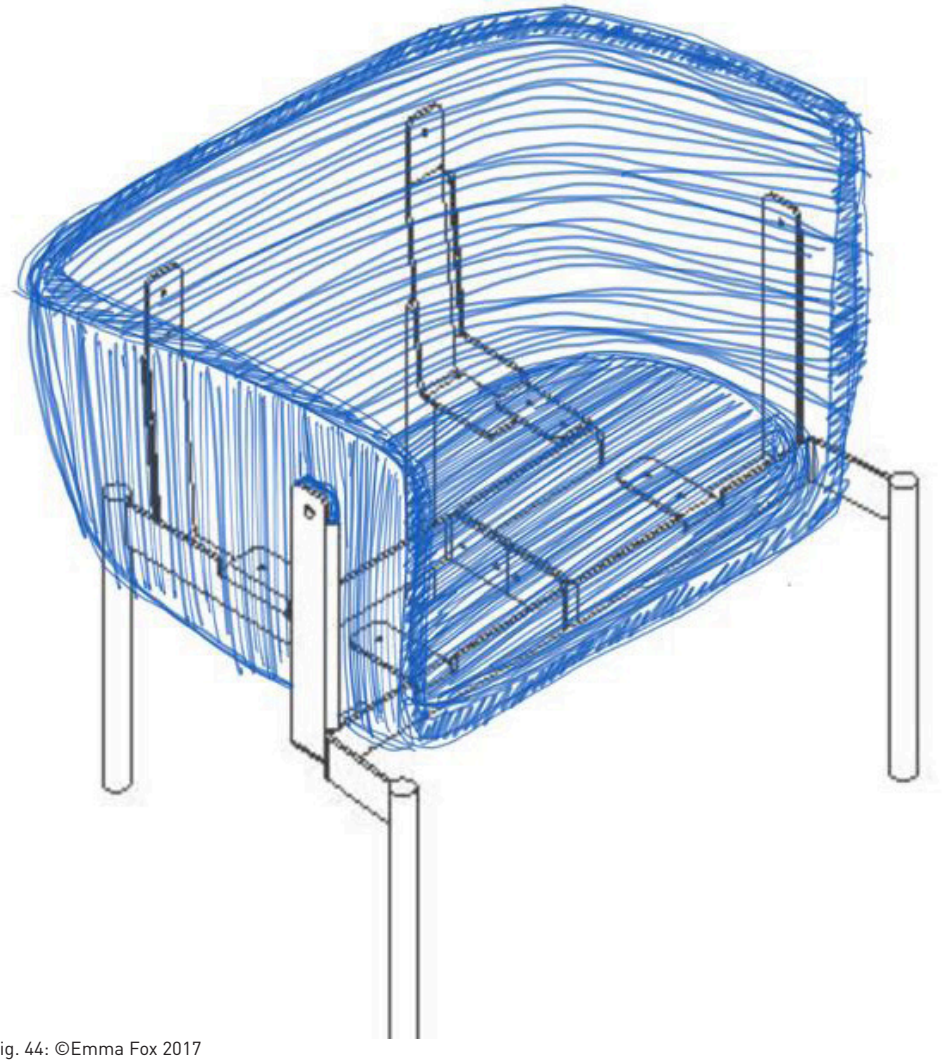


Fig. 44: ©Emma Fox 2017

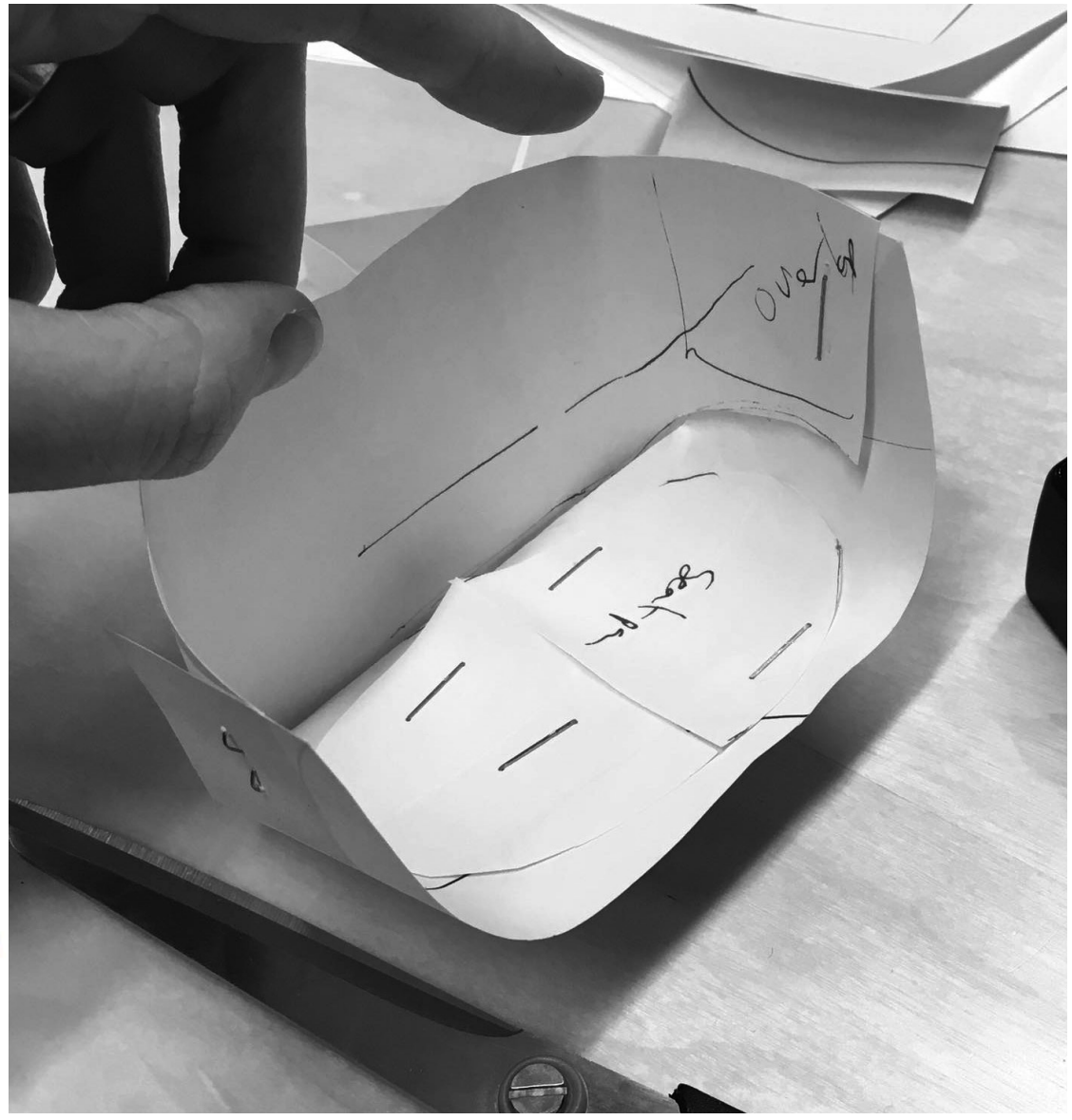


Fig. 45

H/E Chair, Prototype 1. Fig. 44 shows Emma Fox's chair "mass" sketch. The frame is determined at this stage. Fig. 45 shows a paper concept seeking to achieve the desired silhouette within the constraints of the fabric width.

WASTE IN THE FIELD

While Emma was exploring details of the chair (Fig. 46), I was attempting to solve the puzzle of how to generate the basic form (Fig.s 45, 47 and 48) within the constraints provided: fabric width, established chair dimensions, functional and aesthetic goals. On reflection I realised that we were working within different hierarchy of constraints, on the same project, and at times these differences conflicted with each other.

Emma wrote:
I am not asking you to make the basic concept I have sketched magically zero waste, I hope you will see from the frame there is lots of freedom to move within the textile upholstery, and that we can incorporate the ideas I have suggested, for the embossing/folding etc as at the end of the day for my research the flat-pack is of higher value right now than the zero waste, but there must be a balance so both are well resolved and of value for both of us.

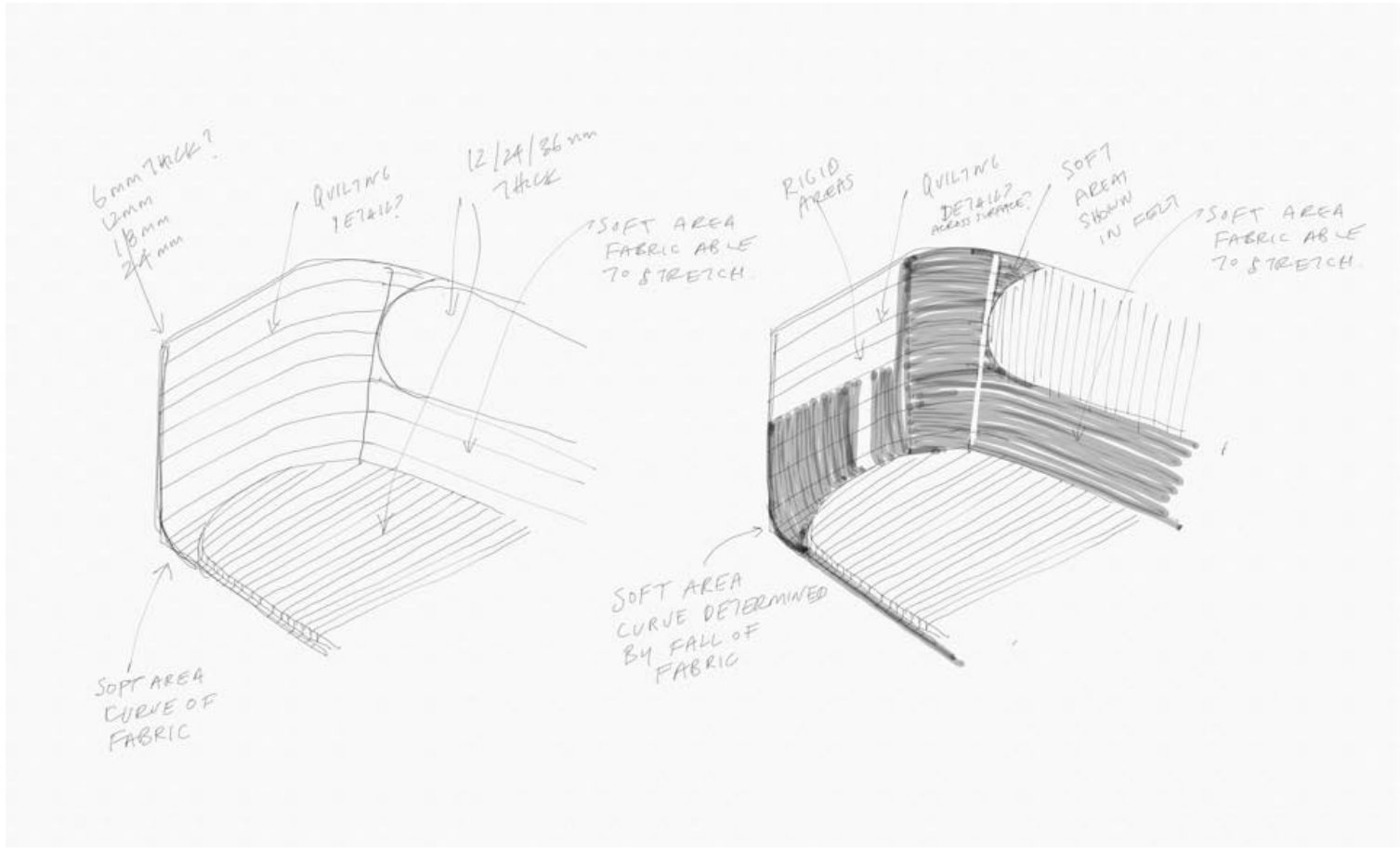
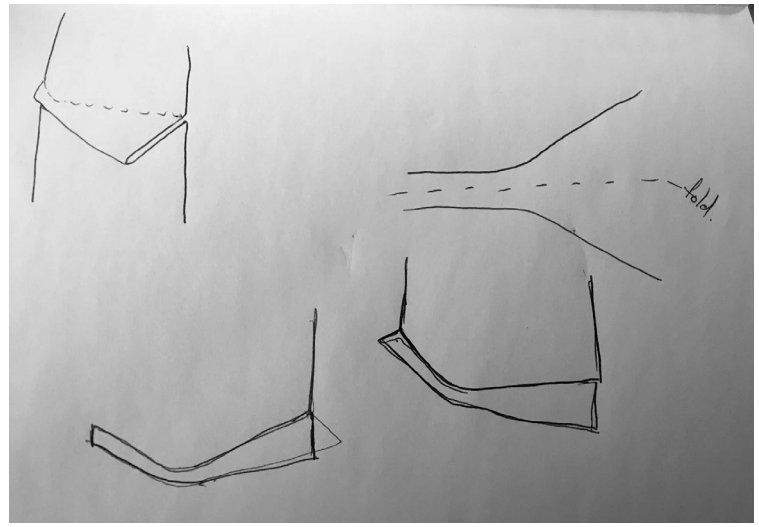


Fig. 46: ©Emma Fox 2017

Fig. 47



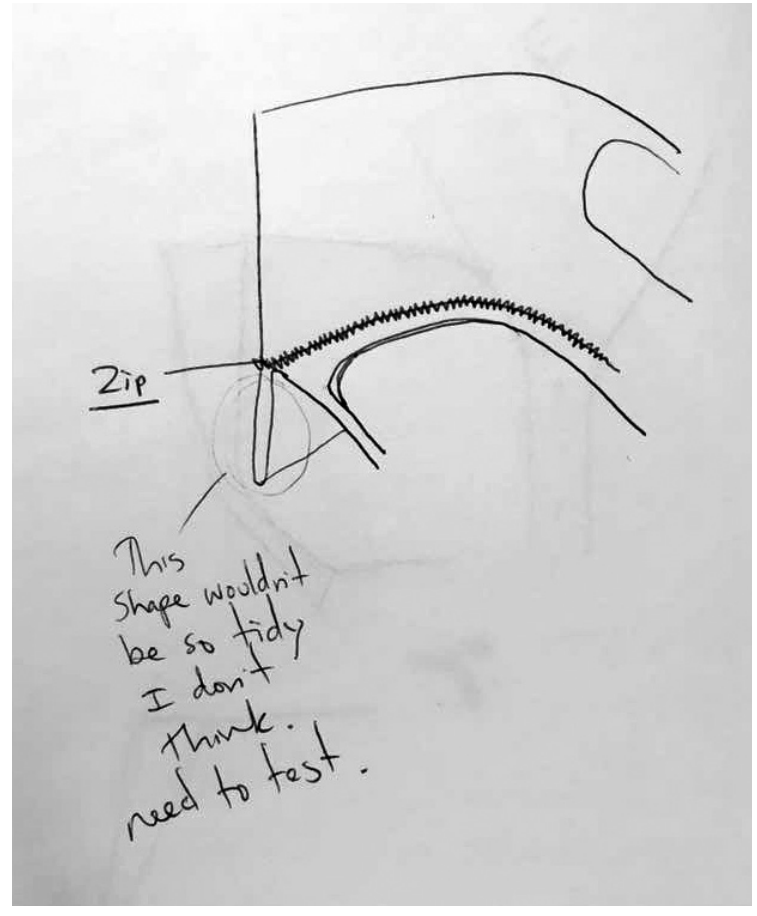


Fig. 48

I wrote that if she designs the whole aesthetic of the chair, there needs to be room in either aesthetic, seams, construction, some space somewhere that allows for the design to be zero waste. It would be possible to accidentally develop a conventional design that happened to enable a zero waste pattern, but it would be improbable. She responded that her drawings "don't have a relationship with fabric width because we can change the design dimension within about 100-200mm depending on fabric choice" – assuring me that it is "not a specific design as such, [but] there are key elements I'd like to achieve". She was happy to change the proportion of the frame if we needed to.

I also hoped to clarify aesthetic 'fit' goals (or silhouette), a common discussion in fashion design, asking if there are "goals in terms of fit between frame and 'dress' … If we were talking about a garment: sleek, tight, clean?". I wanted to know if there were any opportunities in this area to accommodate the full use of cloth while generating interesting design features or required construction details. Her primary concern was the relationship between frame and fabric and the need for the chair to be easily assembled, something I was not used to considering. It could be equated to 'wearability' or 'usability' in fashion however we purchase most garments entirely constructed so this field of research is not commonly required by garment designers, especially relative to hard materials.

While we could in theory design the whole chair frame/body, which could not be done in garment design, in this design context, there was little room for the fabric to move relative to the frame. This means that if the frame was set without an understanding of its scale relative to the chosen fabric, then there was limited design flexibility which is usually needed for zero waste design to be successful.

Once Emma was able to provide me with a basic proportion framework I used the 3D software CLO3D to develop the upholstery layout and resulting upholstery form design, working first with an estimated fabric width until we had an established materials palette. To support this, I also used paper prototyping (Fig. 46), and half-scale fabric sampling to both develop and resolve ideas and communicate them with Emma.

The proportion of the frame remained a problem due to the combination of the desired expression of the chair fabric, the proportion of the chair frame and the width of the selected cloth. I wrote:

> *The relationship between the frame dimensions and the fabric are difficult. For example, if the seat pan was 1x2, and the armrest 1x1 and the seat back 1x2, and those measurements related directly to proportions of the fabric width that would make life easy. The armrest could be 1 x whatever and the seat back 2 x whatever. The widths are where it gets harder, not impossible but it limits the options.*

After some further discussion, I managed to communicate that my comments and questions about the frame dimensions were coming from the perspective of the fabric width because that is a detail I cannot change. The fabric width is not a constraint Emma was used to considering.

For a design where zero waste was not a goal questions about the relationship between scale and fabric with would rarely – if ever – come up. The design would be driven entirely by the desired final dimensions of the chair, and the pattern would be adjusted to fit that and the waste produced would be written off as an unfortunate side effect of something what was more important – how the designer wants the chair to look.

After some initial difficulty in establishing a starting point for proportions, we eventually developed two prototypes of the design following an iterative design process exploring the relationship between the proportions and construction of the chair, the fabric dimensions and related pattern, and how this came together to generate the overall aesthetic and function of the chair.

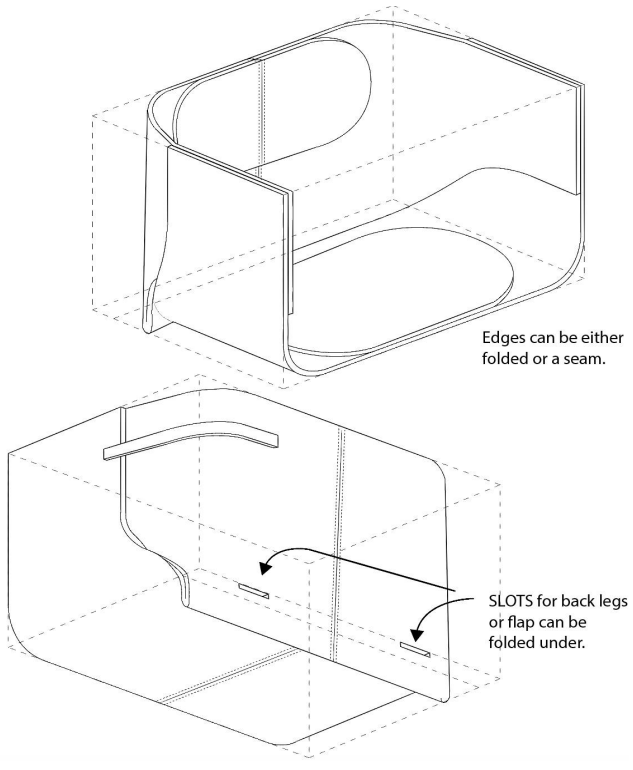


Fig. 49

Fig. 50: ©Emma Fox 2017

H/E Chair, Prototype 1 development, Fig. 49 shows form sketch from pattern development, and Fig. 50 shows an early sewn sample.

Initial reflection: Prototype 1

Prototype 1 was simplistic and lacked finesse and a clear relationship to the frame – the outcome was disjointed because the process itself was not holistic. The pattern wasted only a small amount of material so was relatively efficient; however, its layout was not particularly low yield (see Fig. 51). The chair was never entirely constructed as the issues with the design were perceived as fundamental. However, the development of this prototype gave us a good foundation for our ongoing collaboration.

WASTE IN THE FIELD

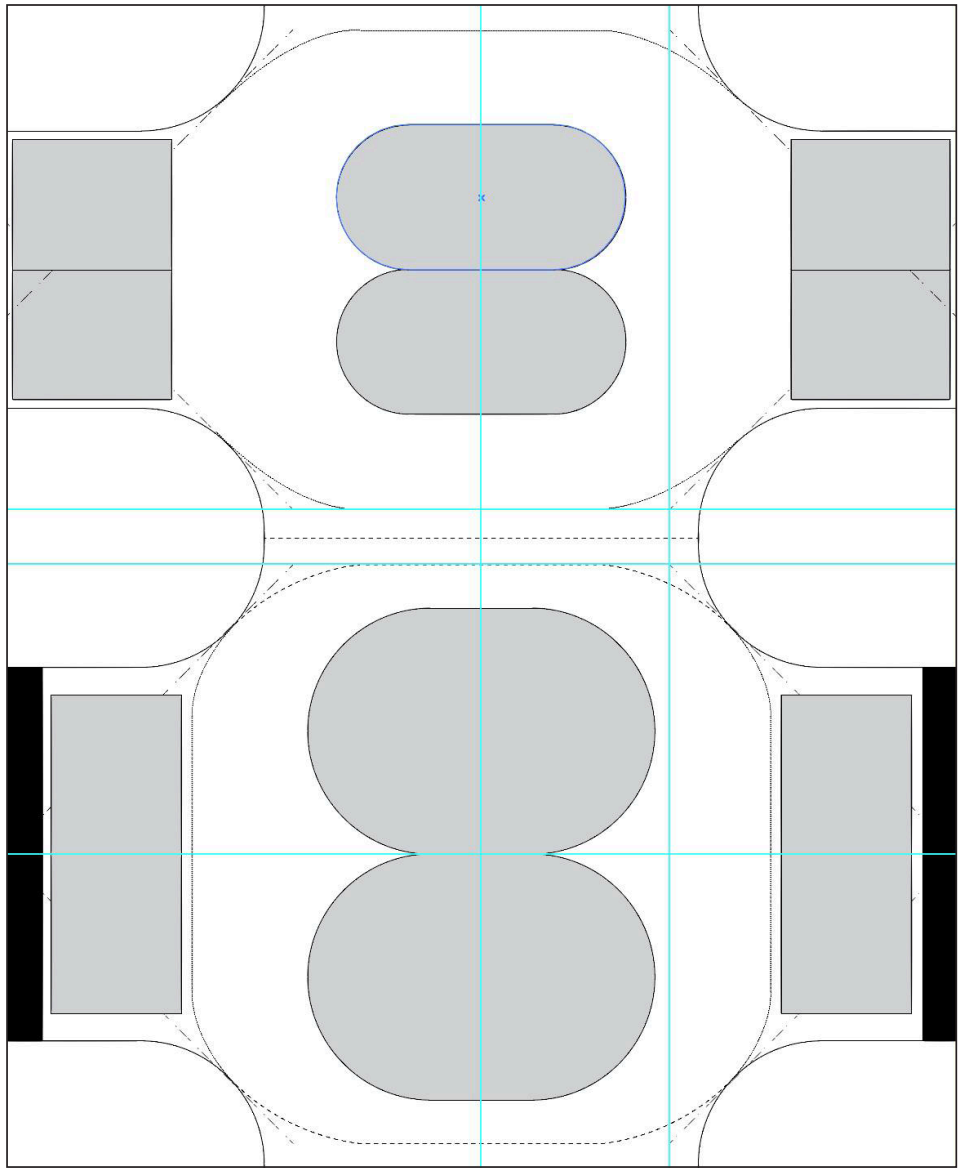


Fig. 51

H/E Chair, Prototype 1 and 2, 2D pattern development.
Fig. 51 shows pattern for Prototype 1. Black sections are waste. This pattern demonstrates a high yield compared to the second prototype, and the 3D design and construction is more complicated, and did not meet the aesthetic goals of the project. Fig. 52 shows H/E Chair, Prototype 2, 2D Pattern. Here the pattern is simplified, with waste and yield significantly reduced compared to Prototype 1.

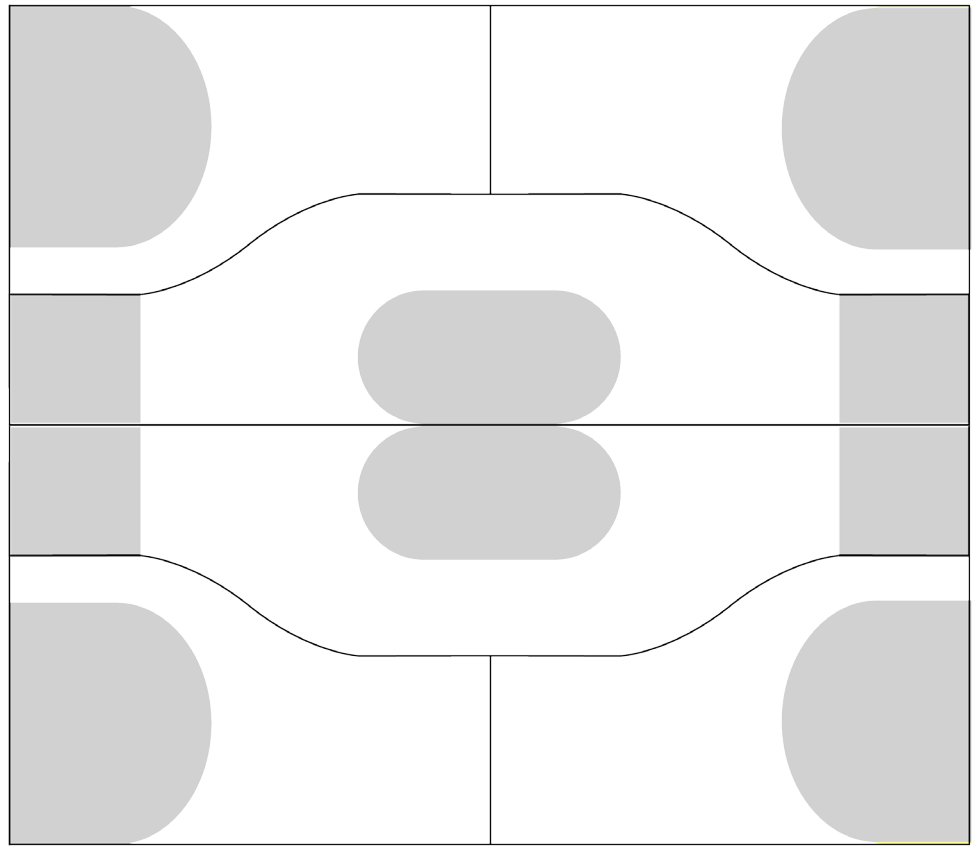
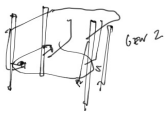
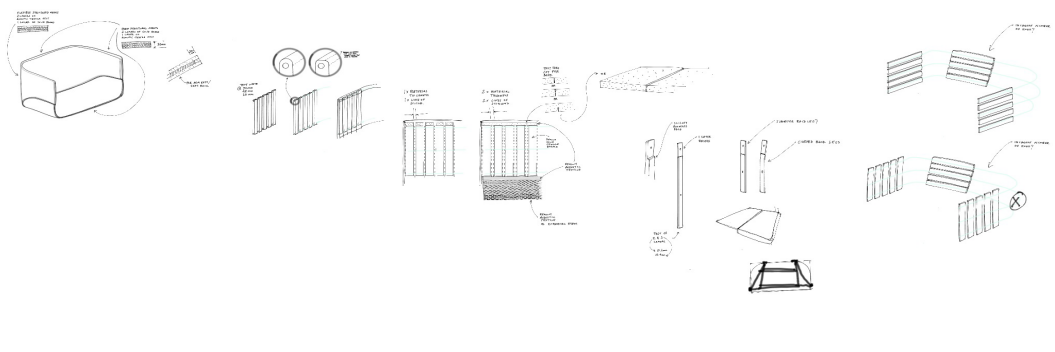
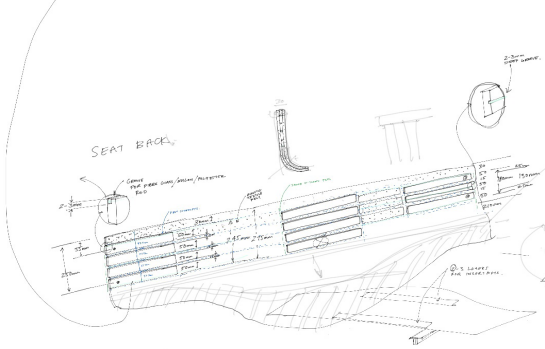
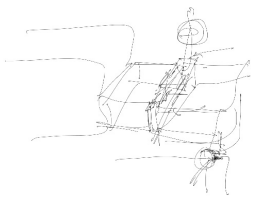


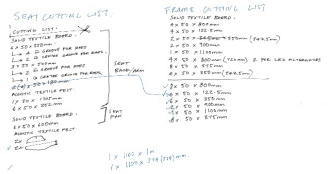
Fig. 52

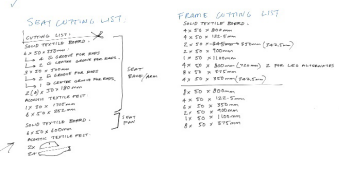


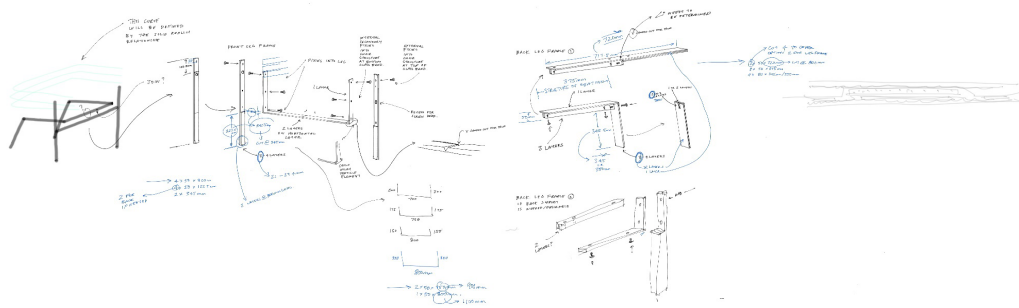












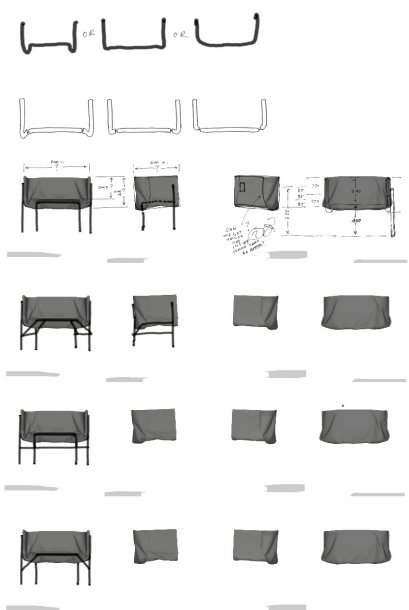


Fig. 53: H/E Chair, Prototype 2 frame development sketches by Emma Fox. The zero waste upholstery design developed is seen in the grey images to the right where Emma explored various frame and leg configurations relative to the cloth seat design.

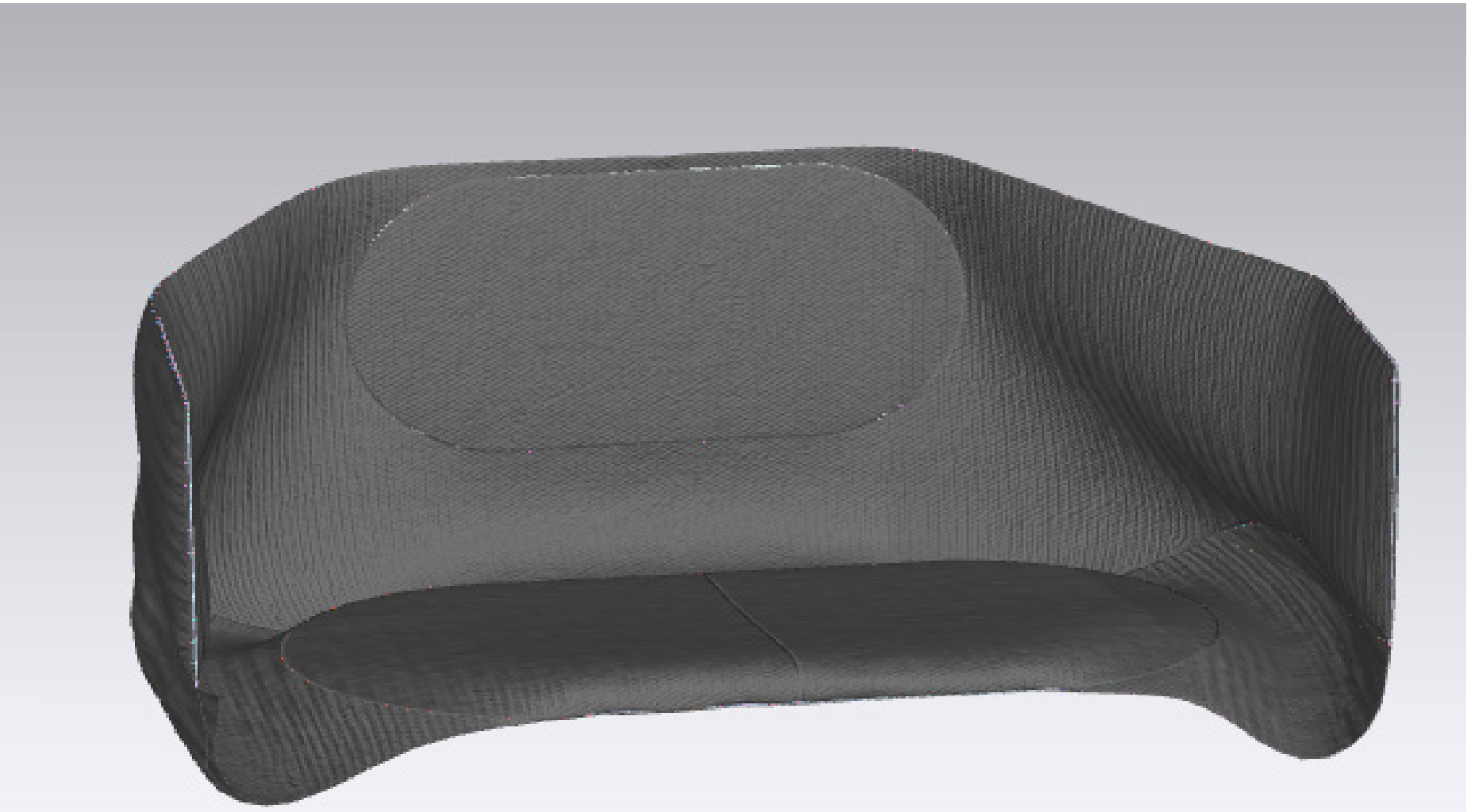


Fig. 54

Initial reflection: Prototype 2

By the second prototype (Fig. 54), we had established a more established and holistic process and we understood each other's design process more intimately. We had also established the details of the particular materials and proportions we were working with already from our work in the first prototype; so we had more control over the resulting outcomes even though the limitations of the proportion and material relationship had not changed. We also become more confident in using the softness inherent in textiles as a design feature for furniture which allowed for some of the dimensional differences to be relaxed. Despite this 'relaxing', the degree of 'acceptable' fluidity and drape in this chair design was significantly less than what may be allowable in a garment, that is to say, the 'space' between body/frame and cloth/upholstery is often less in furniture design than garment design. In many ways this was similar to my experience with FT2 where a tight fit within a specific design framework was desired.

Design process reflection

Different ways of working were highlighted in this project, particularly in terms of design hierarchy and the role that drawing plays in each of our design processes. In zero waste design a drawing, unless we are talking about a scaled pattern, is just a vague concept. For industrial design and conventional fashion design, the drawing holds a different place in the hierarchy. Eventually, it becomes the specification but only near the end of the design process, and before then it is a kind of aesthetic goal. With zero waste design there needs to be a direct relationship between drawing, model and pattern (specification) as soon as possible, ideally from the outset. The sequence of design form > material selection was different from what I experience in the large scale fashion industry, where materials often need to be selected and ordered months in advance. However fashion designers often do not want or need to know the specifics (width for example) of the material at the outset, the material is selected in order to make the design aesthetics and fit work, so width is not relevant.

Terminology was a problem at times, Words like 'fixed', and 'flexible' or 'stretch'. I use fixed and flexible to describe the relative malleability of design variables – for example, is this design element set in stone (fixed) or can we change it if we need to (flexible) – and not relative to material behaviour. This is similar to problems we found in working in the MakeUse project when talking about lines (see Paper I for more detail). In hindsight, this was because I always use flexible materials (cloth) so using the words fixed and flexible to talk about material behaviour is redundant. Establishing a precise shared vocabulary over time when working in cross-disciplinary teams is important, especially in unfamiliar territory such as zero waste design.

From my perspective the design was led by Emma, I felt less confident with aspects of proportion in this context, so she determined proportions and I had to try to make the upholstery zero waste to fit it. I never attempted to design the frame proportions directly; however, in hindsight, this may have been a more effective strategy. I had hoped it would be possible to have a more fluid relationship between the two but hesitation on my behalf, differing ways of working for both of us, and preconceived ideas about the design limited a genuinely holistic approach.

After we completed the first prototype of the H/E chair, I asked Emma a series of open questions regarding her design process. I was trying to gain an insight into how she saw her design process in order to compare it to how I saw mine. It seemed that there were fundamental differences that existed because I work with zero waste, perhaps I operate using a different design hierarchy?

My feeling initially was that Emma knew what kind of fundamental design form and aesthetic she wanted from the start and the design process was a process of bringing this into focus. I thought perhaps an essential aspect of her bringing the idea into focus or controlling the design was through the act of drawing. She seemed to draw a lot especially early on, whereas I draw very little in comparison and design primarily through making digital models, paper models, and prototypes, with drawing functioning as a form of sketch-based notetaking. People often question if I have any control over my design process as a zero waste designer. It seems that this question might be related to both the use of fabric utilisation as a design constraint and the role drawing (or a lack of it) has in my design process as a result.

Many students when attempting zero waste design strategies seeks to apply the design processes they understand and use already to zero waste context and rapidly encounter a problem, they cannot make what they drew zero waste, and either have to change the design aesthetics or not make it zero waste – therefore concluding they have no design 'control'. So, I asked Emma if 'design control' is: you draw it, and you make what you draw.

> *E: No it's not as linear as drawing then make what is drawn, I use physical making of things whether they are material tests, 1:1 foam and card/paper prototypes and manufactured components to development far more to achieve consistency/control. Which is very iterative, the aim isn't to achieve what is drawn, in most of my work an experience or particular material or set of ideas is the start point, sometimes a drawing is used to represent this early in the process but it is very open through making and testing the design evolves from the original sketch. Drawing is used in many different ways throughout my process. Overall for me I don't think it's a process aimed at 'design control' it is a process of using 'design' as an activity to resolve, test and express an idea through a made object.*

H: what do you use to test if it works? Do you try to achieve what you drew or intended when you drew? Or is it open?

> *E: It would depend if I did a drawing. I don't always do a drawing... Depends on the scale of the project; in industrial (design) we work at a wider range of scales in relation to the body/environment than I believe fashion designers do. It also depends on the material, I do very few drawings when I am doing ceramic or if I am trying to find an application for a particular process I've developed with a given material these processes are a combination of CAD and physical making on repeat. A lot of my process is about figuring out how to make things work by developing processes to achieve particular ideas, these ideas can be represented by drawings, both digital and physical models and material tests.*

My questions were attempting to help determine when the act of design occurs? How do we measure the success of a given design? It seems that often when designing products (like garments or chairs), we may act for a time that how it looks is not everything, but eventually, all other aspects are up for compromise in order for it to meet specific aesthetic goals. When does that happen? To what extent? Does aesthetic adherence serve us in our current climate crisis? I knew that I do not personally disregard aesthetics; otherwise, I would not be a garment designer and might be satisfied with sacks as clothes. In the past, I have been accused of being dogmatic regarding zero waste design, and maybe I can be. However, ultimately I am interested in what way does there occur a negotiation between the various goals of a project or product, how should we determine what is important, and how do we and could we design for and against the generation of waste and other negative environmental impacts, and does it matter?

This project is still ongoing.

Field Test 3 reflection

Field Test 3 aimed to explore the use of zero waste pattern cutting in the context of flatpack furniture design. Conceptualising the frame of the chair is like the body and the upholstery of the chair as the garment was somewhat problematic as there remains a second actual body (the seated person) in this context which was potentially ignored. Despite this, the conceptualisation outlined aided in the comparison of the design processes usually use in zero waste design and the fashion industry, with how the design developed for the chair in the furniture design context.

Comparing the two contexts aided in the development of the following understanding of fashion design constraints and standard ways of thinking:

> *Normally with (zero waste) fashion practice the body is a known thing at the start. The garment is for a human. To live in, move in, wear, communicate through. This is both a hindrance and a blessing, as the designer can only change the sex and size of the human that it's for, but there is a lot of freedom in many ways about dressing that body. The body is self-supporting, so the garment dresses it and isn't required to physically 'work' except with and against gravity, it doesn't usually require skin tight clothes, so there is space between the body and the garment, and we always know the basic shape of the form that the void of the garment needs to enclose. Unless designers engage with radical body modification and start removing limbs, the basic forms stay the same (McQuillan/Fox private Facebook group comment).*

This field test reveals that many of the same limitations, roadblocks and constraints arose in the development of the two chair prototypes as emerged out of the design process in Field Test 2. The delicate balance between design and production constraints is always in action and being responded to, even in this small scale collaborative context. Additionally, the field test demonstrates that the implied hierarchy which places constraints relating to aesthetics, over resource use constraints is in play in this context also. The aesthetic/fit constraints relating to the looseness of the upholstery were similar to what was experienced in Field Test 2. However, as there is a higher degree of flexibility in the design of the frame (as opposed to the body), these constraints were mostly able to be mutually resolved.

The use of fabric and not a hard sheet material like plywood raised an issue that is experienced in the fashion industry where the width of the fabric is not standardised. This lack of standardisation is a problematic production constraint which has profound impacts on the longevity of any given zero waste design. The fabric width may change at any moment, even within the context of one season, and a zero waste design produced as a whole marker requires a specific width fabric. Additionally, if a new fabric is desired for an existing design, the new fabric is unlikely to come in the same width as the original zero waste design. The industry does not respond holistically to this inherent irregularity and malleability (such as by allowing for small differences in garments), and instead attempts to enforce consistency either through cutting of more or less selvedge to accommodate for the differences, or by automatically producing a new marker that may produce more or less waste than the original.

Fig. 55: Screen shot of pattern window in CLO3D, mid design development for FT2

Summary of Field Tests

While the research provides considerable insight as to what can be done to ameliorate the implementation of waste reduction strategies in these contexts, through the development of this research it became clear that in the context of large distributed design and manufacturing systems for the fashion industry a simple ‘drop-in’, methods based approach would not be possible. Chapter 4 expands on some of the possible strategies explored in the field test, and reveals additional issues. Chapter 5 reflects further on the insights into why these issues arose, and Chapter 6 reports on the key questions and findings (presented in a series of theoretical models with supplementary explanations) that it is hoped others can learn from going forward.

4. INTERVIEWS WITH THE FIELD

Learning from the success of others

In the following chapter four interviews with designers are reported and reflected on. Each of the designers has implemented zero waste strategies successfully in a range of company settings. They have been interveiwed in this research in order to expand on the observations from the field tests. The interviewees traverse a range of roles and company contexts: from a design director for a large established American brand, to a junior designer for a medium sized sustainable European brand, to a guest designer for a Hong Kong based womenswear brand that specialises in utilising waste from the fashion industry for the luxury market, and an owner/designer for a small New Zealand swimwear brand. Each interviewee was asked similar questions via email, giving them time to reflect upon their own experience. The questions were developed in response to the field test experiments.

The interviews are reproduced as conducted. They were then read, reflected upon, and an analysis process is undertaken. The critical text is highlighted and labelled with related thematic groups, these themes are further reflected on in summary at the end of this chapter, and inform the development of the theoretical models in the following chapter.

INTERVIEWS WITH THE FIELD

Kenneth Cole is a 30-year-old American fashion brand which initially began by selling footwear and are known for their strong stance on social justice issues. They now have an extensive product offering for men and women's footwear and garments. In 2017 Mary Beth McDermott was the designer responsible for the development of a zero waste women's t-shirt.

Q. How did the concept for the zero waste tshirt begin?

I had been toying with the idea of a commercial applications for Zero Waste design since our [Make/Use] workshop at Parsons. I didn't immediately have an obvious outlet in my professional life (as Design Director of Knitwear, Women's at Global Brands Group). In early 2016, we heard that we were getting the license to design RTW for Kenneth Cole, and I saw it as the perfect opportunity to develop a capsule collection of entirely Zero Waste garments because of Kenneth Cole's history of social activism. I proposed this to the Creative director and VP of design, who loved the idea, but wanted to start with a t-shirt.

MOTIVATION: BRAND IDENTITY

Q. Relationship between initial design, zero waste pattern, sampling and final outcome – What was the work flow like?

I was the one who proposed this project, and was given full control of design direction and execution. I was expected to do sourcing, design, sampling and the tech work with the factory. I normally worked every day with the leaders of all of the other departments on other knitwear projects, which was a distinct advantage in explaining and getting everyone excited about the project.

PEOPLE: COMMUNICATION AND HIERARCHY

Q. How did you approach the design process regarding things such as fabric width, was fabric selected first for example?

PEOPLE

PLANT

FABRIC AND PLANT

Since we were going to be using our current fabric supplier and factories to create this t-shirt, the first step in the process was to meet with our VP of fabric sourcing to discuss fabric sourcing. All t-shirt fabrics are knit on circular machines whether in jersey, rib or interlock. Once off the machine, typically a glue stripe is printed on the tub which is then slit in two, allowing factories to process the fabric flat. When the fabric is dyed, printed, or finished, usually fabric is pulled along machine using pin stints along the edge. Pin stints leave tiny holes and many times rips and tears in the selvedge. Between the glue and the pin stinting, it became clear that we needed to work with the fabric in a tubular form, which would present an entirely new set of challenges in finding a factory willing to deal with cutting fabric that arrives in tubular.

FABRIC AND PLANT

FABRIC

Since we would be working with fabric in tubular, it made the most sense to develop yardage in a fine rib since it lays flat when cut. However, rib adds weight to fabric and we wanted to keep the t-shirt light, so that meant using a superfine yarn count to knit. We looked at swatches in 100% cotton, organic cotton, and cotton blends. Ultimately, we decided to knit sample yardage in a cotton/modal blend. The color (black) was dictated by the rest of the collection.

Q In terms of goals what were the main concerns for the design? Was there a hierarchy (was fit more important than 100% zero waste for example), how did it change over time?

MOTIVATION

GRADING

My main concern for design was always to revamp traditional manufacturing by creating commercially viable processes for minimal waste garments. It was essential that these garments were able to be graded in a full range of sizes if we are going to create successful systems. The choices I made throughout the design process were always with this focus in mind.

Q Was the product designed to 'replace' an existing one in your line, or designed as a completely new offering?

PRODUCT

This was a new offering at the relaunch of new brand. This allowed me to focus on concept rather than trying to fit into an established merchandise idea.

Q *How do you think this may have impacted on the design process?*

PRODUCT

We also intentionally positioned the Zero Waste t-shirt as a novelty tee, so that it did not compete with any basic tee program that we would develop. This also release me from the constraint of trying to hit an established cost. The tee needed to be in the realm of other novelty shirts, but our merchandising partners were open to a range of pricing.

Q. *Was it important the design met goals regarding Yield (did you make comparison to similar products) or was the focus on achieving zero waste and a particular fit and design aesthetic.*

PRODUCT

We intentionally went with a generously fit tee, so that it did not compete with a 'basic' tee, so there was no pressure to conform in that sense. It was assumed that the fact this was zero waste garment would maximize yield and compensate for this being a larger garment.

YIELD AND RESOURCE USE GOALS

PEOPLE: SUPPLIERS

The only concern I had was from a sales/ minimum fabric point of view. Every fabric factory has a minimum order quantity to knit custom fabric. We would be forced to buy this amount regardless of what we sold. And, obviously, if we had left over fabric that we did not need to cut, there would be waste. The plan was to cut exactly what we needed and use any remaining on a long sleeve tee I was developing for the following season. This is not a perfect solution, but the best we could do within our sourcing system. Unless we owned our own fabric mills, and/or retail stores, there is no good way to control these numbers.

Q. *Were the cost/price point goals the same for the zero waste garments as for regular pieces?*

PRODUCT

The cost had to fit within the overall cost structure of the line, but not a specific price bucket. It did need to meet the "perceived value" test….. meaning, "does this look like it is worth $x to our final consumer?" That is a very subjective marker, because each market level perceives what it expensive/ inexpensive differently. In the designer market, a $200 t-shirt is normal, but in the world of mass market, anything over $12 is too much. T-shirts in the contemporary market go for anywhere between $40-100, depending on cost and perceived value.

Q *Did you design the whole marker, or pieces that would work together (simple geometric shapes for instance).*

PEOPLE

I made the pattern, first sample, and marker, which is very unusual for a large company. Normally, I would be responsible for the idea, sketch and maybe a tech pack. For me to work in our sample room and actually do pattern work caused quite a stir at work. Everyone that I worked with stopped by to ask what I was working on, because designers, and especially, design directors did not make patterns.

DESIGN METHOD

PEOPLE

The pattern is in simple geometric shapes to make it easier for the factory who was producing the garment to work with. I wanted to come up with a plan that allowed the factory to "lay-up" the fabric and cut in the tubular shape it arrived in, as opposed to forcing them to slice it, and attempt to unfold and lay it flat.

Q. *If you designed whole markers, how did you approach grading? What size range did you work with? Were all sizes zero waste?*

GRADING

Since this was a generously sized tee, we decided in conversation with sales/ merchandising, to sell this in bucket sizes (xs/s

and m/l). I used a standard 1 1/2x grade between the sizes and came up with a plan to cut some panels narrower and some wider on each tee and then swap them so that all the smaller panels created size 1 and all larger panels created size 2.

GRADING

Q How did machinists deal with any complex pattern forms, sewing difficulty, new methods of construction? Was this a consideration in the design process?

I did everything I could think of to make this easy for the factory to follow. I cut and sewed a "sew-by" sample, made a pictorial diagram of how to cut and sent an unsewn sample for them to follow, and held countless meetings in NY with our production staff to make sure they all understood what we were trying to achieve. But, with all things new and different, there is always a learning curve.

PEOPLE

YIELD AND RESOURCE USE GOALS

The yield for each size is approximately 1 yard. But the first counter sample factory sent back used over 3 yards per garment and wasted huge amounts of fabric. I kept the pattern they sent with it because it was so ridiculous. Eventually, after a number of emails back and forth, and the involvement of numerous VP's both on the NY team and the team in Asia, we finally got the factory to understand.

PEOPLE

GRADING

[The factory] still had some legitimate concerns about sizing in production. Normally they are only allowed a tolerance of ½ of the measurement grade to be off spec. When you consider that fabric widths can vary significantly (1-3" in width per lot), if they were forced to use all the fabric from edge to edge, the sizes in bulk wouldn't necessarily hit spec (or pass inspection). We needed to agree in writing to accept the sizing, however it came out based on the width the fabric arrived from the factory. This is way outside of the boundary of normal acceptable practice for most large manufacturers. And, as you can imagine, made some on both teams a little nervous.

FABRIC

PEOPLE

Q. What were the main issues you faced when designing the garment, from management, design and manufacturing etc?

GRADING

FABRIC

I think my biggest challenge in designing this garment was figuring out how to grade the garment for multiple sizes. At first, in my discussion with the VP of fabric, we discussed knitting the tubes in varying widths. This could be a great solution if you have large orders because each width would be a different size, and could be knit to order. But with our smaller project, it was important to limit to one width and make it work for multiple sizes.

DESIGN METHOD

GRADING

FABRIC

After many discussions with the Creative Director, merchandiser, and production, I came up with the plan we used to create bucket sizing and shuffle pieces to create a larger size and a smaller size. In theory, if fabric was knit in 3 different tube sizes and the same technique was used, 6 sizes could be achieved, from xs-xxl. This for me would be an important break through in making Zero Waste accessible to everyone.

Q Do you apply any of things you learned in this process in ongoing garments or collections – In what way has zero waste endured in the company, would the company do it again?

I still primarily design Fully Fashion knitwear currently, so I haven't had a chance to explore this further in a commercial setting. However, I do have my students creating zero waste tees as part of their collections this semester.

PEOPLE

A former student of mine was working at GBG after I left and part of his responsibilities were to develop sustainable practices for Kenneth Cole including developing the additional Zero Waste garments. He worked for months to come up with strategies, but found that it was very difficult to get the various departments (design, tech, sourcing, production, etc.) to work together. Ultimately, nothing was adopted despite the fact that

management green-lighted this initiative to begin with. My student echoed my belief that it takes someone of a director level or higher to shepherd the project through from conception through production in order to make effective change in a large corporation. Everyone is just so used to working a certain way, and busy trying to keep everything going, it would really take true leadership to steer the ship in a new direction.

PEOPLE: HIERARCHY

Q Is there anything else you might like to add?

I suspect, after re-reading my responses to the questions above, there is not as much information about the actual design process as you might be interested in. For me, designing zero waste garments is like solving a puzzle. I use my extensive experience in creating knitwear shapes and try to figure out creative ways to get the pieces to fit together. I really enjoy working on design from this perspective, but have seen first hand with my students, how this is not everyone's cup of tea. Partly, I think students may not have as much of a base patternmaking knowledge and they get frustrated with the fit and shaping aspect (if you take something from one place, it has to end up somewhere else.)

DESIGN METHOD

PEOPLE

I also think that some designers just don't enjoy this method of designing with this sort of limitation. Their priorities may be purely aesthetic, or completely functional, but trying to make all of that work without wasting an inch of fabric is just too complicated for some.

PEOPLE

I keep telling my students that resource shortages will be a reality within their lifetime and will affect what they are able to design in their careers. Mostly, I get blank stares right now, but, hopefully, enough of a seed is planted in the back of their minds to get them thinking about new and creative solutions to keep moving fashion forward despite whatever happens.

MOTIVATION

Hessnatur is a German sustainable fashion design brand with a 40-year history. The Hessnatur Zero Waste Capsule Collection was sold from SS15-SS17, for five seasons. Simone Austen was a designer involved in the inception and development of the collection.

Q. How did the concept for the collection begin?

I initially asked the former head of design if a zero waste collection would be of interest for Hessnatur with garment examples of my Bachelor of Arts collection in the beginning of 2014. I thought it would be a great match for Hessnatur as a sustainable company.

MOTIVATION

Q. Relationship between initial design, zero waste pattern, sampling and final outcome – What was the work flow like?

BRAND GOALS

At the beginning of each season, we first talked about possible, easy understandable styles and accordingly to that fabrics which might make up a capsule collection, then afterwards I started writing to the fabric suppliers to check fabric widths. After having received those, I started working out the patterns. Having finalized that we started sampling and then fitted the first protos, eventually made changes on the pattern/workmanship/ draped things differently on a mannequin. After that, we received photo samples, and after refining them again the styles went into production. This process until production took about 5-6 months. The designing process started always 1 year ahead of the season and the garments were produced about half a year before they were sold instore.

FABRIC

DESIGN METHOD

TIME

Q. How did you approach the design process regarding things such as fabric width, was fabric selected first for example?

DESIGN METHOD

Mostly, I started searching for suitable inspirations such as draping techniques/garments which would be good to be translated into zero waste. Also, I used a lot of my Bachelor ideas and deve-

loped them further. Fabric was mostly second, although after a while I had a certain "pool" of fabrics which I used over and over again because of its behavior or a very convenient fabric width for certain styles.

FABRIC

Q. In terms of goals what were the main concerns for the design? Was there a hierarchy (was fit more important than 100% zero waste for example), how did it change over time?

MOTIVATION AND RESOURCE USE GOALS

PRODUCT

BRAND GOALS

At first, the idea of zero waste was most important, especially for marketing reasons. At the same time, we focused on easy designs which could be recognizable as zero waste designs at first sight. Later the fit became more and more important. The zero waste collection was more and more compared to the regular collection and needed to be improved more and more in terms of fit and wear ability.

Q. Were the products designed to 'replace' an existing one in your line, or designed as a completely new offering?

PRODUCT

The products were created as a whole new offering.

Q. How do you think this may have impacted on the design process?

PRODUCT

BRAND GOALS

This allowed the design to be a bit more expressive, to show some "design" which extended the design language of the prevailing collection.

Q. Was it important the design met goals regarding Yield (did you make comparison to similar products) or was the focus on achieving zero waste and a particular fit and design aesthetic.

MOTIVATION

RESOURCE USE GOALS

PRODUCT

At first, it was only a try to make such a collection and the main reason for it was maybe the aspect to use it for marketing reasons, so the focus was on designing a special shaped garment that would indicate its design background. So the yield wasn't too

important at first.

YIELD AND RESOURCE USE GOALS

But for the following collections the importance of yield grew more and more. For certain products, such as a basic shirt, the yield wasn't actually too bad in comparison to similar products of the regular collection. For more complicated products with draping details, the yield was not as good when compared to similar products.

Q. Were the cost/price point goals the same for the zero waste garments as for regular pieces?

Yes, basically the same.

Q. Did you design whole markers, or pieces that would work together (simple geometric shapes for instance).

PEOPLE

DESIGN METHOD

Yes. I worked together with my technician to find the best workmanship options and embedded them into the patterns.

Q. If you designed whole markers, how did you approach grading?

GRADING

We had some pieces in one size only which would fit size 36-size 42. All other garments had basically 2 sizes- size S/M and size L/XL. As time was very short to do the grading for a whole size set and I also had to work on the regular collection mostly, we only developed 2 sizes.

GRADING

TIME

Q. What size range did you work with?

GRADING

One size fits all, or size S/M and L/XL

Q. Were all sizes zero waste?

Yes, except for the selvedge which was cut off.

FABRIC

Q. How did machinists deal with any complex pattern forms, sewing difficulty, new methods of construction? Was this a consideration in the design process?

At the beginning, I informed our suppliers about what the goal of the collection was: using 100% of the fabric, that's why they would need to follow my patterns quite close to make that happen. As we worked very closely with our suppliers and visited them often, this was not a problem and worked out quite well. Also, we had deviations in fabric width for production sometimes, but the suppliers informed me about that and we solved this together.

PEOPLE

FABRIC

PEOPLE

Q. What were the main issues you faced when designing the collection, from management, design and manufacturing etc?

I felt like the fabric width often limited the grading/size range- there were sometimes critiques from customers who asked for different sizes- but I guess if I had more time this would have been possible to solve.

GRADING

Also, in the end, the price-performance question was very present and it was discussed a lot if the zero waste collection was worth its cost…

MOTIVATION

Q. Do you apply any of things you learned in this process in ongoing garments or collections – In what way has zero waste endured in the company, would the company do it again?

The connection and interaction between fabrics and the perfect garment to be made out of it is I think a very important thing I learned and deepened during this process. This has kind of formed my understanding for design very thoroughly.

PRODUCT

DESIGN PROCESS

I am not sure if Hessnatur would start a collection like this again- but I think it was a good thing- some products were running well, others were maybe to expressive and complicated for the customer.

RESOURCE USE GOALS

MOTIVATION

In the end I guess it was not a tool to increase the yield but to express idealistic values. In that way I think it benefitted the company's image a lot.

Emroce is a small zero waste swimwear brand started in Italy by New Zealander Emma Churchill. All of her product range is zero waste and she incorporates the philosophy holistically, for example saving thread remnants to use in other products.

Q. How does the concept for each piece begin?

BRAND GOALS

First of all with the necessity to offer those classic pieces. The low waist bikini bottom, the high waist bottom, the simple triangle, the one piece. etc. If there is waste left over from the layplans of those pieces I will be planning to turn this waste into new pieces at the same time. For example the Mangia fuoco bikini top which is made from the bits in between the highwaist pattern pieces. Perfect unity (See pattern oppocite.)

DESIGN PROCESS

The other main influence is my want to create functional pieces for surfing. Swimwear that covers up and stays on. Sometimes I'll see other styles or features that are functional, beautiful and that i can create with a zero waste layplan. The concept is sometimes influenced by what [my customers] are asking me to make.

BRAND GOALS

DESIGN PROCESS

Q. What is the relationship between initial design, zero waste pattern, sampling and final outcome – What is the work flow like?

I have had designs work perfectly with the very first pattern (Karmakiss) and I have had others which were so difficult but too beautiful to let go of (Mountain top). There are others which I've had to abandon.

These are small pieces so it generally doesn't take too long to sew the samples. I do everything my self or with one other person so if the first sample doesn't work I can often unpick and make alterations. It's a great excuse to visit my friends for the fit modelling and usually I will only need to make 2 or 3 samples before the final piece is ready. As long as I keep the momentum up a new design can be finished within 1

PEOPLE

TIME

DESIGN PROCESS

to 3 days. The main point in which I lose time is when I'm staring into my paper with numbers multiplying and dividing, trying to fit everything on to the width of the fabric. I've learned to think about the zero waste yield only a little along the way. It's best to keep it till the very end and to tweak the pattern slightly if I need to.

DESIGN PROCESS

Unless I have a deadline or an order I let my workflow happen quite organically. Sometimes I feel extremely motivated to make new styles, sometimes I just want to produce in preparation for the coming season, sometimes I want to update my website. I feel like I get more done and make less mistakes this way.

Q. How did you approach the design process regarding things such as fabric width, was fabric selected first for example?

In the beginnning I had no idea of what I was doing. After a lot of trial and error, making quite a few horrible designs with unsuitable machines, and jumping out of bed to scribble ideas down in the middle of the night, I eventually realized that It was all about the fabric width. I already had my fabric.

FABRIC

The fabric was actually the whole reason I began to make swimwear. I disovered Auria swimwear and read that they were using the econyl recycled nylon. Before that I always believed that all clothing could be sustainable except for sportswear. I wanted to jump into that opportunity straight away and swimming was my favorite thing to do so it just made sense. I didn't check to see if there were other sustainable sports fabric out there. I just didn't think there would be and sadly I'm surprised to see that there still aren't many other options available.

FABRIC

MOTIVATION

My machines also determine what I can do with the design. I have limited space so to finish the garments I have a zig zag machine which can do a straight stitch for sewing darts or other projects.

DESIGN PROCESS

Because they are small pieces I don't just work with one garment. I work with lay plans which make between 2 to 20 garments with 2 or 3 different sizes or designs within the same layplan.

GRADING

Q. In terms of goals what were the main concerns for the design? Was there a hierarchy (is fit more important than 100% zero waste for example), how does the hierarchy change over time?

A swimsuit is such a tiny, revealing garment that I feel like i can't give a hierarchy to one thing or another. It must fit well, It must function well and it must be zero waste. One concern that has recently changed for me is the durability of the swimsuit. I see a swimsuit as a tool but most people see it as an accessory so they like to have 2 or 3 on hand and a new one every year or so. At the moment I use a thicker than average lycra. I also use a polyester thread and a nylon thread to stop seems from breaking. I was worried about using biodegradable fabrics and natural rubber because of the durability factor but now it seems to me that it could be better that the swimwear is more of a disposable item and is completely biodegradable. I will try to make some zero waste swimwear with 100% natural fibres but I will still offer the recycled nylon swimwear for those who need it.

PRODUCT
BRAND GOALS
FABRIC
MOTIVATION

Q. Was it important the design met goals regarding yield (did you make comparison to similar products) or was the focus on achieving zero waste and a particular fit and design aesthetic.

My yield goal is that every lay plan is zero waste. That, combined with my rules that it must fit and function well. I really like working within these tight but simple parameters. It forces me to be more creative and come up with something new. I only look at aesthetics with the colours or prints I choose to use. Otherwise I leave them to be controlled by my layplans. Sometimes I have little triangles left over in the corners of the lay plan and I set these aside to make frills for the childrens swimwear. I save all of my thread ends to be used as cushion stuffing.

RESOURCE USE GOALS
DESIGN PROCESS
CONSTRAINTS
DESIGN PROCESS
YIELD

When I first started, zero waste patternmaking was more of my design concept and something fun, economical and sustainable to play with. Now that there is a movement of people living zero waste lifestyles I feel more encouraged to work in this way for them and they've made me see the necessity to not just design my lay plans to be zero waste but to create an entirely zero waste business model.

MOTIVATION

Q. Did you design whole markers, or pieces that would work together (simple geometric shapes for instance). If you designed whole markers, how did you approach grading? Are all sizes zero waste?

I design whole markers. I make one size first, I offer that design in all sizes and make to order if it's asked of me. Each size has it's own layplan.

DESIGN PROCESS
GRADING

Q. How do machinists deal with any complex pattern forms, sewing difficulty, new methods of construction? Was this a consideration in the design process?

DESIGN PROCESS

Because I work with mainly straight lines I think the sewing is actually easier than it otherwise could be. The machinist works with me. We produce small runs of 5 or 6 pieces a time in a 2 person production line, them on the overlocker, me zigzagging or finishing. I will show him or her the first seem putting emphasis on how I hold my hands. S/he will run through those and so on.

PEOPLE
PLANT

This was actually the reason of why I wanted to start working with whole rolls of fabric instead of recycled garments or sheets. With too many variables in the fabric it is hard to mass produce. I really want to compete with the fast fashion industry and prove to them that this method of zero waste design is economically viable and can can also be used to make large quantities. I want sustainable fashion to be affordable so that the average Joe Bloggs can learn to make informative choices of which clothes he should be buying and why.

MOTIVATION

Q. What were the main issues you faced when designing your pieces?

PRODUCT
GRADING

My main issue before was that all bodies are so different, and these are tiny, tight fitting garments which on one size M will look great and another will cut in, in all the wrong places. It makes you feel like you're failing as a fashion designer. That the product isn't good enough. But I've stopped searching for perfection because it's not always possible.

DESIGN PROCESS
CONSTRAINTS

Now my issue is that the fabrics that I'd like to use and that should be available, aren't there. I know momentum is slowly picking up on this but there should be a swimwear fabric that is as luxurious as Jersey Lomellina's Renew Prime but is biodegradable (without the petrochemicals) or perpetually recycleable.

The R Collective is an upcycled fashion brand with a mission to create clothes using waste materials that was born out of Redress, the pioneering Hong Kong-based charity working since 2007 to reduce waste in fashion. Avoidance is a zero waste collection designed by 2018 Redress Award winner Tess Whitfort, released in 2019.

Q. How did the concept for the Avoidance collection begin?

MOTIVATION
BRAND GOALS

The main goal I had when starting out was creating a sustainable collection that was really different to trends commonly seen in the sustainable fashion sphere. I wanted to diverge from that wholesome, natural style often associated with ethical dressing and create sustainable fashion that has streetwear influences and a bit of edge. The challenge here is that the collection also had to work for The R Collectives brand aesthetic, which is extremely different to mine. So the starting point was looking at ways of toning down my style while preserving my design signature and simplifying my approach to zero waste pattern cutting so it can be applied to manufacture. Conceptually, I wanted the collection to be personal and reflective of my personality and views, the collection is technically womenswear but has definite androgynous leanings which aim to break down gender barriers and norms. We chose the name "Avoidance" because the Collection is all about "avoiding" waste, through zero waste pattern cutting and upcycling deadstock textiles. The word "avoidance" also resonates with me on a personal level as I've struggled with anxiety and mental illness my whole life and avoidance is my biggest coping method and mind trap. So the concept of avoidance is something that I've had to overcome a lot in order to be where I am now. Creating a collection called "Avoidance" therefore feels quite cathartic.

MOTIVATION

PLANT

BRAND GOALS

PRODUCT
FABRIC
RESOURCE USE GOALS

Q. Relationship between initial design, zero waste pattern, sampling and final outcome – What was the work flow like?

TIME
DESIGN PROCESS
FABRIC
DESIGN PROCESS
DESIGN PROCESS
PEOPLE
TIME
PEOPLE
DESIGN PROCESS
GRADING
PEOPLE
PEOPLE

The timeline for the collection was a lot shorter than I would have liked. I started by sketching all my design concepts, while planning the zero waste designs in my head. At this point we were still sourcing the fabrics for the collection so I couldn't create the actual zero waste patterns without knowing the fabric widths. Initially I was creating vague concepts of pattern shapes and how they'd fit together. From there we handed over the designs and zero waste concepts to the manufactures at TAL in Thailand, I ideally would have preferred to be handing them complete zero waste markers but the timeline was working against us at this point. We initially had a lot of trouble communicating the concept of zero waste pattern cutting to the factory, since it's not something they'd done before, so the first samples weren't actually zero waste. From there I did create complete markers including all the measurements and multiple sizes within the fabric widths. At this point everything was happening at the same time. We'd confirm the fabric for 1 style, I'd make the pattern, send it to the factory, they'd make the new sample, we'd move on to the next style. I then went to Thailand to stay in the factory and work directly with the manufacturers, so we did a lot of problem solving and developed the zero waste patterns through doing quick mock ups and using their CAD pattern making software.

Q. How did you approach the design process regarding things such as fabric width, was fabric selected first for example?

FABRIC

All the fabrics we used are deadstock textile waste, so we had extremely limited choices regarding fabric selection. We also made most styles in at least 2 colourways so we had to pair fabrics that had the same width, in most instances we ended up with only 1 or 2 viable fabric options for each style. Added to this, we also had very limited yardage available so each fabric could only be

HOLISM
DESIGN PROCESS
FABRIC

used for 1 or 2 styles. It all ended up being a bit of a jigsaw puzzle with a lot of moving parts. The fabric selection was happening alongside the zero waste pattern development, and in collaboration with the rest of the R Collective team. We selected fabrics that would work for the design and then I designed the zero waste patterns to fit within the fabric width. I do find it a lot easier to be able to select a fabric width that works for a specific zero waste design rather than the other way around, so I did end up with some fabric widths that made things a lot more challenging, especially when creating graded zero waste patterns.

Q. In terms of goals what were the main concerns for the design? Was there a hierarchy (was fit more important than 100% zero waste for example), how did it change over time?

MOTIVATION
PRODUCT
RESOURCE USE GOALS
PEOPLE

The main priority was translating zero waste into a collection that could be manufactured and worked within the style of The R Collective brand. It was also really important that we were making garments that people would want to wear for a long time so yes fit and quality and design did take priority over 100% zero waste. We achieved less than 1% waste on the Tshirt, dress, jumpsuit, and pants. The shirt and jacket had about 4% waste, which I think could be improved on but that was the best we could do in the factory setting within the time frame. I pushed for 100% zero waste as much as possible but ultimately we did need to make compromises.

Q. Was it important the design met goals regarding Yield (did you make comparison to similar products) or was the focus on achieving zero waste and a particular fit and design aesthetic.

RESOURCE USE GOALS
YIELD
PRODUCT

Yield was a consideration, especially since we were working with textile waste so had very limited quantities of fabric. But our focus was more on the design and zero waste. Some of the designs we did note that the yield was lower than what you'd expect from a similar style and fitting garment but we didn't actually compare them to similar products. We did opt for looser, generous fits so

they do use more fabric than small garments — YIELD

Q. Were the cost/price point goals the same for the zero waste garments as for regular pieces?

I think so, but I wasn't actually involved in the costing process. I think the sampling process may have been slightly longer/more complex, but the manufacture wasn't more complex than regular garments and the fabric consumption was lower so it may have evened out.

PEOPLE: HIERARCHY
TIME
YIELD

Q. Did you design whole markers, or pieces that would work together (simple geometric shapes for instance).

I created whole markers within the fabric width, predominately based on geometric shapes. I kept the patterns and shapes as simple as possible so they could be manufactured effectively at a fairly commercial price point.

DESIGN PROCESS
PRODUCT: COST

Q. If you designed whole markers, how did you approach grading?

I designed the patterns for all sizes at the same time. My main approach to grading is to place 2 size M pieces next to each other and then a size S next to a size L, so they equal out and fit within a rectangle. I either expanded on that concept for more complicated patterns, or I created the graded pattern in the same way I would any zero waste pattern, just with 3 times the amount of pieces. (I hope that makes sense)

DESIGN PROCESS: GRADING
GRADING

Q. What size range did you work with?

We used a very limited size range, most of the styles are a fairly relaxed fit so one size can fit a range of bodies. The dress, tee, shirt, and pants all have 3 sizes (S, M, L) the jacket and the jumpsuit are a looser fit so have 2 sizes (XS/S and M/L)

GRADING

GRADING

Since The R Collective is a Hong Kong based label and we're retailing in Lane Crawford the size range is quite small since the Asian luxury market doesn't have much demand for larger sizes apparently. I'm definitely wanting to expand the size range of my zero waste patterns and cater for bigger bodies too though.

Q. Were all sizes zero waste?

GRADING

Yep all sizes were zero waste for most of the styles, excluding the styles that weren't completely zero waste to begin with.

Q. How did machinists deal with any complex pattern forms, sewing difficulty, new methods of construction? Was this a consideration in the design process?

PEOPLE
PLANT

This is probably the part of zero waste design I find the most challenging, especially when communicating with manufacturers. When I'm sewing one of my zero waste patterns myself I'm okay with weird seam allowance shenanigans and can compensate for how the pattern fits together (or doesn't fit together) but that's very difficult to do in a factory setting. We used deadstock bindings for most of the necklines, and I made sure the zero waste patterns were more straight forward to sew. The factory we worked with (TAL) are excellent and the workers there are extremely experienced so they were able to problem solve these kinds of issues and suggest ways of finishing garments that worked with the zero waste patterns.

PEOPLE

Q. What were the main issues you faced when designing the collection, from management, design and manufacturing etc?

PEOPLE

The biggest challenge was communicating with the manufacturers. We're a small team and this was my first commercial collection so I was very much jumping in at the deep end and working out how the process worked as we went along. I found keeping track of specs really difficult and making sure that everything was communicated in a way that was consistent and clear.

Q. How did you feel the media and consumers is responding?

I think media and consumers are interested in seeing sustainable fashion in a style that's has a bit more edge. We've made telling the story behind the collection a big priority in our marketing campaign so hopefully consumers feel more connected to the garments and value them more because of it. I've received some positive feedback but I'm a bit isolated from the brand being back here in Australia now so I'm not getting a super clear idea of sales and things. I do think the concept of zero waste is quite difficult for consumers to really understand, especially because pattern cutting in general is not something they would know much about or really consider in relation to their clothing. When talking to consumers about sustainability issues textile waste at the cutting stage isn't often discussed so I don't think it's an issue that's on their radar or that they're looking to solve. I shared a few of my zero waste patterns on social media which I think helped people to understand the concept more. The R Collective has decided not to share the patterns from our commercial collection publicly though so we're communicating the zero waste aspect to consumers via story telling.

MOTIVATION

MOTIVATION: CONSUMERS

MOTIVATION

Interview themes

Several interconnected themes emerge out of the analysis of the interviews. They have been grouped initially into the following categories: motivation, brand goals, yield and resource use, people, grading, product, design process, fabric, plant, time, and lastly holism.

Motivation

Most companies were motivated by a brand history of social or ethical action.

> *I saw it as the perfect opportunity to develop a capsule collection of entirely Zero Waste garments because of Kenneth Cole's history of social activism. I proposed this to the Creative director and VP of design, who loved the idea (Design Director)*

They also were motivated by the use of zero waste as a storytelling mechanism,

> *At first, the idea of zero waste was most important, especially for marketing reasons. At the same time, we focused on easy designs which could be recognizable as zero waste designs at first sight. (Designer)*

...though some acknowledged the difficulting in then telling it.

> *I do think the concept of zero waste is quite difficult for consumers to really understand, especially because pattern cutting in general is not something they would know much about or really consider in relation to their clothing. When talking to consumers about sustainability issues textile waste at the cutting stage isn't often discussed so I don't think it's an issue that's on their radar or that they're looking to solve (Guest Designer)*

Brand Goals

Adhering to current brand goals was important for all designers, three of the four were existing employees or company owners, so they had a real understanding of what the overarching brand goals are, giving them somewhat of an advantage. Tess Whitfort was an 'outsider' and expressed some challenges around this area:

> *The challenge here is that the collection also had to work for The R Collectives brand aesthetic, which is extremely different to mine. So the starting point was looking at ways of toning down my style while preserving my design signature and simplifying my approach to zero waste pattern cutting so it can be applied to manufacture. (Guest Designer)*

Yield and Resource use goals:

No companies interviewed outside expressed the same strict adherence to yield and resource use comparisons as FT2 or FT1. This is likely because all four were developing new products, or products designed within a collection where the aim was to be zero waste from the outset.

> *It was assumed that the fact this was [a] zero waste garment would maximize yield and compensate for this being a larger garment (Design Director)*

> *Yield was a consideration, especially since we were working with textile waste so had very limited quantities of fabric. But our focus was more on the design and zero waste. (Guest designer)*

People

Linked to motivation is notions of hierarchy; the interview responses indicate that who is driving the project and what their motivations are can have a great deal of impact.

> *I was the one who proposed this project, and was given full control of design direction and execution. I was expected to do sourcing, design, sampling and the tech work with the factory. I normally worked every day with the leaders of all of the other departments on other knitwear projects, which was a distinct advantage in explaining and getting everyone excited about the project...it takes someone of a director level or higher to shepherd the project through from conception through production in order to make effective change in a large corporation. (Design Director)*

Additionally, the interviews indicated that clear communication and collaboration is crucial, most expressed difficulty at production stages to communicate the unique zero waste goals of the project.

The yield for each size is approximately 1 yard. But the first counter sample factory sent back used over 3 yards per garment and wasted huge amounts of fabric. I kept the pattern they sent with it because it was so ridiculous. Eventually, after a number of emails back and forth, and the involvement of numerous VP's both on the NY team and the team in Asia, we finally got the factory to understand. (Design Director)

Grading

All use mixed markers to enable grading within zero waste design, something that allows for and requires some flexibility in terms of the design goals and construction.

Because they are small pieces I don't just work with one garment. I work with lay plans which make between 2 to 20 garments with 2 or 3 different sizes or designs within the same layplan. (Owner/Designer)

We had some pieces in one size only which would fit size 36-size 42. All other garments had basically 2 sizes- size S/M and size L/XL. (Designer)

I designed the patterns for all sizes at the same time. My main approach to grading is to place 2 size M pieces next to each other and then a size S next to a size L, so they equal out and fit within a rectangle. (Guest Designer)

Since this was a generously sized tee, we decided in conversation with sales/ merchandising, to sell this in bucket sizes (xs/s and m/l). I used a standard 1 1/2x grade between the sizes and came up with a plan to cut some panels narrower and some wider on each tee and then swap them so that all the smaller panels created size 1 and all larger panels created size 2. (Design Director)

This approach was sometimes a problem in production however as it deviated sharply from existing practices and might have impacts on contractual agreements regarding quality control:

The factory] still had some legitimate concerns about sizing in production. Normally they are only allowed a tolerance of ½ of the measurement grade to be off spec. When you consider that fabric widths can vary significantly (1-3" in width per lot), if they were forced to use all the fabric from edge to edge, the sizes in bulk wouldn't necessarily hit spec (or pass inspection). (Design Director)

Product

All the garments discussed in the interviews were new products, and so lacked the tight design constraints of FT1 and FT2.

A swimsuit is such a tiny, revealing garment that I feel like i can't give a hierarchy to one thing or another. It must fit well, It must function well and it must be zero waste (Owner/Designer)

This was a new offering at the relaunch of new brand. This allowed me to focus on concept rather than trying to fit into an established merchandise idea. (Design Director)

Design Process

All expressed a balance between the need for flexibility within the design process and the desire to meet specific goals.

I created whole markers within the fabric width, predominately based on geometric shapes. I kept the patterns and shapes as simple as possible so they could be manufactured effectively at a fairly commercial price point. (Guest Designer)

Fabric

The fabrics behaviour, structure and width were all considered important design constraints

The fabric was actually the whole reason I began to make swimwear. (Owner/ Designer)

All the fabrics we used are deadstock textile waste, so we had extremely limited choices regarding fabric selection. We also made most styles in at least 2 colourways so we had to pair fabrics that had the same width, in most instances we ended up with only 1 or 2 viable fabric options for each style. Added to this, we also had very limited yardage available so each fabric could only be used for 1 or 2 styles. (Guest Designer)

Plant

The systems for handling fabric (for example the Kenneth Cole t-shirt) were questioned and challenged in some instances. Limitations of equipment or systems within factories were pointed out as problems or constraints to work within and around.

> *Between the glue and the pin stinting [of the knit fabric], it became clear that we needed to work with the fabric in a tubular form, which would present an entirely new set of challenges in finding a factory willing to deal with cutting fabric that arrives in tubular (Design Director)*

Time

The interview responses indicated that time was an essential factor for all of the designers, with all four indicating there was not enough time to fully develop the designs.,

> *I ideally would have preferred to be handing them complete zero waste markers but the timeline was working against us at this point. (Guest designer)*

Although when it works well, the design process can be very fast.

> *As long as I keep the momentum up a new design can be finished within 1 to 3 days. (Owner/Designer)*

Holism

Balancing multiple variables at the same time was a factor expressed by all interview responders.

> *The connection and interaction between fabrics and the perfect garment to be made out of it is I think a very important thing I learned and deepened during this process. This has kind of formed my understanding for design very thoroughly. (Designer)*

> *It all ended up being a bit of a jigsaw puzzle with a lot of moving parts (Guest Designer)*

Summary of Interviews

The field tests and interview responses show an emergence of an understanding of the workflow that a company or designer may follow as a reaction to encountering constraints and roadblocks. There is a lack of explicit articulation in existing research of how the various forces at play impact on the successful implementation of zero waste design processes and methods in the fashion industry. The Background chapter demonstrates that the majority of research in this field has been to explore design method and process, and not how this method and process interfaces with the industry. This research proposes that having a clearer understanding of these factors at the outset may help mitigate some of the negative impacts. The following chapter attempts to articulate these and map them out in the environmental and economic context.

5. REFLECTIONS ON WASTE

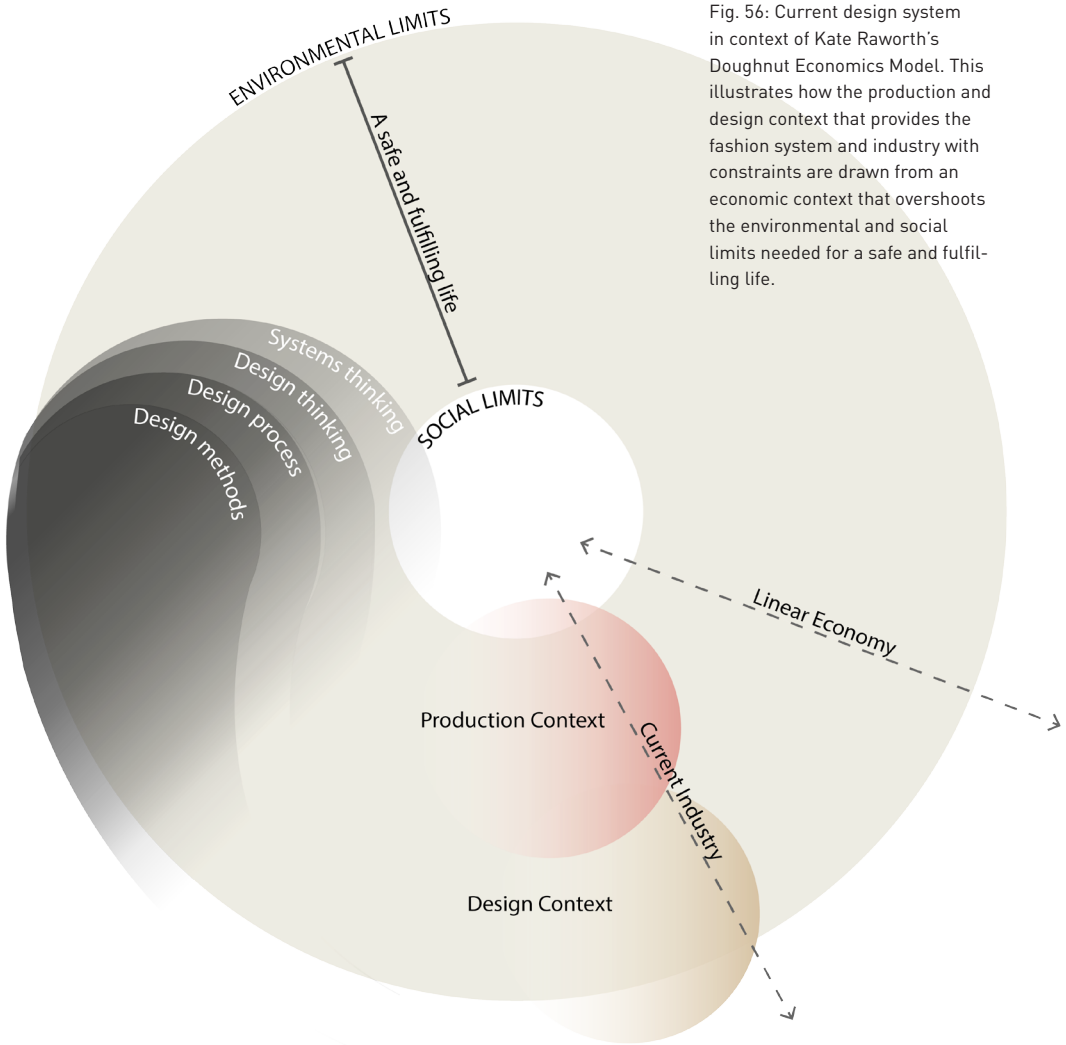


Fig. 56: Current design system in context of Kate Raworth's Doughnut Economics Model. This illustrates how the production and design context that provides the fashion system and industry with constraints are drawn from an economic context that overshoots the environmental and social limits needed for a safe and fulfilling life.

In this chapter, the relationship between constraints and waste in response to the interviews and field tests is reflected upon. Additionally, the chapter speculates about the role of the designer, and the 'value' of waste in the context of the proposed circular economy, and how the experience in the field tests resulted in a significant recalibration of the ongoing research. The research does not argue that little of use emerged from the field tests and interviews, but rather that the findings from field tests revealed a much larger issue at play than a 'drop-in' design method based approach could address.

Make it zero waste: Waste in a linear system

Field Tests 1 and 2 took place in what is generally considered to be a linear fashion system; raw materials are extracted, products are made, sold, used and eventually discarded. The value of waste and the role of the designer in this system needs to be considered within the context it operates in. Both companies have made some attempts made to move towards a circular model, FT1 enables consumers to drop off their unwanted garments in store for recycling, and FT2 provide repair and recycle services. However, the use of these services compared to their current output is relatively low. They both primarily still operate in a linear design and production model.

The first field test reveals the role of value and investment in decision making. A key finding was that when using a conventional production process, within a high volume, low-cost context reducing yield and improving waste is not seen as a valuable investment in time and resources unless material cost a significant part of the cost of a garment. It is probable that if linked with a serious commitment to waste reduction – either internally driven, or motivated by external forces – the perceived value of fabric waste may change and the tradeoff would be seen as worthwhile even if the fabric cost remained the same. The changes required to the profoundly ingrained system are too significant for them to be worth it unless there is motivation outside of a financial imperative. The business model constrains meaningful improvement and change.

In the process of working through Field Test 2, conversations took place with the wider team at the company regarding textile use and waste. There were discussions with textile designers and material developers about the possibility of specifying fabric width or having a consistent width across their product range as a method of enabling efficiency. Specifying the width for increased efficiency had not been considered by them before, and was considered infeasible due to the complex relationship they had with their many suppliers.

REFLECTIONS ON WASTE

At times it was compelling to attribute a monetary value to the waste generated as a result of their established design process. However, in many cases company's do not technically own the waste created because the factory producing the garments own the fabric, and once the garments are complete, the company repurchases them and they are shipped for retail. Effectively a company may only have a moral responsibility for the waste; this is a responsibility some take seriously but can be challenging to implement. In general, information about the volume of waste generated by the production of garments, the actual markers, yields and patterns used are closely guarded by many factories because it might reveal a difference between what they quote and what they use. The factories profit off the difference, and when margins are tight, this revenue can be substantial. Additionally, if a garment producing company reduced waste by reducing yield, they would need to order less cloth unless garment sales were increased to compensate for this. Textile producers do not want a reduction in orders for obvious reasons, so they are not financially motivated to support the reduction of yield or waste unless they can be financially compensated for their increased efficiency or orders increased. Waste it seems in an inbuilt component of the fashion industry.

The interviews point towards a particular set of quite unusual conditions to be present in order for the attempt at zero waste design to be successful. A robust inherent motivation is needed; the core of the company in every case is rooted in sustainability or social justice. Of the four examples explored through the interviews, only one exploration of zero waste design (Emroce) is still actively being pursued. In the other three, these were more like temporary expeditions into the world of zero waste design, lead by intrepid explorers. The designers either had good prior knowledge of zero waste design (Hess-Natur, R Collective), or pattern cutting in general (Kenneth Cole) or were a small brand in total control of the design process and timeline (Emroce).

Time encompasses almost all the comments made in the interviews, bracketing the attempts made by the designers, hurrying them when they wanted to move more slowly. Tess Whitfort's first comment in the interview was that "the timeline for the collection was a lot shorter than I would have liked". In an industry that is renowned for speed, this research demonstrates that the time needed for holistic approaches is difficult to find.

In the interviews where the designers were working within an existing company structure and attempting zero waste, all three expressed conflicts when their inherently holistic process interfaced with the established linear and siloed system. The conflict between the holistic requirements of a zero waste design process which is situated in design aesthetics and production simultaneously (and so requires a balance and understanding of both), and the siloed, hierarchical and linear design process the companies were used to working is a definite roadblock.

In Field Test 1 and Field Test 2 there seemed to be a lack of understanding of the spatial reality of a given garment design using conventional production methods – both company's seemed to want the design to remain the same, but for it to somehow take up less space. Change without change. The law of conservation of mass implies that mass can neither be created nor destroyed, although it may be rearranged in space. Importantly the total mass of the starting materials must be equal to the mass of the products. So if the mass of a garment is determined by its manufacturing method and design (including its pattern and fabric use), and no aspect of the garment form, design, material or manufacturing method can change, then it cannot change mass. A conventionally designed garment could be made 'zero waste' by selling the garment as it is with the waste it generates in a bag – as Timo Rissanen and Salla Salin did in 15% (2012-2016). This makes a political statement, but in an industry context, it does not fundamentally change anything about how garments are made. If the design of the garment is already determined (either implicitly or explicitly), then only minor adjustments at the edges are possible and the impact will be severely limited. So there must be an opportunity to change the design, the way the design is manufactured or the system in which it is produced.

The waste hierarchy asks that we first eliminate the production of waste and that all other approaches, including recycling, are secondary to this. It is common to consider waste an inevitable 'by-product' of industry and disregard the role designers play in its creation. However, it is essential to remember that before it was waste, it was potential. Consider the garment: Fibre into yarn, yarn into cloth, cloth into a garment, at every stage materials are imagined and manufactured into existence – what we do with them, how we make them, how we utilise them – each step we transform them from ideas and materials with potential, to products. So waste – we design that too. If we consider design as an act of future-making (Simon, 1969; Yelavich & Adams, 2014), we have designed our reality and continue to generate the future. Our models of design, our society and industries are making a future consumed by both products and waste.

REFLECTIONS ON WASTE

There exists a fundamental schism between design as an act of identity and product creation and design as a simultaneous act of waste creation. Waste is considered a management problem that requires collection and disposal. For cut and sew garments waste is the parts cut off when making the desired/designed form and detail – it is emphatically NOT part of the design – perceptions of fit, function, form, aesthetic and cost are exponentially more important. Consider though, if design is not only what is designed into existence, but also what is designed 'away' (Tonkinwise, 2014), then the waste is also what is designed. The problem is currently, where only 10% of textile waste is recycled, there is no 'away'.

The industry seems content to design out adverse outcomes that do not have an impact of aesthetic, form, function, fit and cost. They use organic cotton, but only if it does not impact on cost or aesthetic. They specify for the removal of toxic dyes so long as the replacement is equally vivid and colour fast. There is not yet a solution for non-toxic waterproofing, so they continue to use it despite its impact. Please, make it zero waste, but do not change any aspect of the form, fit, function, cost or aesthetic. The fashion system is designed to prioritise almost all things above the environment we all rely on. The result is the world we live in now.

This research asks: should 100% resource use in production be the ultimate goal? Should the industry aim to reduce resource use overall? If the answer is an ideal yes, then work is needed to address expectations of aesthetics/fit of garments or to develop new methods of design and production which eliminate waste and reduce resource use while maintaining current expectations.

The complex relationship between hierarchy, constraints and process was evident in Field Test 2 where the design was developed through an intensive process which resulted in the efficiency for the given design being improved by 5% while maintaining fit and overall aesthetic goals. This design went through another iteration which reduced its efficiency to an improvement of 4%, at which point the design was evaluated by the regular design team who were not involved in the high-efficiency project. This team made what appeared to be minor visual changes to the design without any consideration for the impact these might have on the pattern and resulting efficiency. As a result, the efficiency ended up back where we started.

There was an established process, which had an established hierarchy, and inputting to this were design constraints – both explicit and implied – relating to aesthetics, fit and function. Perception of the value of various constraints differ depending on the company and the individual, and in most cases, the efficiency of a product is not considered at all to be an act of design. Reframing can help. For example, when evaluating the costs and benefits of design changes consider the % reduction in waste, not only the increase in efficiency. To illustrate this while an increase from 82% to 87% efficiency may only seem like an improvement of 5%, it results in an almost 28% reduction in waste for that style. The lack of a holistic integration of all the processes that impact on efficiency (like the final fitting in this example) means that waste and yield reduction through design are difficult to implement when the hard work can be undone with a swish of a pen or the pinning of cloth.

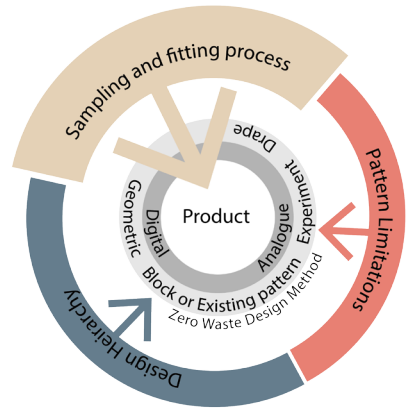


Fig. 57: When one part of the design process overides the others, the design process becomes imbalanced

The Kenneth Cole example is particularly interesting as it was led by a design director with significant internal power and clout, undertaking roles well outside of her usual activities. Each interview expresses the interconnectedness required in a zero waste design process, and the importance of communication across the company structure, and in-depth interaction with manufacturing staff. The hierarchies hard-wired into most large companies makes it difficult for a designer to make profound impacts. Mary Beth McDermott writes of her successor to the zero waste work she undertook at Kenneth Cole:

Everyone is just so used to working a certain way, and busy trying to keep everything going, it would really take true leadership to steer the ship in a new direction.

(Design Director at Kenneth Cole)

He worked for months to come up with strategies but found that it was very difficult to get the various departments (design, tech, sourcing, production, etc.) to work together. Ultimately, nothing was adopted despite the fact that management green-lighted this initiative to begin with. My student echoed my belief that it takes someone of a director level or higher to shepherd the project through from conception through production in order to make effective change in a large corporation. Everyone is just so used to working a certain way, and busy trying to keep everything going, it would really take true leadership to steer the ship in a new direction. (Interview Response from Design Director at Kenneth Cole)

A key observation from Field Test 2 was that the most rapid and successful period in the design and product development process was when many of the stakeholders were working together in the same space and time –when the hierarchies and silos were partially broken down. The tightly managed hierarchies governing who controls the design process and the sequence these levers of control are used became very apparent in Field Test 1. The marker makers in this field test were experts at making pattern pieces fit efficiently into a marker, often performing much better than computer software. However, they had no contact with the designers or pattern cutters in this context. So any insights they had as to waste and yield reduction via changes to the pattern or design had no avenue for communication.

Field Test 1 also speaks to a particular way of thinking that dominates both society and industry. Even if a design can be made more efficient in terms of material use, it needs to save money overall to be considered viable. So, how much fabric needs to saved for it to be 'worth' the human effort and financial cost?

Reducing yield and improving waste does not seem a valuable investment in time and resources when using a conventional production process, particularly within a high volume, low-cost context such as fast fashion – especially if the material cost is not a significant part of the cost of a garment like in Field Test 1. The changes required to the profoundly ingrained system are too significant for it to be worthwhile unless there is motivation outside of a financial imperative. This observation is supported by the interviews and an examination of Runnel et al. 2017 report on textile waste. Despite advocating for a somewhat radical rethink of the role and value of textile waste in the industry, the report still only attempts to address waste once it is made, not the prevention of its production through design. This omission is perhaps because doing this impacts on design systems, hierarchies in both design and production and potentially garment aesthetics.

Field Tests 1 and 2 can be seen as both a failure of my zero waste design methods to adapt to the industry's rules and a testament to the inflexibility of the industry, a failure to change even when acknowledging the need to change. As Barbara Adams states "Designers are increasingly being called upon to contribute their particular knowledge and experience to the hornets' nest of contemporary crisis exacerbated by the habitual default to obsolete systems." (In Yelevich and Adams, 2014, p. 183). The overall experience for myself in this project was of a forced arbitration between 'what exists' and 'what can be' – where 'what exists' won due to the massive force the scale and complexity of the industry exerts on those who seek to change it.

Despite these tensions, this research does demonstrate that zero waste design can encourage a different way of thinking, allowing us to ask different questions and potentially find alternative solutions. Zero waste design cannot be considered merely a design or pattern cutting technique that we 'drop-in' to the existing system. It enforces a holistic way of working which in many ways is unlike the conventional fashion design system – a perspective this research argues for as 'zero waste design thinking'.

Fig. 58: Factory line from FT2. Garment workers at this factory wear uniforms which indicate the specific area they work in. Hierarchies, and siloed workplaces are the norm right across all aspects fo the fashion design process and supply chain.

IN A CIRCULAR FASHION SYSTEM CAN THE INDUSTRY CONTINUE TO OVER PRODUCE AND BE INEFFICENT BECAUSE THE WASTE CAN ALL BE PUT BACK INTO THE CYCLE?

The circular economy will save us?

Between 35% (Kerr & Landry, 2017) and 25% (Runnel et al., 2017) of the raw materials used to produce garments becomes waste at the factory. An average of 15% (Rissanen, 2013) is generated at the design stage via the pattern cutting-to-marker making process, and the remainder is end-of-roll, selvedge waste, and other yarn waste. Assuming a theoretical 100% recapture and recycle rate at both pre and post-consumer stages, the fashion industry would be almost 33.5million tons p/a short of recycled material to maintain even current levels of consumption, assuming both zero growth and no improvements in efficiency in production. This shortfall would need to be met by the extraction of virgin materials, and the consumption of more energy.

Zero waste through design can lead to a reduction in waste while maintaining yield, or both a reduction in yield and a reduction in waste before meeting a theoretical minimum yield (see Chapter 6). If a theoretical 100% utilisation of raw materials can be achieved, two entirely different outcomes are possible depending on how it is done. For example, if 200cm of a roll of cloth is needed to make a dress but only 160cm is utilised, this results in 40cm or 20% waste. If the pattern is redesigned or the production method is changed to make the same style utilising the full 200cm, without generating waste and maintaining yield – then this will *maintain* overall total demand. It will also drive an *increase* in the need for virgin materials (a theoretical increase of 21,7 million tons per year) because of the resulting increase in recycled material shortfall. If instead, the same dress is constructed utilising only the 160cm needed to make the style (the theoretical minimum yield) then the demand of recycled material will be reduced while maintaining demand for virgin materials, assuming current levels of consumption is maintained.

Should the reduction of waste without the reduction of yield be disregarded as a strategy for zero waste? Under theoretical 100% recycling rates yes, it seems to serve little purpose. However a 100% circular economy is not currently functioning and it is not likely to ever entirely be the case – according to de Wit et al. (2019) globally we are 9% circular and going backwards. So achieving zero waste while maintaining yield will remove significant volumes of waste from landfill and incineration (up to approx. 8.3 million tons per annum at the 2015 rate of consumption, see Paper III for more detail), leading to at the very least a delay in the emission of GHG as they

burn or decompose. However under a theoretical circular, 100% recovery and recycle scenario the goal shifts to reducing yield while also reducing waste. If consumption increases, which it is expected to do so (from 62 million tons per annum in 2015 to 102 million tons per annum in 2030 (Kerr and Landry, 2017)) then the benefits to be gained from achieving theoretical minimum yield in production increase further. However, in all these scenarios growth in virgin material demand driven by growth in overall demand is still clearly a problem.

At a theoretical 100% recovery and recycling rate, the key driver for the demand for virgin material use becomes how long people use their garments and its relationship to growth in consumption. If people hold on to their garments without using them (hoarding) while also increasing consumption, then the demand for virgin materials increases as the material available for recycling cannot keep up with demand driven by growth. However, if people reduce consumption because they hold on to their garments and use them – slow fashion – then demand for virgin material is kept in check. Alternatively, if people can speed up the flow of products through their lives and industry can capture and recycle 100% of these products, and there is no growth in demand as one garment is made for every garment recovered, then more recycled materials will be available and less virgin materials required.

In addition to the above observations and findings, this research reflects on the industry's motivation for increasing efficiency. It is impossible perhaps for a company operating in neo-capitalism to view efficiency gains as anything but 'guilt-free' raw material for more production and therefore growth – the 'rebound effect'. The potential problem, however, is that without a limit on growth the notion of a circular economy will always be an ever increasing spiral requiring ever more inputs.

6. THEORETICAL MODELS

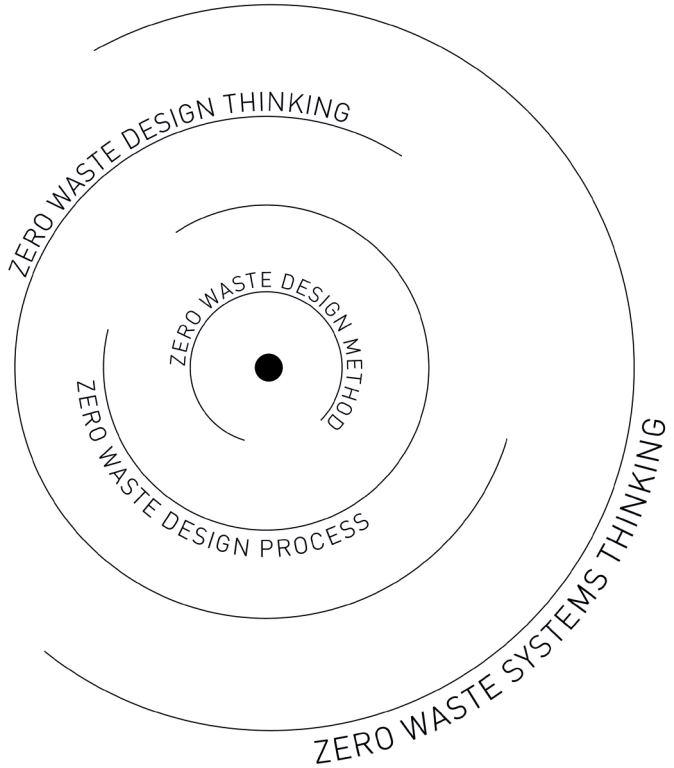


Fig. 59

Zero waste design as a lens to view through

Emerging out of the reflection on the interviews and field tests this chapter proposes a series of radiating zero waste design models (Fig. 59) which outline the ideal scenario in which this practice occurs.

The following theoretical models for zero waste design are a 'lens' that can be useful when attempting to develop an alternative mindset regarding resource use in the context of product design, development and manufacture. These are applicable across a range of subgroups within the industry, for example: technicians, engineers, management, designers, textile designers. The models are framed as questions to ask, points to consider, things to know or negotiate. As such they are equally applicable in an educational context and allow for an alternative framework for holistic design, as all of these factors impact on or are informed by design.

The zero waste design models explore the context of zero waste practice beginning with the broadest social and environmental contexts. It is with this understanding this research proposes that Zero Waste Systems Thinking occurs - systems thinking through a zero waste design lens. Zero Waste Design Thinking encompasses a broad understanding of the design and production constraints - this is the area the majority of the research discussed in this licentiate has taken place. Within this, in response to the constraints, is situated the Zero Waste Design Process, in which is situated the context that the majority of research into zero waste design takes place, Zero Waste Design Methods.

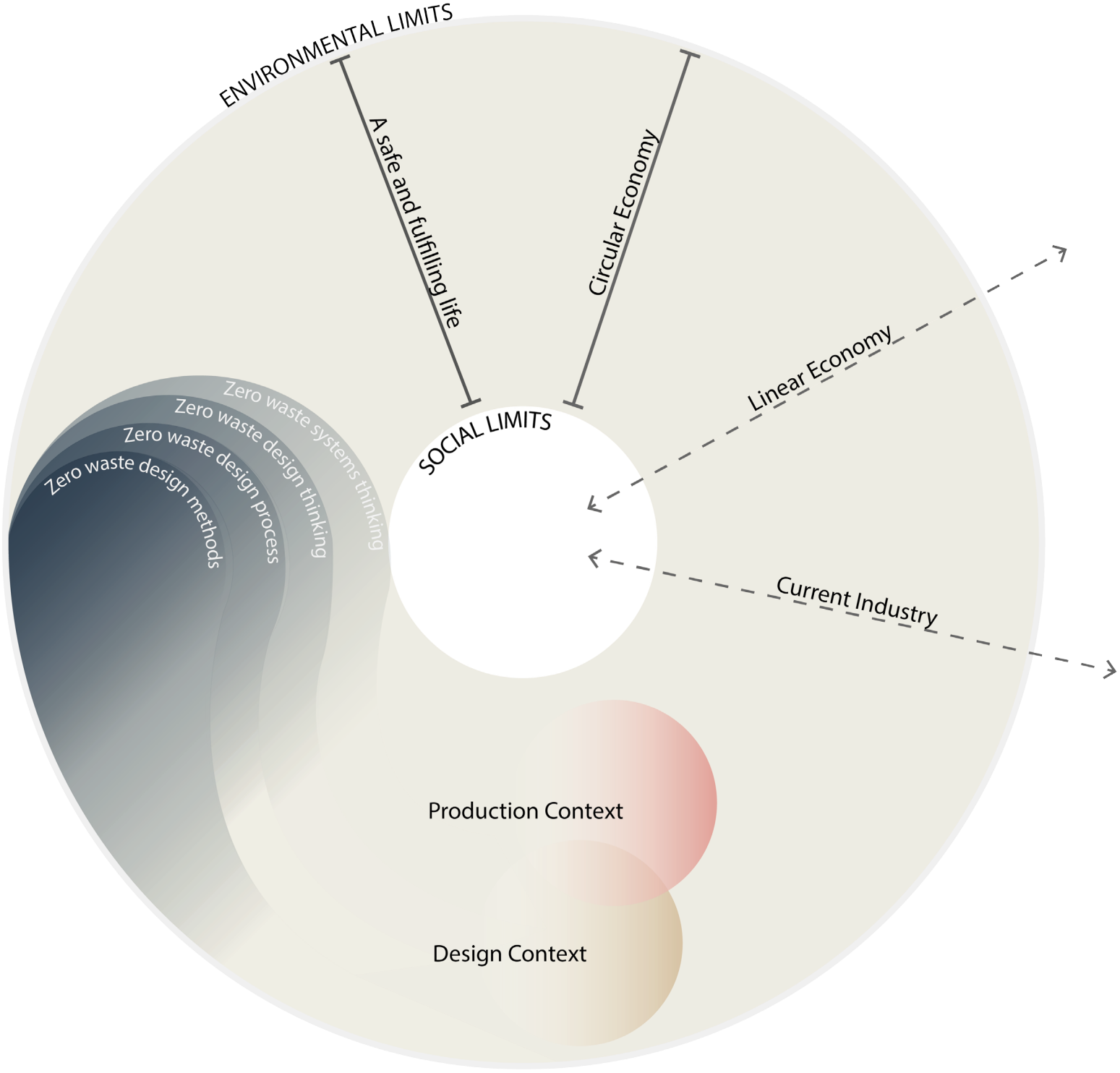


Fig. 60

Social and Environmental Context

Developed from Kate Raworths Doughnut Economic model, the model shown in Fig. 60 explores the relationship between the broader social and environmental contexts of industry and the proposed zero waste design model. All design and economic models need to be bound by the limits placed on them by social foundations (for example fair pay, safe work conditions and socially responsible advertising), and the environmental ceiling. As shown our current industry and linear economy overshoots both these boundaries in a variety of ways.

From the space between the social and environmental limits comes the design and production context which informs and is informed by the theoretical zero waste design model

Zero waste design model in the context of constraints

The zero waste design model (Fig. 61) is comprised of 4 layers of decreasing specificity and increasing influence. The boundaries between layers are permeable and fuzzy. The most significant potential sphere of influence is zero waste systems thinking which is focussed on the design of systems using zero waste design thinking as a tool. Zero waste design thinking encompasses all the interrelated and holistic inputs and constraints from production and design contexts that impact on the zero waste design process. The zero waste design process encompasses all the inputs from zero waste design thinking that lead to the application of zero waste design methods which results in a product.

In this model the four layers of the zero waste design model are weighted towards Kate Raworth's environmental ceiling. This is because the majority of research and motivation for exploring zero waste design has been driven by environmental factors. However as the understanding of zero waste expands into zero waste design thinking and zero waste systems thinking, it is important that this new knowledge encompasses a clear acknowledgment of the social foundation all these practices are built from.

The space between zero waste design methods and zero waste design thinking is where the research explored in this licentiate is situated.

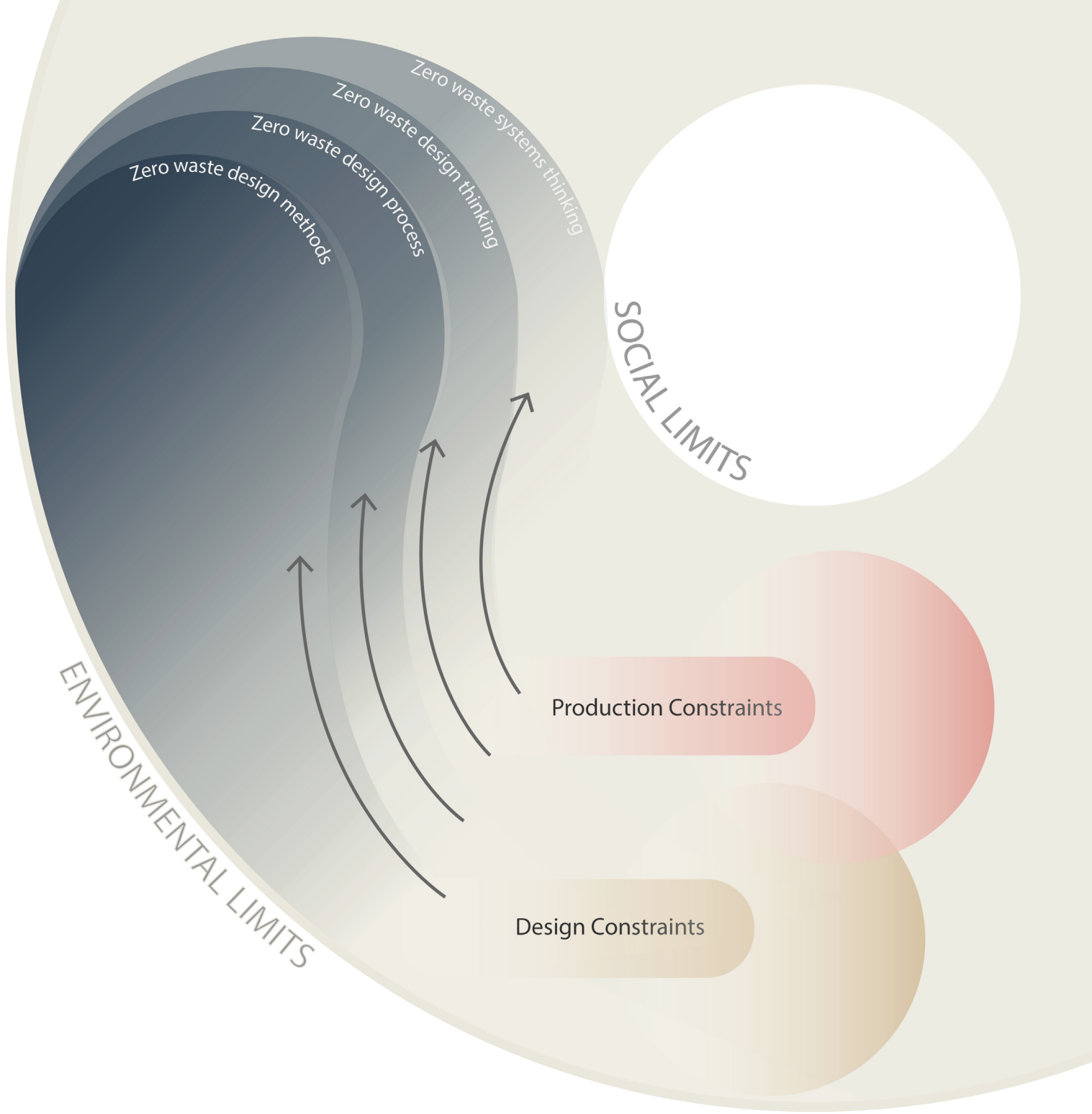


Fig. 61

Zero Waste Design Thinking

This Zero Waste Design Thinking model (Fig. 62) embraces all the inputs into the zero waste design process from within the broader context of the companies explored through this research. It is developed from the field tests and interviews and includes many aspects which are not usually considered as parameters for design. This model explores the garment context; however, with modification, could be utilised for a range of design contexts.

There are different approaches required when attempting the design of a low waste or zero waste product. The considerations needed and constraints provided when developing a zero waste redesign of an existing product can be quite different to when developing an entirely new zero waste offering, and potentially different again if the context is an entirely new brand, or one that already exists. This research has developed a model for implementing zero waste design strategies into a company, but not all branches will be entirely relevant for all companies.

Before beginning a process of waste reduction in a given company, there is a range of considerations and questions that need to be asked. These can be grouped into two broad categories – Design context and Production context – and include macro-structures like company motivation, to micro decisions such as the cost of the fabric used. It is important to consider a continuum of waste reduction strategies for different industry segments: From doing nothing (because it might be best to use other strategies to achieve sustainability goals), through to high efficiency, or zero waste. It is also essential to question the fixed nature of all decisions and inputs.

It is imperative that we acknowledge that time – a lack of it usually – is encompassing and impacting on all aspects. In most cases the development of a zero/low waste garment will take longer, particularly in the first instance, so providing an environment conducive for success is imperative. How much time will there be to develop the design?

In this section, each branch of the tree is explained, and the ways that the model might assist in the decision-making process and company analysis is explored.

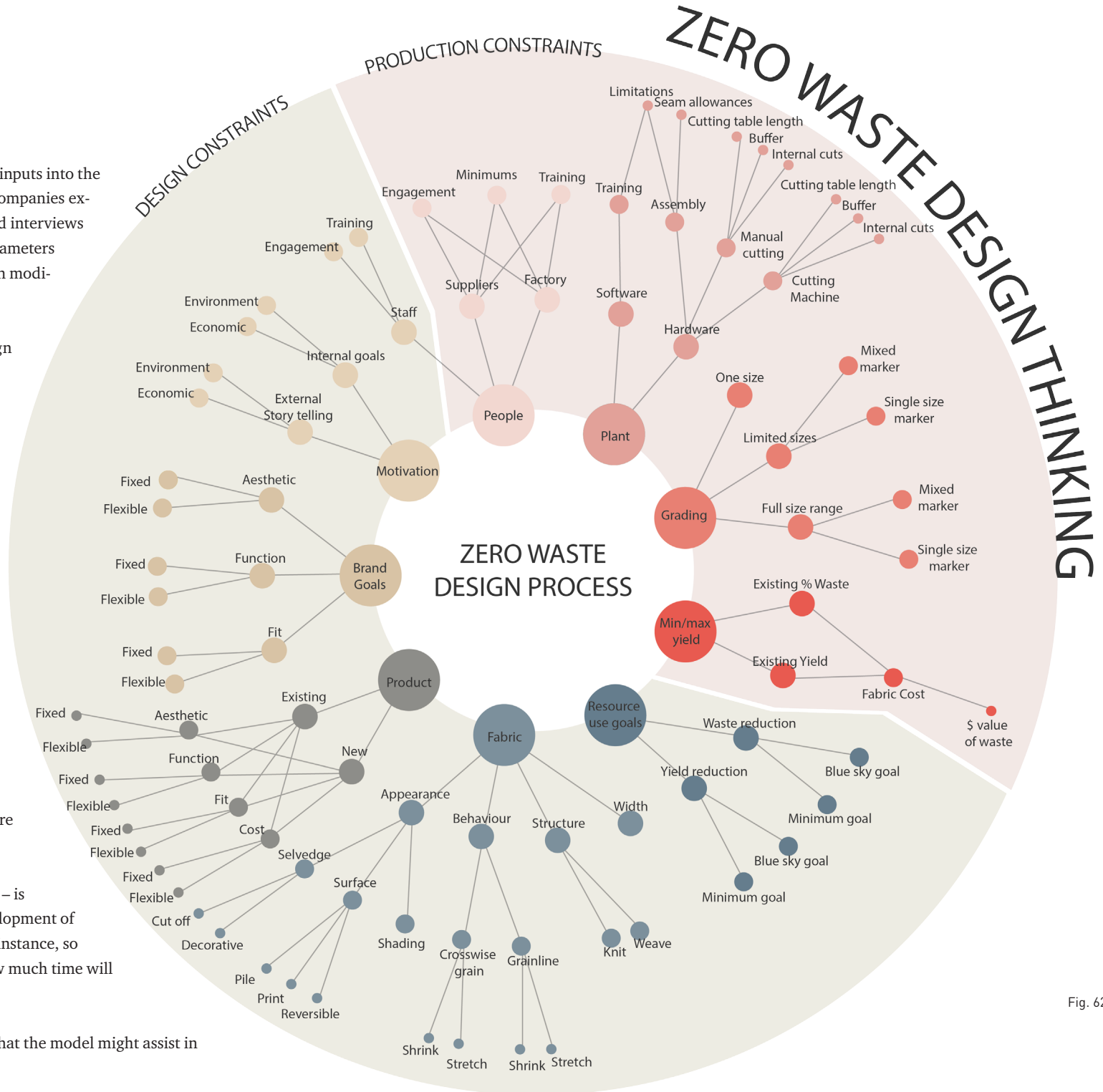


Fig. 62

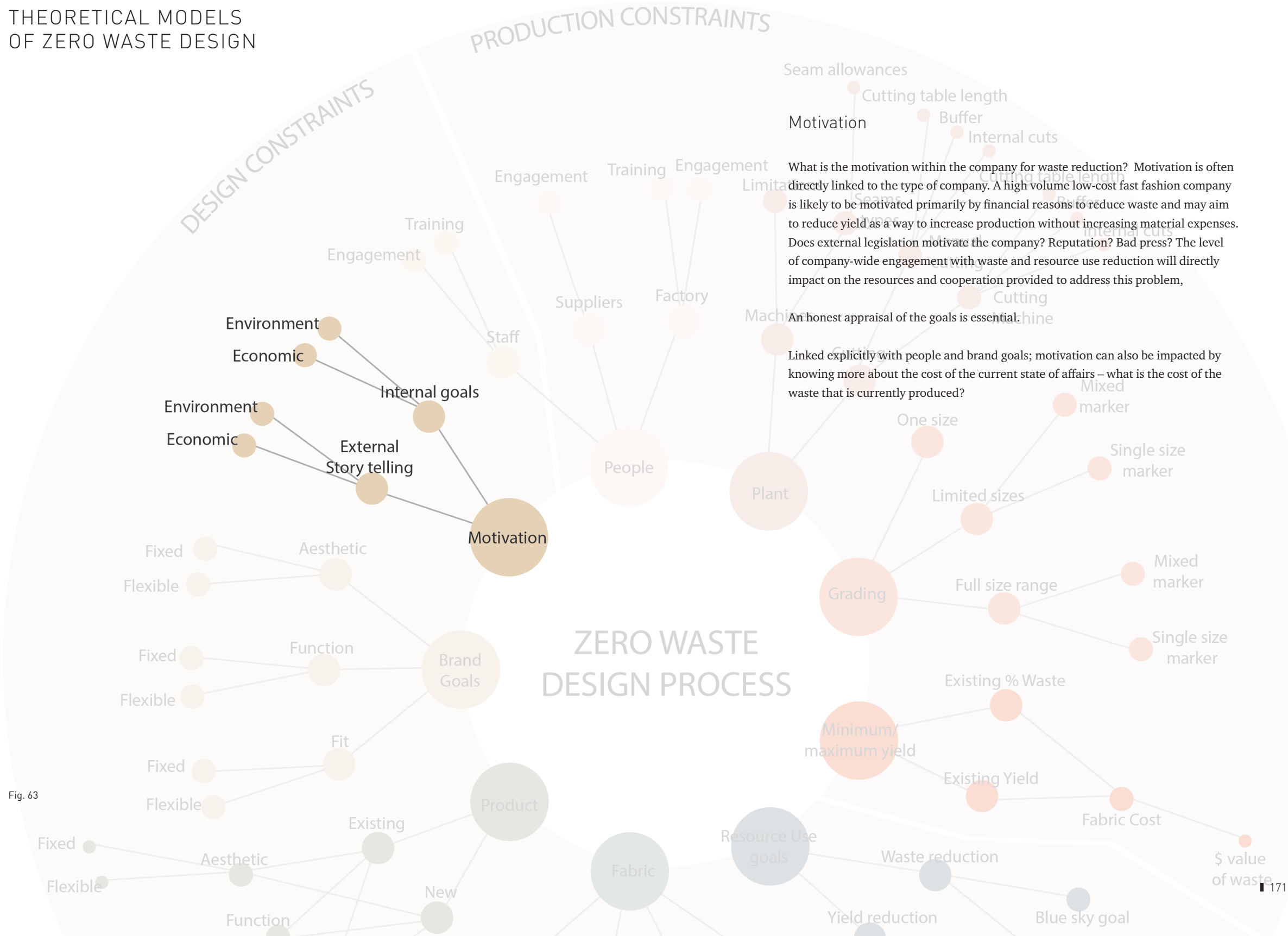


Fig. 63

Motivation

What is the motivation within the company for waste reduction? Motivation is often directly linked to the type of company. A high volume low-cost fast fashion company is likely to be motivated primarily by financial reasons to reduce waste and may aim to reduce yield as a way to increase production without increasing material expenses. Does external legislation motivate the company? Reputation? Bad press? The level of company-wide engagement with waste and resource use reduction will directly impact on the resources and cooperation provided to address this problem,

An honest appraisal of the goals is essential.

Linked explicitly with people and brand goals; motivation can also be impacted by knowing more about the cost of the current state of affairs – what is the cost of the waste that is currently produced?

THEORETICAL MODELS OF ZERO WASTE DESIGN

Brand Goals

Brands have explicit and implied goals regarding aesthetics, fit and function; it is vital that everyone involved in this process understands what they are and how fixed or flexible they are, as they these core brand beliefs will cascade into the rest of the design development.

Consider the brand goals divided into aesthetic, function and fit. There might be certain types of design lines that are commonly adhered to within all products that the brand produces. There may be aesthetic aspects of fit that fall outside of the brand's identity. It is essential to articulate these to all members of the team to reduce deadends. Working through each of these branches enables the team to identify the core brand goals determine how fixed or flexible they are for this product, and establish a clear hierarchy that can be referred to and adjusted throughout the products development.

The development of a brand goal hierarchy may also take input from motivation, resource use and maximum and minimum yield, to establish guidelines that can be applied across the development of all the products the brand produces.

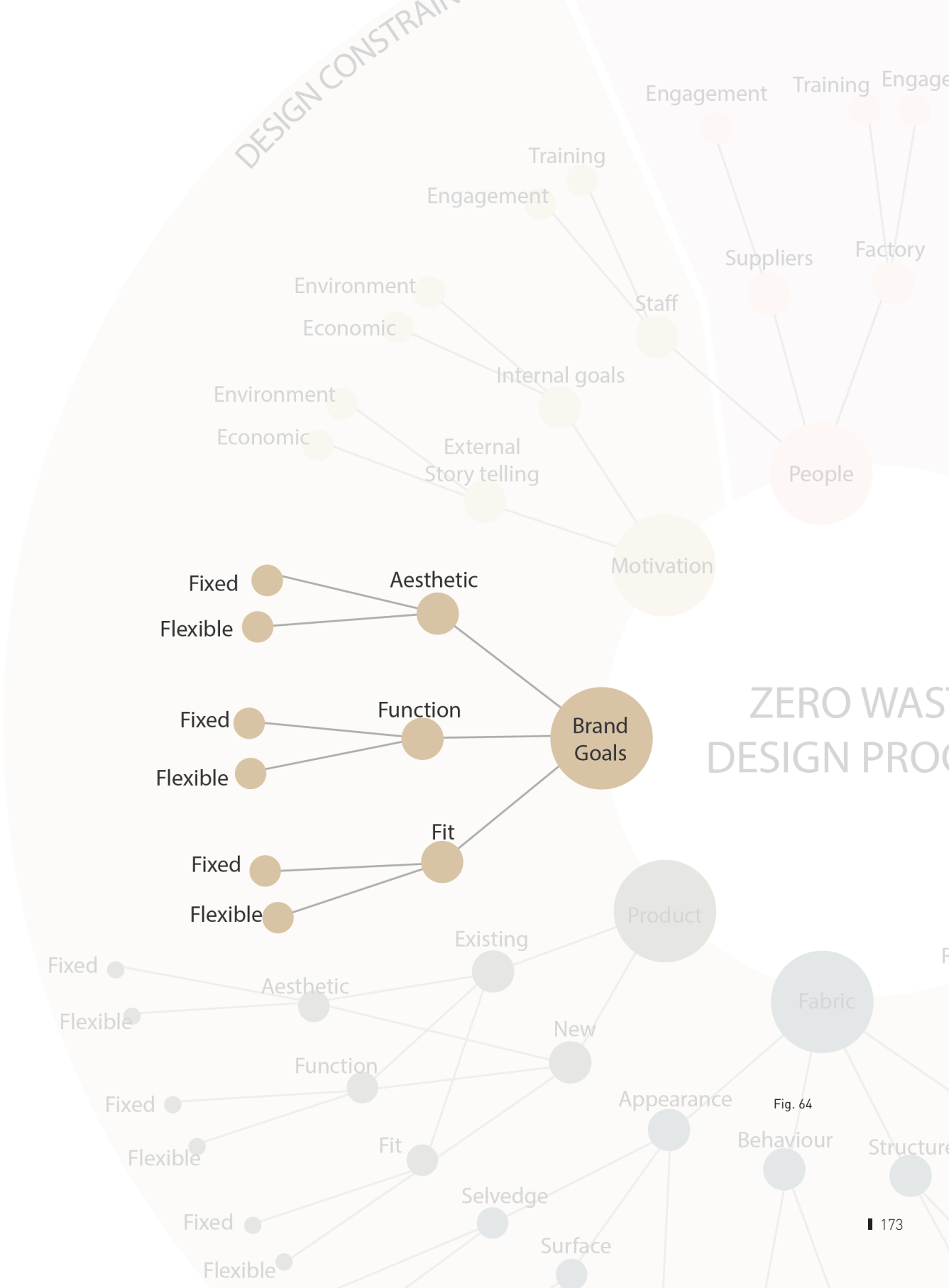


Fig. 64

THEORETICAL MODELS OF ZERO WASTE DESIGN

Product

Product is the area most often considered, but this research argues that companies and designers need to think differently about it – what are the explicit and implicit design and production constraints? Are they fixed or flexible, hard or soft?

High volume:
Selecting a high volume product will mean that the investment is more likely to be repaid and the impact on waste reduction is amplified. A reduction of yield of only 3% on a high volume style might mean saving many thousands of metres of fabric a season on a single style.

Use Longevity:
Is it anticipated that the product will have a short life span? In this case, the impact of reducing waste will be amplified.

High yield/low efficiency:
High yield products with low efficiency provide more opportunities for waste elimination and resource use reduction. Achieving significant efficiency gains in easier when there is more 'room'.

Design longevity:
Choosing a product which is a 'staple' for the company can mean that investment in its efficiency will have a more prolonged period to repay the investment before needing further change.

Existing

With an existing product, it is crucial to consider which product from the existing line will be developed. Look for the easy wins first.

Once the product is selected, analyse its features from a function, aesthetic and fit perspective. What must remain, what must change, what is flexible, how flexible, what are the limits, how much can the design team push it? If the fit is going to change for an existing style, make the fit alterations first before developing the updated version.

New

It is significantly easier to achieve zero waste if there is no existing design to emulate. While it makes it harder to know how successful a design is, the freedom provides a great deal of opportunity with the design.

What garment type will be developed? What are the aesthetic requirements for the garment? These can be hard to parse out from function and fit sometimes, but consider the designs more esoteric features. It is perhaps driven by mood/vibe derived from an examination of the Brand goals. What are the functional features the garment must have (pockets, hood for example)? Establish if it is going to be based on a block or perhaps loosely based on the current pattern. How fit fixed or flexible are each of these?

When linked with the constraints provided by the analysis of Brand goals, Motivation, People, Fabric, this analysis provides a shared understanding and design hierarchy on which to develop the design.

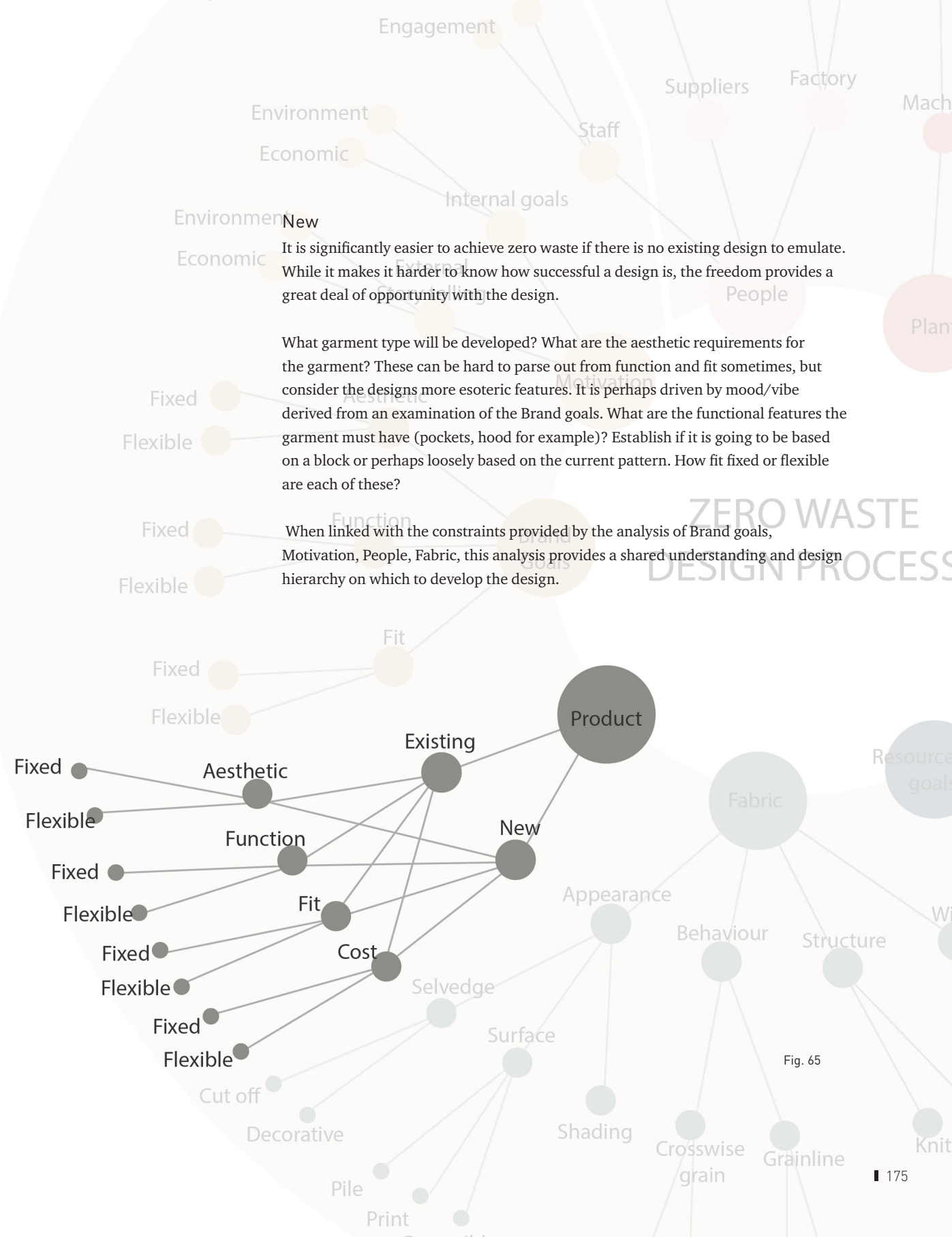


Fig. 65

THEORETICAL MODELS OF ZERO WASTE DESIGN

Fabric

As with conventional garment production, the appearance, cost and qualities of the fabric used has a profound impact on the outcome and feasibility of the garment. With zero/low waste garments there are additional factors to consider that directly impact on the design process. Importantly, when selecting garments to redevelop, it may be best to chose those that use expensive fabrics as they will yield higher financial returns, even if the changes may require greater use of time to produce them.

Appearance

Consider any surface treatments to the fabric that may impact on the pattern layout. These include features such as the nap of a pile impacting on grainline of pattern pieces, or a directional print or weave structure. Consider if the fabric is reversible, the same on both sides or if the difference between sides could be used as a design feature – this may enable the flipping of pattern pieces in unconventional ways. Shading is related to the features listed above relating to the surface but is usually more subtle. Determine how important it is to avoid shading effects on the product. What is the appearance (and behaviours) of the selvedge? In most cases, it needs to be removed in industry, but consider the possibility of using it as a feature (like in the case of selvedge denim).

Behaviour

Consider the behaviour of the fabric, the bias drape, and importantly the crosswise grain and grainline. How do they shrink or stretch when washed, but also how similar are their behaviours. If the grainline and crosswise grain behave the same (as in some plain weaves), or if a small variation is deemed acceptable, then placing pattern pieces perpendicular to the usual manner may work and provide the designer with more options.

Structure

Is the fabric a knit, woven or non woven. How might the structure impact on seam allowances, finishing, or behaviour for example?

Width

One of the most critical pieces of information needed, especially when designing the garment as a whole marker, is the width of the fabric the design will use. Remember to account for shrinkage and selvedge removal (if it is not being utilised).

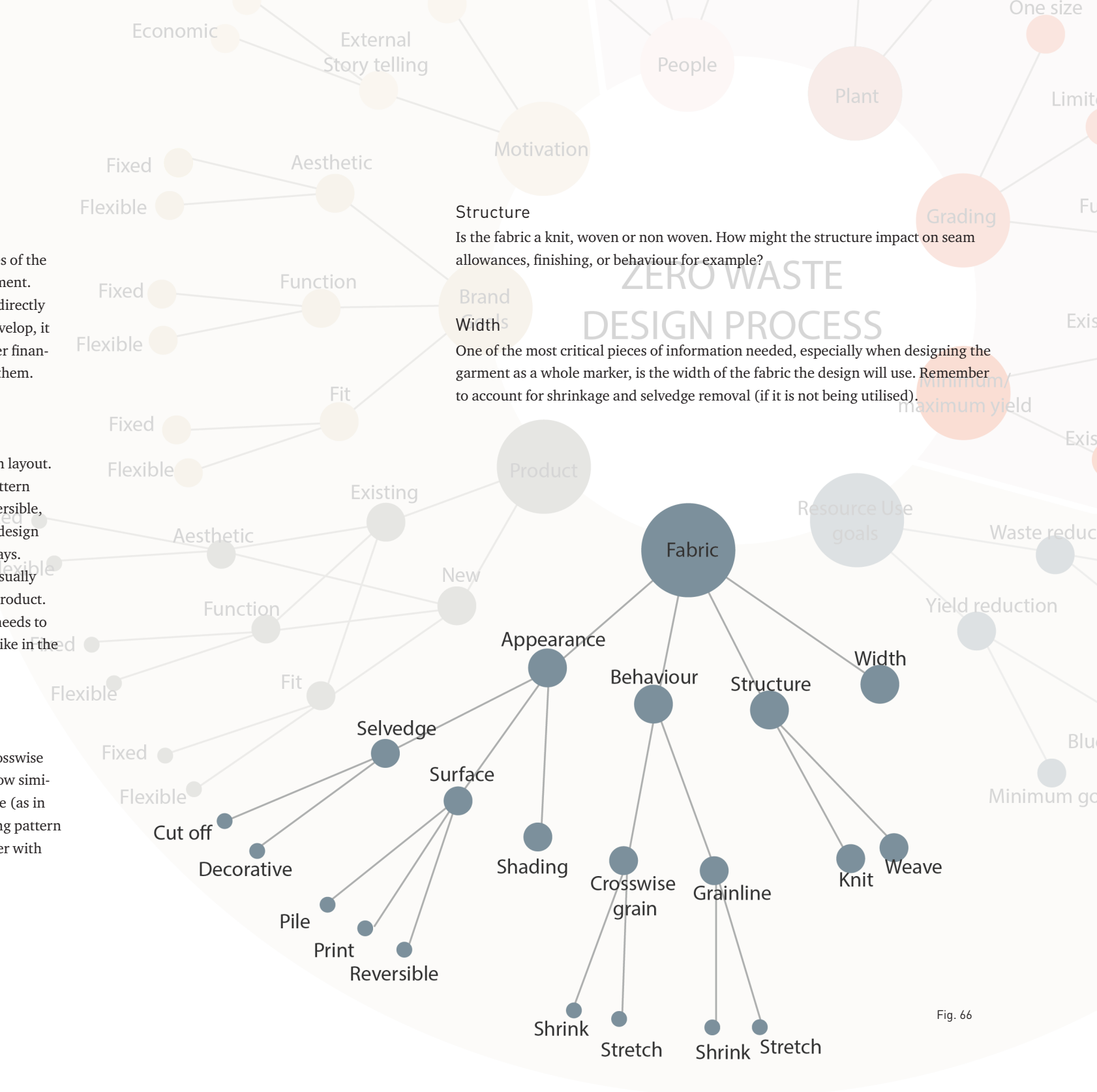


Fig. 66

THEORETICAL MODELS OF ZERO WASTE DESIGN

Resource use goals

Resource use is usually the primary driver when exploring waste reduction or elimination approaches. Part of the discussion around motivation needs to consider this question: does the company want to reduce waste or yield? This impacts on the design approach taken and also points to the overall motivation for the company. Also consider, what is the minimum goal for it to be worthwhile, how does the company determine this. Is there a 'blue sky' goal?

If the yield is reduced while maintaining an existing style, then waste will automatically be reduced, whereas it is possible to reduce waste without reducing yield at all. It is not usually desirable to reduce waste while increasing yield, but it is, of course, possible to do if care is not taken. The desired goals point towards the overarching motivations for the brand, linking with either with environmental storytelling (waste reduction) or economic drivers (yield reduction). The best case scenario is both a reduction in yield with an additional reduction in waste, and approach that compounds the positive environmental and economic impacts.

If the offering is a new product, goals should be based on similar styles from within the companies existing brand or similar garment types externally if there is nothing comparable internally.

These considerations directly interact with Minimum and Maximum Yield and have clear links with the 'branches' relating to Fabric, Product, Motivation, People, Plant.

There may be 'fixed' constraints placed on these goals from Plant (such as the need for a buffer) and Fabric used.

Percentage of waste reduced

When evaluating the costs and benefits of design changes made, consider the percentage reduction in waste, not only the increase in efficiency. For example, while an increase from 82% to 87% efficiency may only seem like an improvement of 5%, it results in an almost 28% reduction in waste for that style.

When setting minimum and blue sky goals consider that the higher the improvement desired, the more difficult it will be, and that this difficulty increases exponentially the closer to 100% efficiency and theoretical minimum yield a design becomes.

ZERO WASTE DESIGN PROCESS

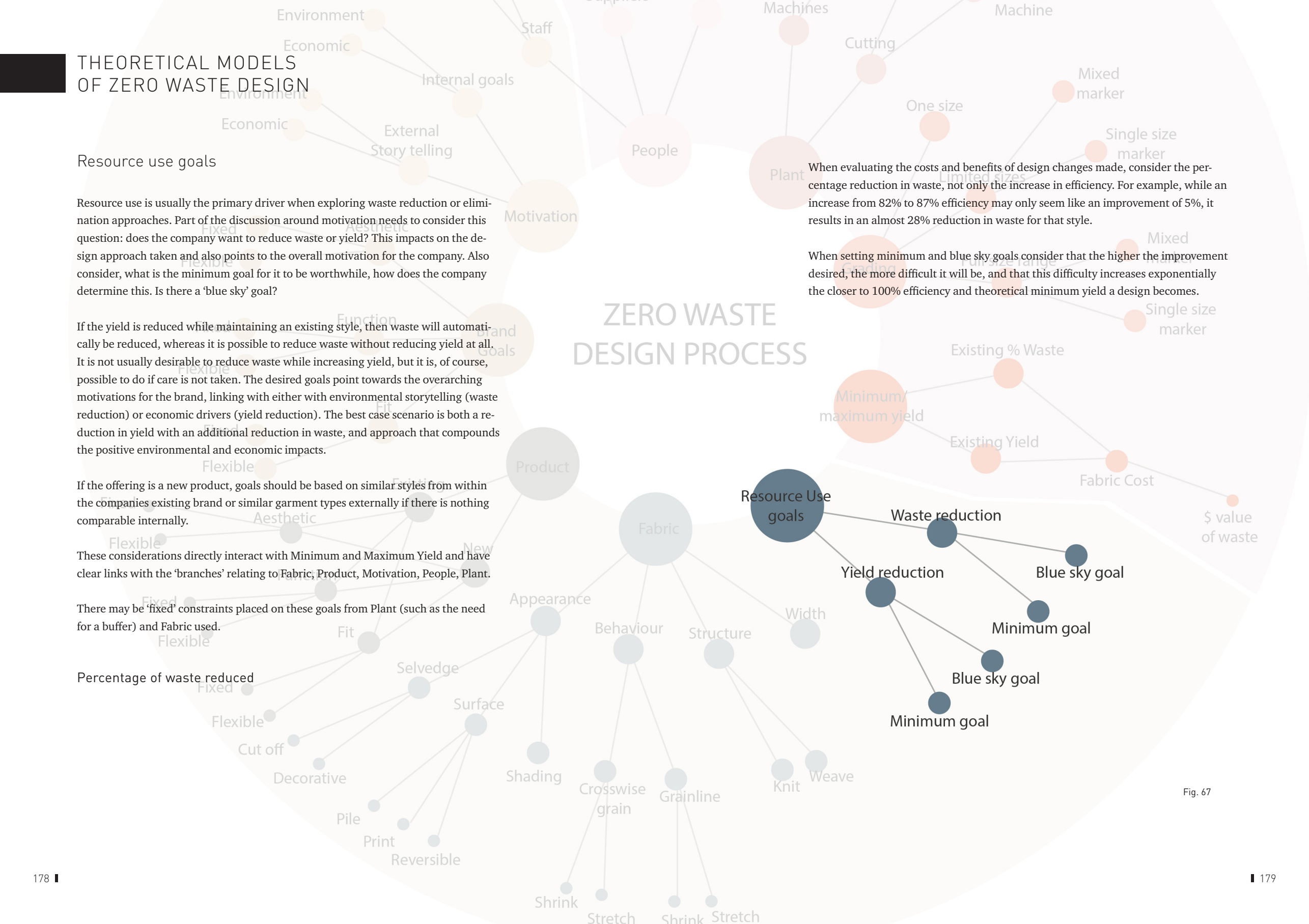


Fig. 67

THEORETICAL MODELS OF ZERO WASTE DESIGN

Minimum/ Maximum Yield

Between the minimum and maximum yield is the space for zero waste design methods, processes and thinking to act to reduce waste and yield. The theoretical minimum yield is the amount of fabric needed to make the garment if there was no waste. This figure will be an estimation if the product is a new offering, or an absolute figure if it is a redesign of an existing garment.

In addition to the environmental impact of producing waste, the financial cost of waste (both in terms of loss of value and cost of disposal) should be factored into discussions about motivation and goals. Currently, the cost of the waste is included in the retail price of a garment through the garment costing (yield includes waste, and the cost is based on yield) – so the cost of waste is passed on to citizens without their explicit knowledge.

Calculating the Theoretical Minimum Yield:

If the fabric width stays the same determining the minimum yield is a simple calculation. Subtract the waste percentage from the current yield. If the fabric width changes with this new design, then make a theoretical marker with the new yield, determine the waste percentage and then subtract the percentage of waste from the theoretical marker. The theoretical minimum yield gives a theoretical 'best case', and between that and the current best yield that the design achieves, provides a framework to work within.

If the design is a new offering, then use a similar garment style to provide a framework or decide to ignore this parameter when the design is being developed.

CALCULATION: Yield
- % Waste
= Theoretical Minimum Yield

STYLE X EXAMPLE:

Yield	x 120cm	
Waste	- 18%	
TMY of Style X	=	98,4cm length

Redeveloped style needs to use between 120cm and 98,4cm of fabric per unit.

This theoretical minimum yield imagines that the stuff that makes the garment is like a fluid (something like whole garment knitting, or a cast fluid/plastic, 3D printed). However, with cut and sew garments it is not possible. The limitations provided by the fabric and construction methods, combined with limitations of fit, aesthetic goals and conventions, means this minimum is theoretical only. It is useful as a tool to give an extreme 'decisive constraint' to aim for.

It is important to note that if the manufacturing method changes, such as using fully fashioned or whole garment knit instead of cut and sew methods, then to assess for improvements in resource use, the weight of the cloth for the original will need to be calculated instead.

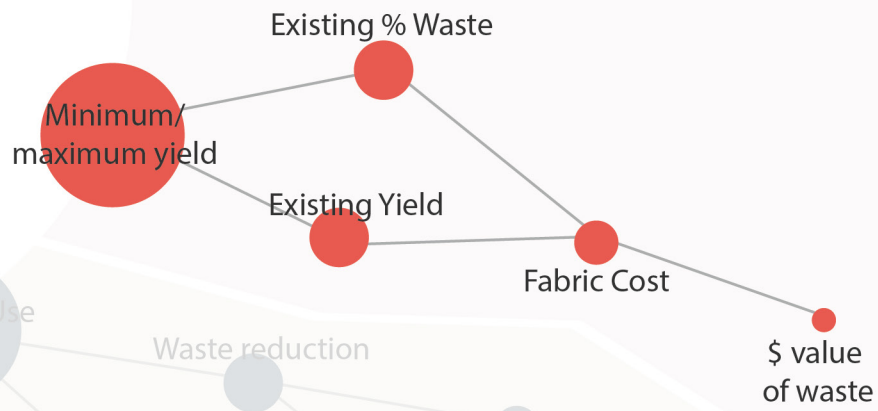


Fig. 68

Grading

Grading is one of the most often questioned issues relating to zero waste design in the industry. If aiming for higher efficiency – and not zero waste – then standard grading can be used (as was the case in Field Tesr 2). However, if zero waste is the goal then more radical approaches are necessary. Rissanen and McQuillan (2016) discuss the use of one size fits all, graded markers (where each size is a new marker and variations between sizes are accepted as inevitable), and embedding the size range into the pattern from the outset.

Additionally, the interviews point to the use of limited or 'bucket' sizes which enables the grouping of small with extra large, and medium with large for example. A similar approach could be used that group different garment types that use the same fabric. It is important to discover if mixed markers are possible, or if the markers all need to be a single size and garment type. Deciding what size range and grading approach are needed will directly impact on the design method used.

One Size

Using one-size-fits-all is the easiest method as only one design/pattern/marker needs to be developed. Other sizing approaches can be utilised such as drawstrings and wrapping to accommodate a range of bodies.

Limited sizes

Limiting the size range is the second most straightforward approach for grading, and works for many companies that have a more casual fit. Care needs to be taken pairing sizes together to accommodate the variable sizes of the garment pattern pieces. In the case of the grouping of limited 'bucket' sizing, a mixed marker provides the best flexibility. The interviews reveal the technique of pairing different sizes is used in industry contexts.

Full size-range

Aiming for a full size-range will usually require that the project aims for waste reduction, not elimination. This is because zero waste in a full size-range requires extensive development of a marker for each size separately to the rest. If fabric can be ordered to specified widths this approach could be achieved more simply, but specifying width is usually problematic for the majority of brands.

Probably the method most compatible with existing industry is to aim for a reduction in waste/yield, in a limited size range. The ease of implementation, of course, reduces the positive impact.

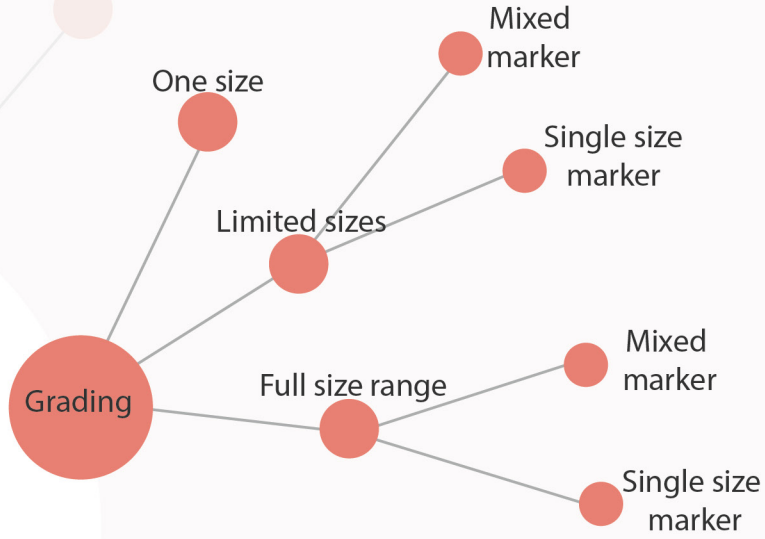


Fig. 69

Plant

Plant includes all the equipment – hardware and software – utilised in the development of the product. These factors are not commonly considered part of the design process.

Question production methods

It is vital to question the methods used to produced garments. This research finds that in many instances attempting to achieve zero waste or super high efficiency for an existing design or within a very tight design brief in the context of existing production methods, will be a futile exercise. Companies already seek to optimise as much as possible within these constraints because it saves them money – so as a result there is very little room to move. Moreover, the more significant the desired efficiency increase, the more difficult it is to achieve it. However, it may be possible to make more substantial gains in efficiency if the right technology and production method (or combinations of these) is applied to the correct garment.

Understanding the technology and equipment used (cutter buffer, marker software, sewing machines for example) can reduce waste without having to change the design. This was the case in Field Test 2 where the cutting buffer could be reduced which reduced waste without impacting on the design. Accesss to good quality marker software during the design development process ensures accurate markers can be developed in the design process. In Field Test 2 the factory achieved same yield and efficiency with automated marker making software as the technical designer did – however the technical designer had to take significant time to adjust the marker manually.

Sewing machinery and cutting can impact directly on the design process. Any cutting buffer, cutting techniques such as manually cutting or plunge cuts, or physical aspects such as cutting table length or seam allowances also feed data into the design process. The available equipment at the factory will impact on seam types – which impacts on zero waste design method, garment aesthetic and finish.

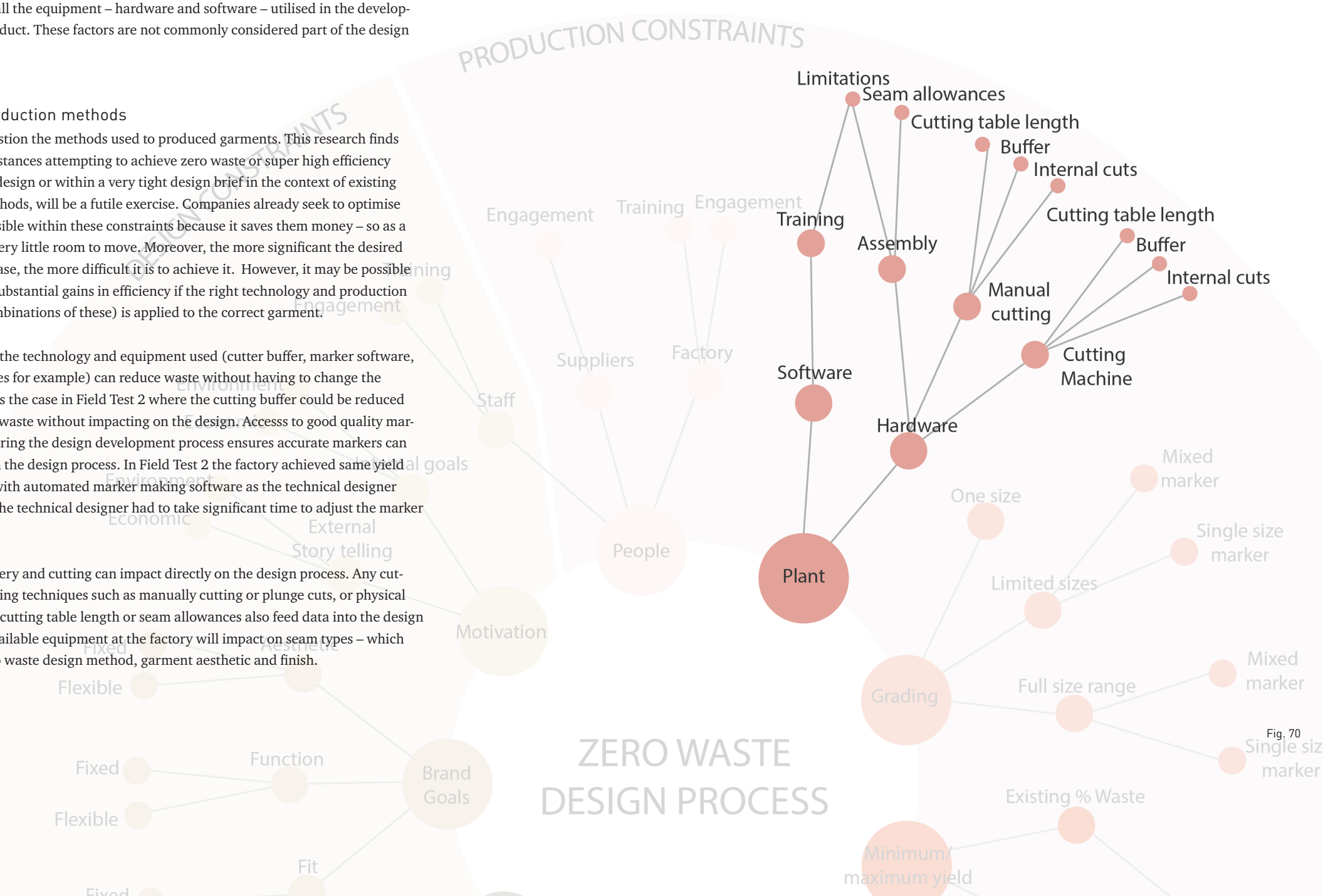


Fig. 70

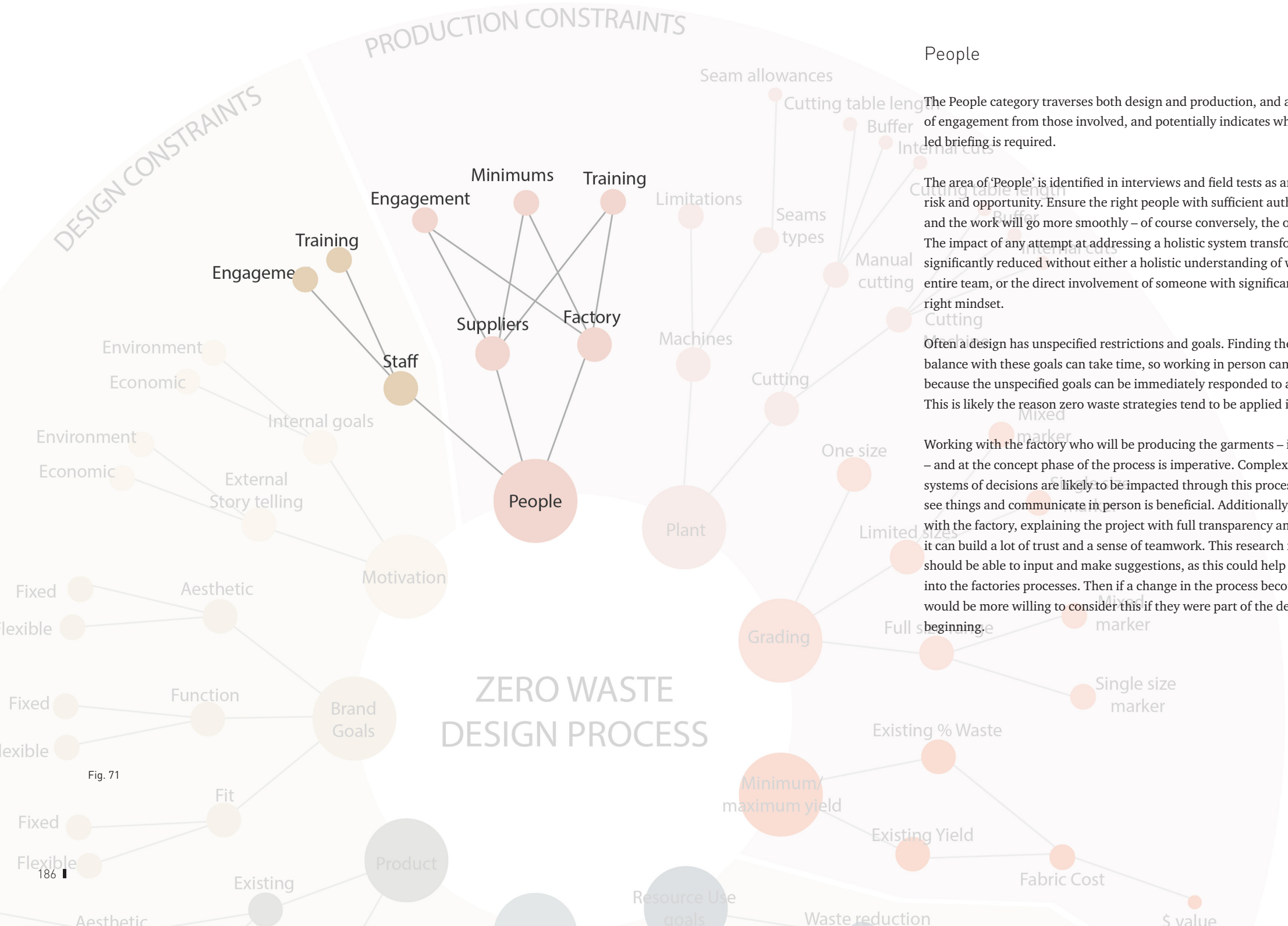


Fig. 71

People

The People category traverses both design and production, and addresses the degree of engagement from those involved, and potentially indicates where training or detailed briefing is required.

The area of 'People' is identified in interviews and field tests as an area of potential risk and opportunity. Ensure the right people with sufficient authority are involved, and the work will go more smoothly – of course conversely, the opposite is also true. The impact of any attempt at addressing a holistic system transformation will be significantly reduced without either a holistic understanding of what is needed by the entire team, or the direct involvement of someone with significant authority and the right mindset.

Often a design has unspecified restrictions and goals. Finding the right technique in balance with these goals can take time, so working in person can be more successful because the unspecified goals can be immediately responded to as they come up. This is likely the reason zero waste strategies tend to be applied in small companies.

Working with the factory who will be producing the garments – ideally at the factory – and at the concept phase of the process is imperative. Complex and integrated systems of decisions are likely to be impacted through this process, so being able to see things and communicate in person is beneficial. Additionally, working in person with the factory, explaining the project with full transparency and the motivations for it can build a lot of trust and a sense of teamwork. This research finds that the factory should be able to input and make suggestions, as this could help integrate the design into the factories processes. Then if a change in the process becomes necessary, they would be more willing to consider this if they were part of the development from the beginning.

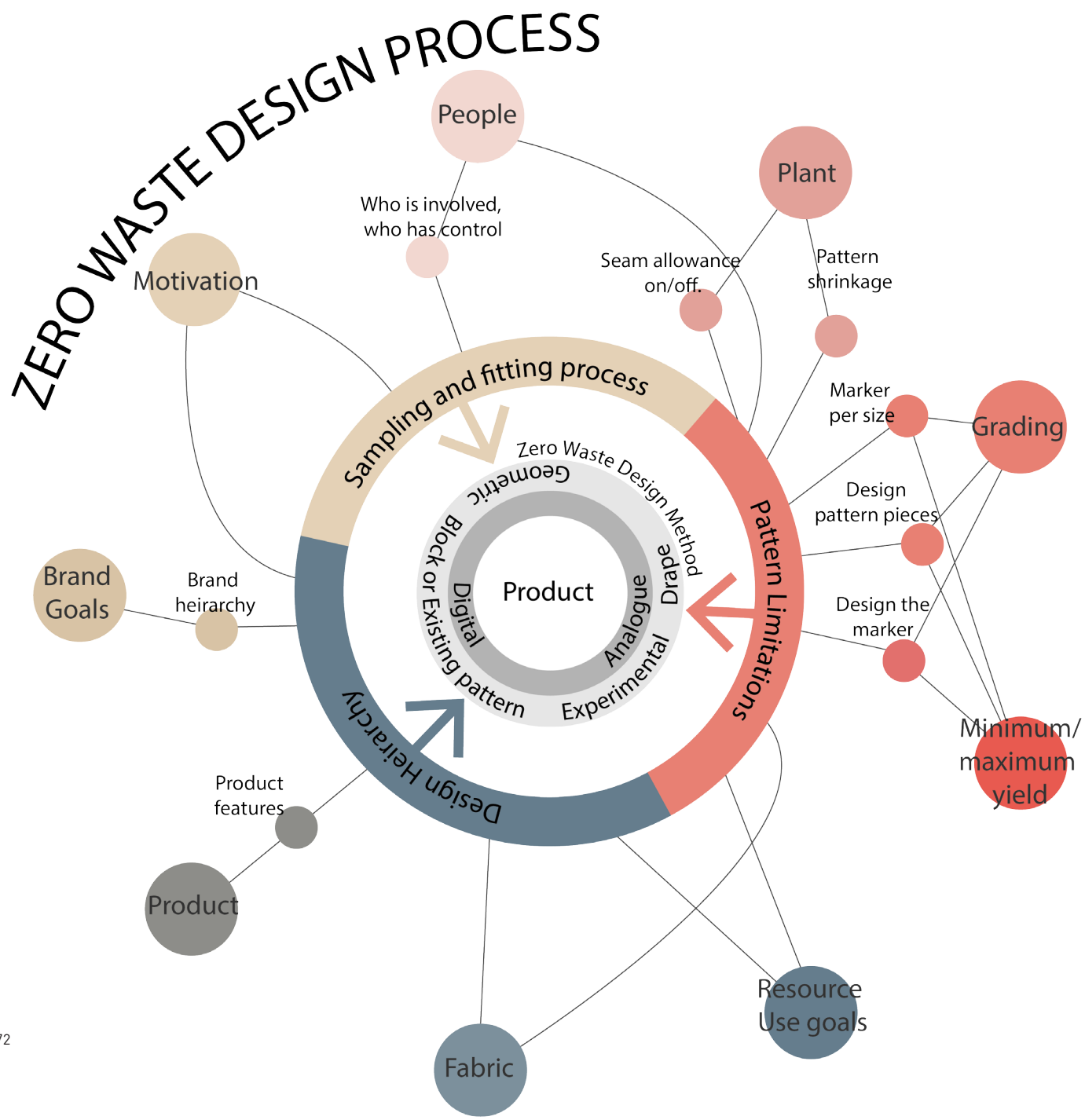


Fig. 72

Zero Waste Design Process

The constraints and inputs taken from the nine areas outlined in the previous pages – Plant, Grading, Yield, Resource use goals, Fabric, Product, Brand goals, Motivation and People – impact on the zero waste design process in a variety of ways. These limitations in turn then impact on three areas which interact with each other and on the design process for zero waste and low waste products.

All three interacting areas – Pattern limitations, Design hierarchy and Sampling and fitting process – need to be considered and in balance for the model to work. As was the case in Field Test 2 the sampling and fitting process derailed the delivery of a more efficient design outcome because the holistic goals of the project were not communicated to the team responsible for the final fitting.

THEORETICAL MODELS OF ZERO WASTE DESIGN

Pattern Limitations

An analysis of the company, plant, grading, yield, resource use goals, fabric and people using the lens of the Zero Waste Design Thinking reveals a range of inputs and constraints which provide Pattern Limitations.

Pattern limitations include knowing what grading method to use, the impact of Plant on the design method (for example is a buffer between each piece required, how big is it?), the theoretical minimum yield to aim for and requirements such as allowing for fabric shrinkage.

Design Hierarchy

An analysis of motivation, brand goals, product, fabric and resource use goals will establish a design hierarchy relating to why the company want to do this work, the desired features of the product, the limitations of the fabric and how all these fit within the overall brand goals.

The design hierarchy provides inputs into the zero waste design method such as which pattern block to use, what design features are wanted, the fabric choice, and importantly how to evaluate the design.

Sampling and fitting process

In addition to the significant impact that Design Hierarchy and Pattern Limitations have on the sampling and fitting process, the other fundamental impact is people and the internal hierarchy relating to roles within the design process and their motivations.

This results of this research find it is vitally important that all those involved in the development of the product understand the motivations and the goals of the design. Keeping track of this across the sequence of activities and people involved can make this problematic, however. It may be useful to produce an 'efficiency report' that travels with the specification to foreground the impact that minor design changes may have on the ability of the design to meet those goals. More radically, the industry could implement 'Industry 4.0' strategies (Stock & Seliger, 2016) in aid of sustainability goals – enabling a level of oversight of the entire value chain across the life cycle of products, making all relevant information available and responsive in real time. Without a clear method of communicating these goals or sufficient authority, it is easy for the existing systems to override attempts at reducing waste and resource use.

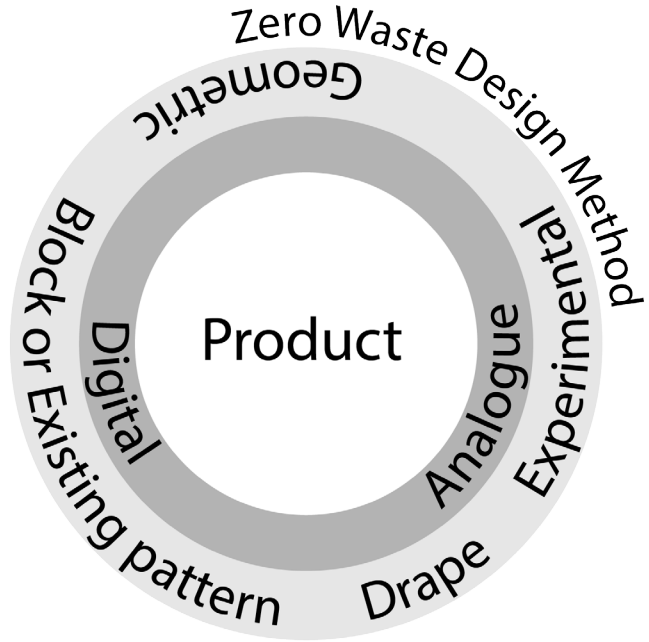


Fig. 73

Zero Waste Design Method

The Zero Waste Design Method (Fig. 73) rings situated at the centre of the zero waste design model illustrate the design methods utilised to facilitate the realisation of the identified design goals into a product. It is the context for which the majority of zero waste design research has taken place before the beginning of this research.

In addition to the intersecting methods explored by Rissanen and McQuillan (2015), this research explored the use of digital 3D design tools and Field Test 2, in particular, developed an approach for designing gradable, low waste patterns (see Field Test 2 methods pg. 64-72). The model presents the methods as a circular continuum, as the techniques do not work best when kept separate – the best combination of approaches will depend entirely on the specifics of the design hierarchy, pattern constraints and skills of the people involved in the development of the product.

THEORETICAL MODELS OF ZERO WASTE DESIGN

Use of the model

The zero waste design models are presented in a sequence from the macro scale to design process and methods. Taking this perspective (Fig. 74) is essential as often it is easy to forget the bigger picture. The research proposes that for Zero Waste Design Thinking to be effective holding the big picture in mind is imperative.

Companies can use this model to generate discussion points and as a tool for decision making. There will be parts which are not relevant, depending on the broader context, the structure of the company and the product selection and design approach. Perhaps it is useful to begin in an area that the team is most comfortable with, and work outwards and then back inwards to ensure all the potential issues and inputs are addressed. Another approach is to start with Motivation to ask why the company wants to do this work? The model enables companies and designers to establish a clear set of design parameters which can be referred to again and again throughout the design and evaluation of the product.

The model can also be used to evaluate the company as a whole in a theoretical way. In this way it is a holistic lens for seeing what exists in a different way, enabling the company, and the industry to identify areas for action and change.

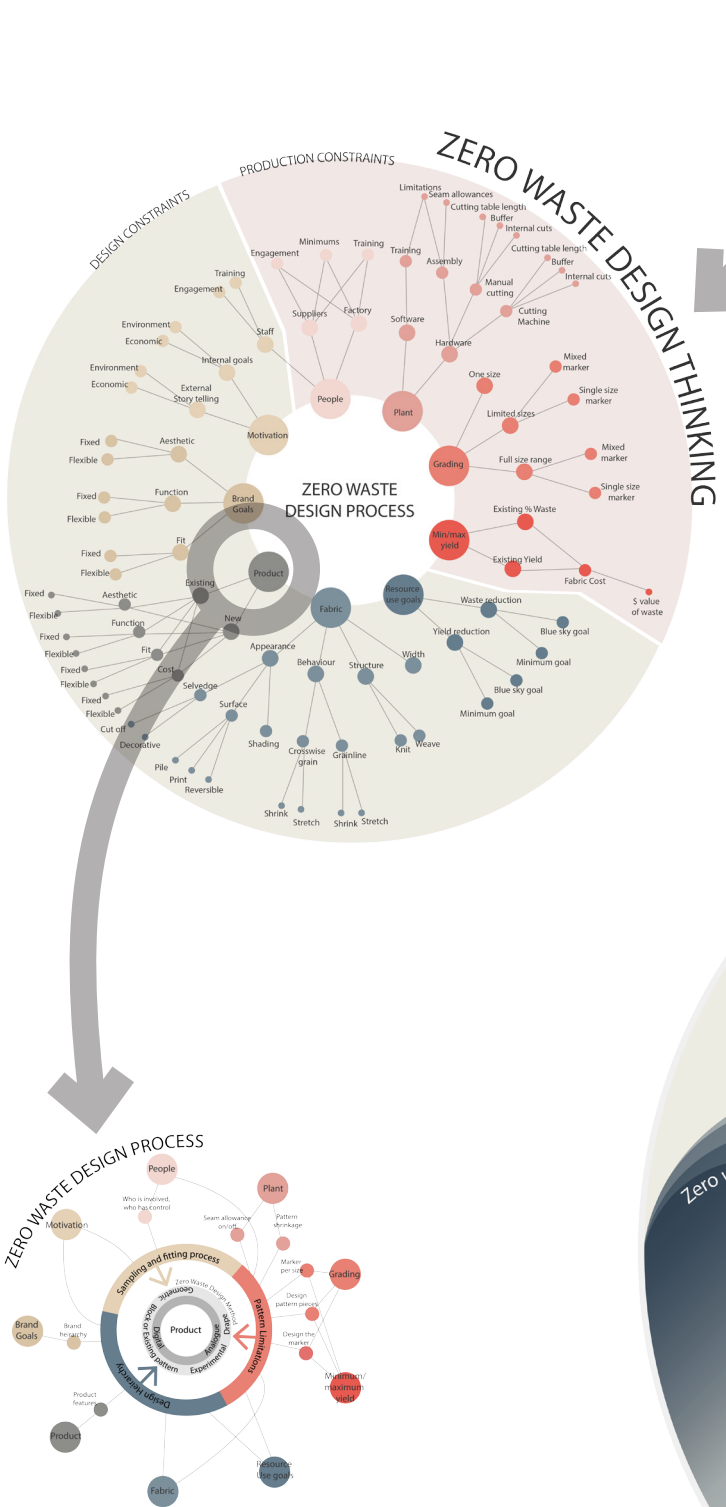
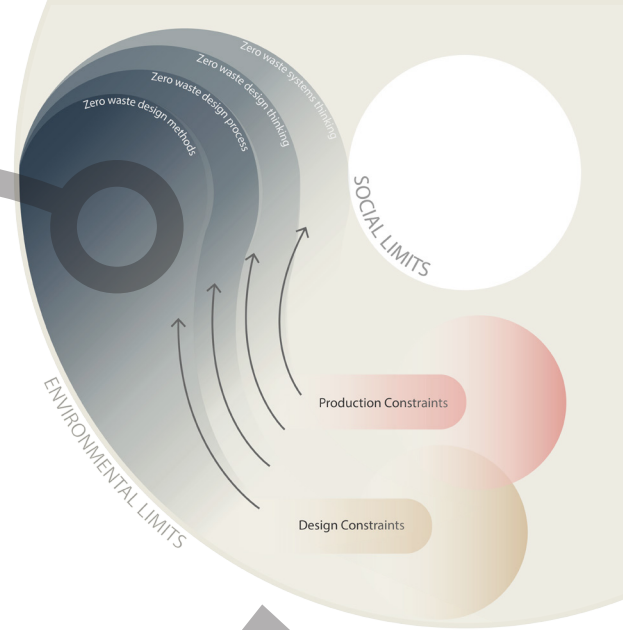
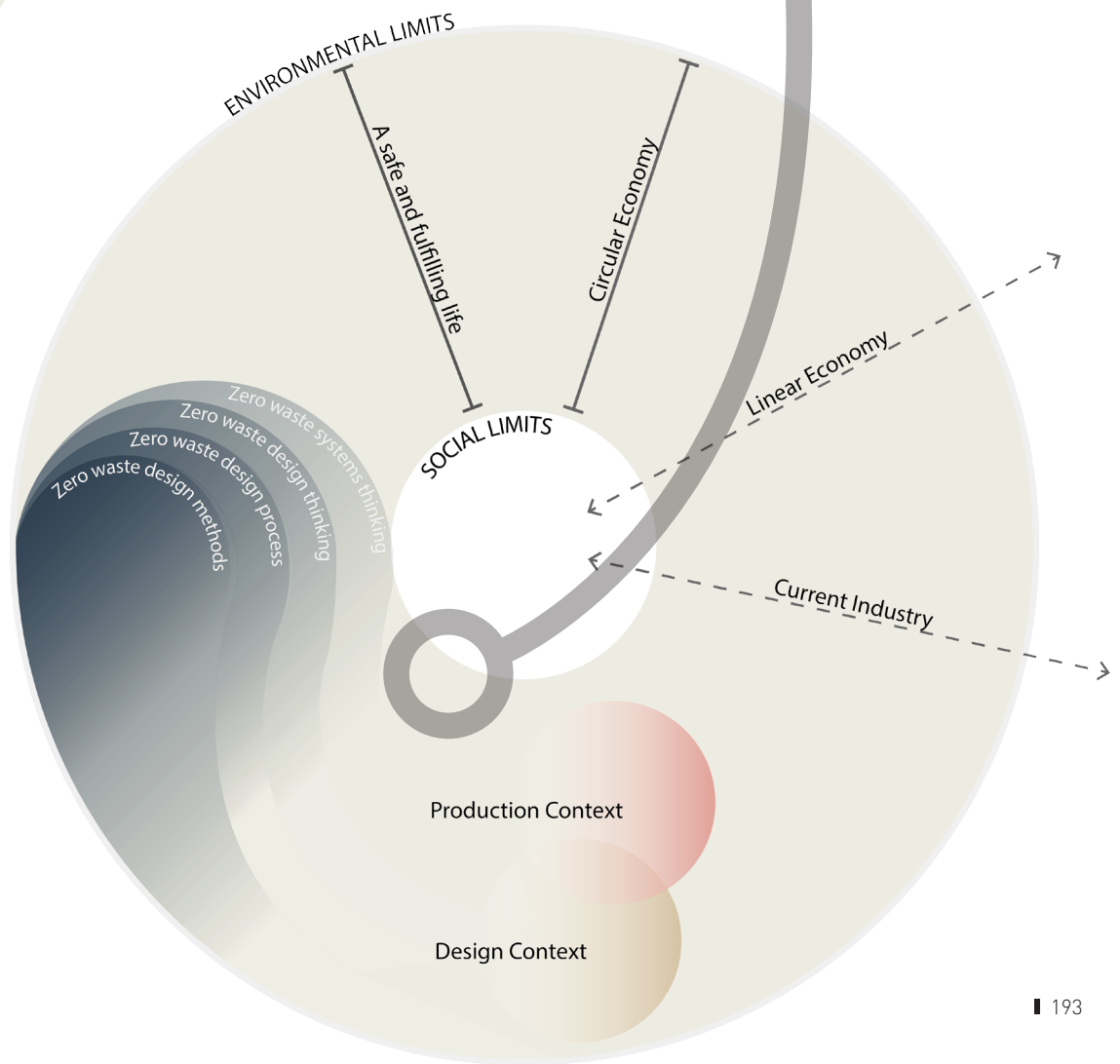


Fig. 74





7. CONCLUSIONS

This chapter concludes this stage of the PhD research which argues for a shift in thinking about the use of zero waste design and sustainability in the industry. It summarises the primary outcome of this research – the establishment of a new lens to view the industry through called Zero Waste Design Thinking. Lastly it articulates the limitations of the research, proposes areas for further study, and discusses a trajectory for the continuation of the PhD research.

This research aimed to explore new methods and implications of eliminating textile waste from the production of clothing at the pre-consumer stage, specifically through zero waste pattern cutting and design practices. It sought to apply existing knowledge in this area in an industry context, and develop new methods and guidelines to assist the broader application of these waste elimination and reduction approaches. However, as the research progressed through the field tests, it became clearer that the research cannot merely be concerned with designing objects or forms, but should also design the systems that this practice operates within. The research concludes that zero waste cannot be considered a method to be 'dropped-in' to the existing linear systems of the industry, and instead needs to be considered as part of a diverse range of approaches seeking holistic transformation. The research outlines the clear mismatch that exists between what is needed to be done to transform the industry, and what the industry wants to do or sees as possible. This conflicting space leads to paralysis in the status quo when holistic action is needed. Zero waste design thinking is proposed as one of the tools the industry and education could use to enable a shift in thinking. The research argues that all actors in the fashion system need to to understand that it is a holistic system they are a part of, and that holistic actions that prioritise a different set of constraints to those the industry and society currently focus on are needed to change it.

Thinking through the lens of Zero Waste Design

The outcome of the field tests shows that zero waste as a design method to reduce resource use in the context explored has minimal effect. However, as a way of thinking about resource use through design, zero waste methods are well situated to support the development of highly efficient circular systems. To design using zero waste methods requires a holistic understanding of the whole system and its interconnections – it is not only a design, pattern cutting or marker making exercise. It has the potential to be used as a tool in education and industry to expand the role of sustainable design beyond a product, and therefore increase its impact across a range of industries and products. Teaching students to think about the design process holistically through a zero waste lens will provide them and the industries they go on to work within, a diverse range of tools to identify where improvements and transformations can occur. The inherent 'extreme' nature of zero waste design brings the problems into sharp focus – forcing us to take notice and, hopefully, act. Focussed, sharp and holistic; this is the kind of thinking we need for the emerging circular economy.

Zero Waste Design Thinking enables us to recontextualise the constraints we choose to impose on the products we design. Designers need to be provided with the tools to think about constraints differently, importantly we need to choose the right constraints, and place importance on a broader range of product attributes when developing and evaluating them. Most importantly we – designers, technicians, engineers – need to be provided with a way to do this.

It is clear that a diverse approach is required. First, this research demonstrates (appended Paper III) that industry needs to reduce the amount of material required (aiming for theoretical minimum yield) to make garments. Secondly, recapture and recycling rates of waste and unwanted garments need to achieve as close to 100% as possible. Thirdly, the 'hoarding' of garments needs to be eliminated, and instead have two distinct kinds of garments (Earley and Goldsworthy, 2015; Goldsworthy, 2017; Peters et al., 2018). Garments that are designed to last, that do not drive consumption increases because they are used – and repaired, cherished, reused, lent, on-sold – these are the only garments (if any) we should consider making from virgin materials. Fast '1:1 garments' are needed; those which move through the fashion cycle rapidly, providing their own raw material to be reborn, therefore meeting their own demand for recycled material. The globally distributed (and therefore energy intensive) nature of the fashion industry needs to be reconsidered, and manufacturing

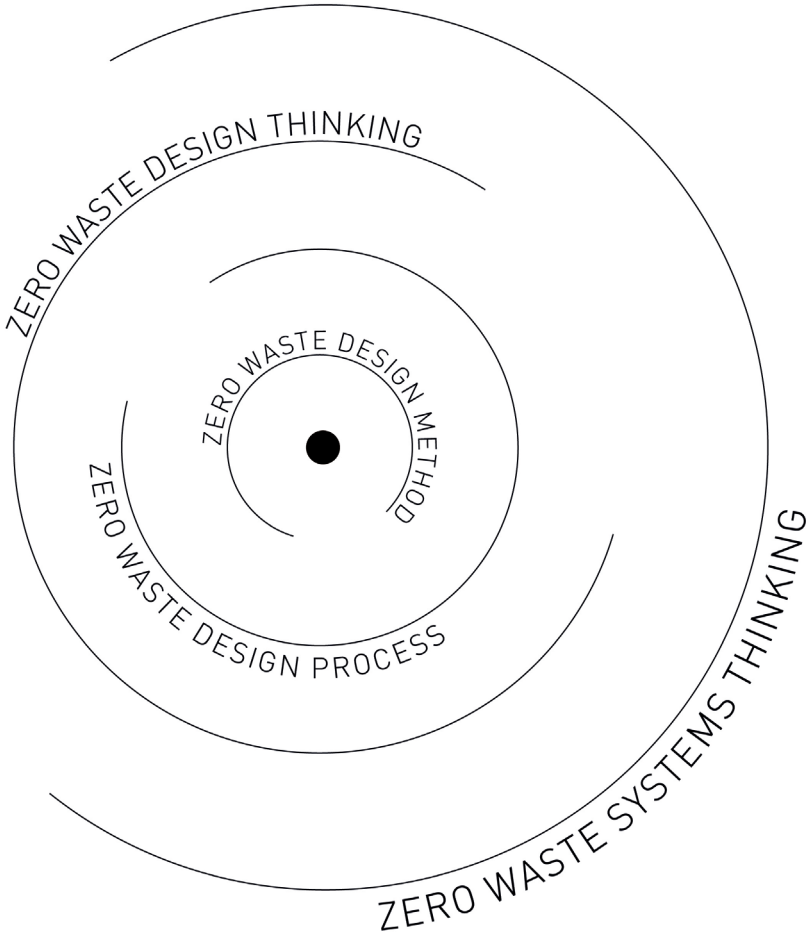


Fig. 75

models need to be developed which enable production to be located closer to where the garments will be sold and used. Lastly, growth in material use ideally needs to be flattened to achieve a steady state economy. This research proposes that the theoretical models for zero waste design outlined in this licentiate could help facilitate this holistic shift in thinking about design.

CONCLUSIONS

There is an incompatibility between what industry and citizens want (in our products and systems) and what needs to be done (for both the environment and our our survival). This conflict is at a personal level – we want to buy strawberries all year round, but we need to buy the local in-season apples instead because the strawberries need to be shipped from the other side of the world. For the fashion industry, there is a mammoth mismatch between these kinds of needs and wants. The industry needs to reduce resource use, eliminate waste, improve recycling rates and decrease consumption. However, the fashion industry wants to continue as they have been – in fact, they want to sell more. The most critical reflection from the field tests was the realisation of the degree to which the constraints of industry prevent meaningful change and innovation. Within the field tests, a variety of strategies were attempted to address this; however, more extensive reflection has led to this research to question the role of constraints, the value and role of waste within our future (as yet theoretical) circular economy and its relationship with the complexity of the industry, and the hierarchies evident between fabric and garment. It is clear there is a vast chasm between what is wanted and what is needed. Designing zero waste garments requires a fundamentally different approach to what the vast majority of the industry uses, and conventional zero waste design attempts to 'drop-in' to the existing 'cut and sew' system. This research shows that playing at the edges of the existing linear system will result in a struggle to achieve the degree of change necessary – a radical rethink of the models that the design, production and use of textile products take place within must occur.

In response to the crisis, it can be common to become paralysed by fear and doubt; we worry that nothing can be done to enable the kind of change we need. In the face of this fear, indecision and sense of helplessness, tools are needed – for designers, educators, management, CEOs, CTOs, technicians – and new ways of seeing and understanding the industry. It is common to teach sustainability in education from the perspective of materials, resource management, and occassionally systems. However, this research demonstrates the need to consider how we design things and what that can teach us, not only what they are made of or how they look and function. Things are the physical manifestation of ideas, through materials and systems, and if we do not understand the problems with the ideas, materials and systems, we cannot effectively change them.

Throughout the development of the fashion industry, we have sought to diminish complexity by dividing up the actions required to make a garment so that each person only needs to deal with their own discrete unit. However, we have merely spread the complexity out – making it harder to see, harder to wrangle, and far more inflexible. And now, when we need to change it, we say we can't because the system is too complex.

McQuillan and Rissanen in Mind-Body-Cloth-Garment.

CONCLUSIONS

Limitations of the research

This Licentiate builds on the body of work in zero waste design that has been explored for the last 15-20 years and has attempted to apply methods in the context of the fashion industry as it stands. When applying these strategies to existing industry models and processes, it is clear that zero waste struggles to gain traction as a design method – it becomes a round peg in a square hole. Within the constraints of the existing fashion industry zero waste feels like too hard of a task. However, by conceiving of these constraints as 'decisive constraints' (Mose Biskjaer and Halskov, 2014), they instead act as a catalyst which forces a shift in thinking about what sustainable design can be and how it interfaces with industry and society. Because the actions of the designer are directly impacted on by its interconnected and complex context, the designer is forced to consider and respond. This understanding has pivoted the ongoing research for this PhD toward conceiving of zero waste design as an interconnected system of thinking because of the constraints and the increased understanding of the broader context that they present.

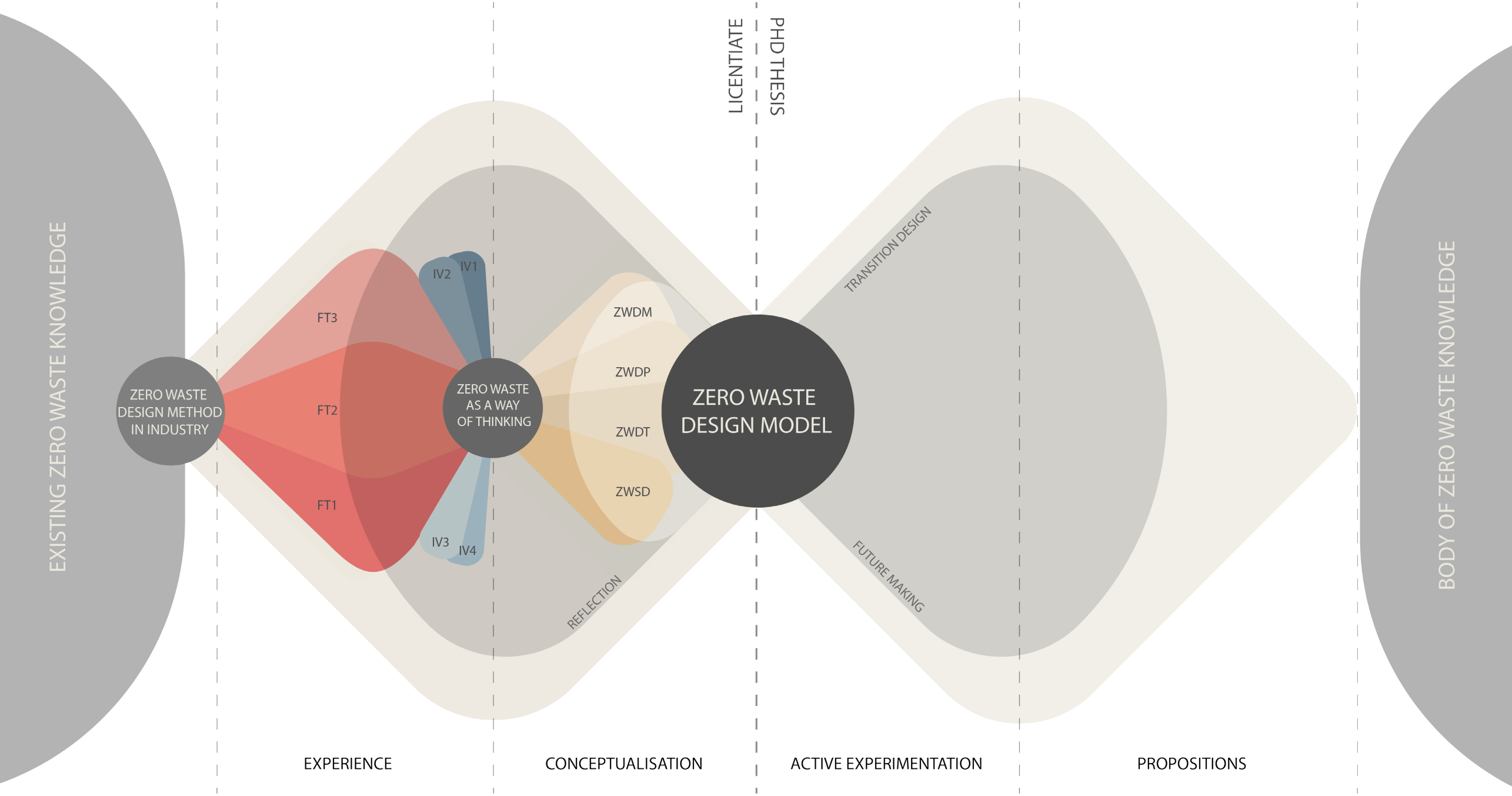
There are several limitations of the findings of this research which point towards further areas of investigation. Given the small sample size (two fashion case studies, one furniture case study, and four interviews), the research has a relatively narrow frame of reference. The lack of information about waste reduction through design interventions in the industry is primarily due to the scarcity of attempts but it also due to the opaqueness of industry. There was a case which the research sought to include in the interviews, but could not get a response from anyone in the company. So, to build a clearer picture of what can work, more case studies need to be undertaken in industry, and it would be valuable to test the application of these models in the industry, workshopping them to seek gaps and appropriate workflows. It would also be of value to see how these models might apply to other industries.

As always, more data is needed about the scale of the waste problem, although based on the data we have, wider research asserts that it is a problem that needs addressing. Beyond waste, this research interfaces with all other aspects of the developing circular economy, from new fibre developments, mechanical and chemical fibre recycling, to life cycle analysis, use practices, and habits of disposal/return. A vital issue in the development of a circular economy which was highlighted in this research is the industry's super-complexity; in fact, complexity seems to be a hallmark of the industry. Existing complexity needs to be dealt with by developing systems, software and machine learning to support some aspects of this complexity – how might an 'Industry 4.0' approach augment our attempts in this regard? – and through simplification of other aspects. How might the industry be simplified so that change is possible? Continuing the status quo is insufficient for the kind of change required. Importantly, further research is needed into economic models that limit growth. How might the zero waste design models presented here assist in the development of a steady state economy?

It would be of value to explore the use of the models in education – can they be useful to help students in understanding the complexity of the system they operate within? What is the role of constraints in education? Resource shortages will likely be a reality for many of our students as they transition into their working lives, how can we adequately prepare them for designing in a (hopefully) circular but finite world.

Lastly, examples are needed that demonstrate how this new world might look through the lens of future making and transition design. In my PhD Thesis, I will expand on this model, illustrating an alternative way of working that builds a way of thinking about the design of textile-based forms and their production from the yarn onwards through a lens of Zero Waste Systems Thinking.

Fig. 76


EXISTING ZERO WASTE KNOWLEDGE
LICENTIATE
PHD THESIS
BODY OF ZERO WASTE KNOWLEDGE
ZERO WASTE DESIGN METHOD IN INDUSTRY
FT3
FT2
FT1
IV2
IV1
IV3
IV4
ZERO WASTE AS A WAY OF THINKING
ZWDM
ZWDP
ZWDT
ZWSD
ZERO WASTE DESIGN MODEL
TRANSITION DESIGN
REFLECTION
FUTURE MAKING
EXPERIENCE
CONCEPTUALISATION
ACTIVE EXPERIMENTATION
PROPOSITIONS

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PUBLICATIONS

Appended papers

I. McQuillan, H. Martin, J., Menzies, G., Bailey, J., Kane, K. and Fox, E., 2018. 'Make / Use: A System for Open Source, Zero Waste Fashion Practice', in *Fashion Practice*. Routledge, pp. 1–27. doi: 10.1080/ 17569370.2017. 1400320.

II. McQuillan, H., 2019. 'Waste, so what ? A reflection on waste and the role of designers in a circular economy.', *Nordic Design Research Journal.* Espoo, Finland, 8(8), Available at: http://www.nordes.org/opj/index.php/n13/ article/view/485/456.

III. McQuillan, H., 2019. 'Hybrid zero waste design practices. Zero waste pattern cutting for composite garment weaving and its implications', in the *EAD: Running with Scissors, 2019, conference proceedings published by The Design Journal*, Taylor and Francis.

PAPER I

McQuillan, H. Martin, J., Menzies, G., Bailey, J., Kane, K. and Fox, E., 2018. 'Make / Use: A System for Open Source, Zero Waste Fashion Practice', in *Fashion Practice*. Routledge, pp. 1–27. doi: 10.1080/17569370.2017.1400320.

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Fashion Practice, 2018
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Make/Use: A System for Open Source, User-Modifiable, Zero Waste Fashion Practice

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Abstract

This paper discusses *Make/Use*, a multi-disciplinary research project exploring "User Modifiable Zero Waste Fashion". In particular, it addresses the use of textile print and a parametric matrix to facilitate the cognitive and creative processes involved in the transformation from two-dimensional (2D) to three-dimensional (3D) form. The *Make/Use* project centers on the development and testing of an embedded navigational system by which users can formulate a functional understanding of the form and construction of a garment and its opportunities for manipulation. It questions how the encoding of navigational clues and markers into a garment might aid in its facility for creation and modification by the user, aiming to enhance emotional investment and connection, and extending its functional life by providing embedded opportunities for alteration and visible repair.

KEYWORDS: zero waste fashion, textile print, wayshowing, use practice, open source, matrix

Introduction

This paper discusses "Make/Use", a multi-disciplinary research project exploring "User Modifiable Zero Waste Fashion" (UMZWF): garments that can be made and modified by users, with no fabric waste. Exploring what occurs if we consider the esthetic of the garments we wear and how we make and use them, *Make/Use* responds to the crisis of waste in today's fashion industry. The project builds on Holly McQuillan's "Zero Waste Fashion" (ZWF) research, questioning industry conventions in relation to knowledge-keeping, production, and consumption. To date, *Make/Use* has undergone two key phases. McQuillan developed "MakeUse v1" through involvement in "Local Wisdom," part of Dr. Kate Fletcher's "Craft of Use" project (Fletcher and Toth-Fejel 2014). Curious about the intersection of ZWF design and "use practice" (the ways in which people use their clothes), McQuillan imagined a fashion industry of both experts and non-experts, collaboratively engaged with the sustainable making and ongoing use of garments. To further the positive impact of ZWF by reducing material waste in both production *and* use, she hypothesized that the lifespan of garments could be lengthened by enhancing the garment-user connection through processes of making and modifying. This paper discusses "Make/Use v2," in particular the development of an "embedded wayshowing system" that encodes navigational markers into the textile print of the fabric, and the discovery of a "zero waste matrix" that underpins the relationship between garment form and fabric width for *Make/Use* garments. Findings from these interconnected lines of enquiry establish a platform for further innovation in UMZWF systems.

The *embedded wayshowing system* is the original focus of *Make/Use*, and attempts to exploit the direct relationship between fabric, textile print, and garment form in zero waste construction. In ZWF none of the fabric is lost as waste, which allows for alternative design and modification options to be built into a single garment pattern as layered cut lines, printed directly onto the fabric. Because the fabric is retained, the garment form is open and can be reset (mended), recut and remade using different cut lines.[1] *Make/Use v1* tested embedding the modifiable garment pattern and the instructions for its use into the textile print design. Both pattern and guide, the print aimed to facilitate the cognitive and creative processes involved in the interpretation of a two-dimensional (2D) garment pattern and its transformation into a three-dimensional (3D) garment form. Makers were aided in gaining a functional understanding

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Jo Bailey is a lecturer and designer at Massey University School of Design in Wellington. She's interested in facilitating access to information through design, whatever format or form that takes. With a former-life degree in Geography, she has a strong interest in the environment and conservation. She believes in making things as simple as they can be, but not simpler.

Karl Kane's research focuses on service, experience and social design, civic participation, and brand communication. His research interests primarily sit within the area of twenty-first Century Citizenship. He teaches in the visual communication degree and consults/mentors within Massey University's Open Lab, with a focus on service, experience, and social design.

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of the construction of a zero waste garment, and its opportunities for manipulation, through engaging in the making process. Producing a custom garment from a range of possible options gave them creative agency, with the cut of the garment collaboratively determined between our creative intent and the creative decisions made by the maker during interpretation and construction. This system suggests that the user can adopt a mode of active engagement rather than passive consumption, challenging the user–garment relationship. The predominant designer–producer–consumer model of wasteful consumption is shifted to a democratic alternative that engages the wearers of clothes as not just users, but "maker-users."

Testing of *Make/Use v1* prototypes (Figure 1) confirmed the viability of digitally printed zero waste fabric patterns ("flats") that could be user-made and modified, but found that for unassisted non-experts, achieving well-constructed garments (forms) was problematic. Extensive instructions were necessary for uninitiated users to decode the guides within the textile print. *Make/Use v2* proposed to remove these barriers to engagement and to develop an open-source system for UMZWF that acknowledged a spectrum of participant skill levels, time and available resources. One barrier identified was the inflexibility of the zero waste pattern, because it is directly tied to the width and length of the fabric. This strand of enquiry uncovered a flexible parametric grid—the *zero waste matrix*. This matrix can be considered a ZWF garment block[2] that gives the relationship between body measurements and two-dimensional pattern for a particular garment typology. The matrix can be adjusted to suit the interrelated parameters of fabric width/length, size/fit, and garment design variations. Using the matrix as a foundation, it is possible to generate an infinite array of zero waste garment designs. The matrix helps the maker/user to rapidly grasp the underlying geometry and sequence of construction moves needed to transform *flat* to *form*. This innovation aims to increase access to ZWF and provide the flexibility required for further uptake in the fashion industry.

The paper reviews relevant literature that locates *Make/Use*'s UMZWF in relation to the fields of ZWF and *use practice*, and contextualizes the necessity of expanding ZWF research beyond the waste management practices. Key theories are introduced around the redistribution of creative agency from the designer to the user, setting up the two platforms by which we seek to democratize fashion production: open design process and product. The development and testing of the Make/Use textile print as *embedded wayshowing system* is outlined, along with the discovery and subsequent application of the *zero waste matrix*. Research processes and findings are recounted through a discussion of three user testing scenarios: in-house testing, and two public workshops. While conveyed in a linear fashion, it should be made clear that the research strands acted as interconnected feedback loops, an open process that allowed for the emergence of a new territory for UMZWF exploration.

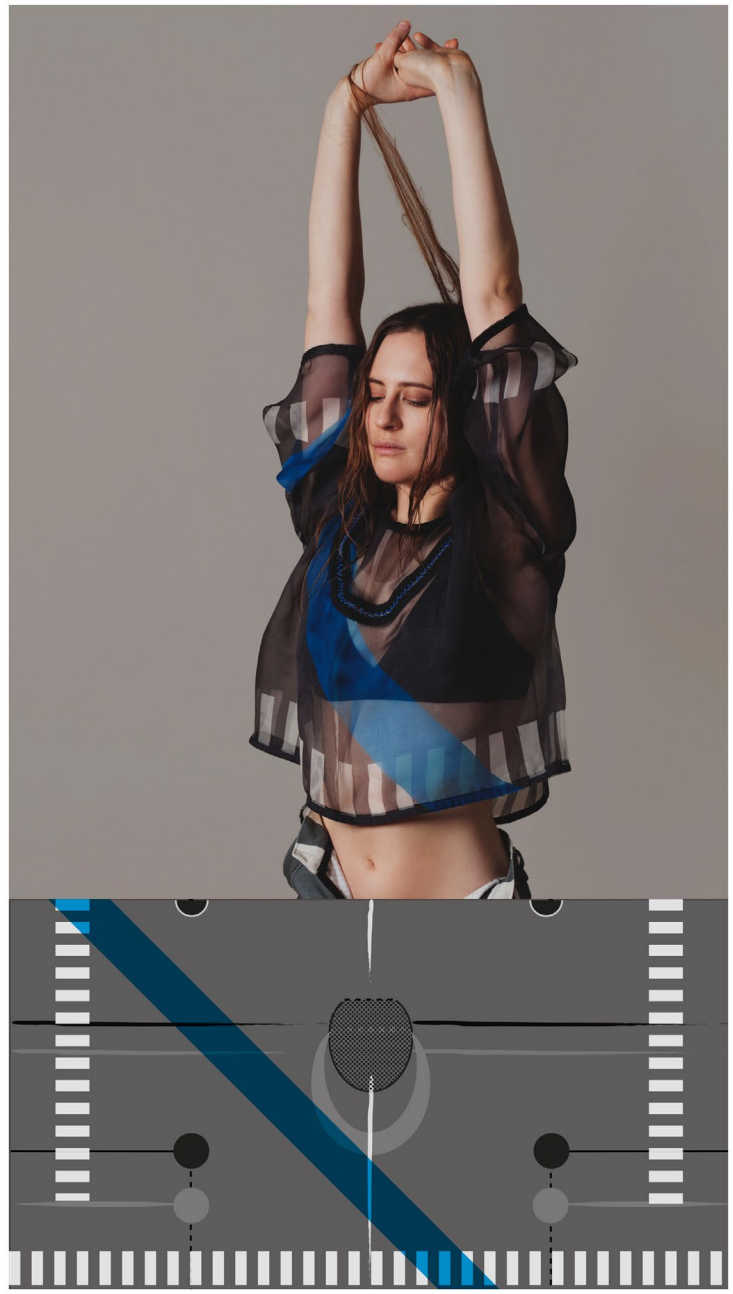

Figure 1
Make/Use V1 Cropped T-shirt showing pattern (bottom) and form (top). The digital textile print shown was the first test of textile print as instruction and esthetic that is explored in Make/Use v2. Photograph by Agnes Lloyd-Platt, Digital file by Holly McQuillan.

Review of Literature

Locating the research: user modifiable zero waste fashion

Prior to the publication of the first comprehensive book on the subject *Zero Waste Fashion Design* (Rissanen and McQuillan 2016), research in the relatively young field of contemporary ZWF design has primarily

focused on decoding the actions of the zero waste designer/pattern-cutter to identify modes of working (McQuillan 2009; McQuillan in Chin et al. 2010; Lumsden 2010; McQuillan in Adank and Mehzoud 2011; McQuillan in Gwilt and Rissanen 2011; Townsend and Mills 2013; Niinimäki 2013; Carrico and Kim 2014), and the relevance of ZWF to sustainability goals such as timelessness and waste elimination (Rissanen 2005; McQuillan, Rissanen, and Roberts 2013; Niinimaki 2013). The reduction of material waste in production is central to ZWF. It is estimated that, in 2015, 400 billion square meters of cloth will be made for the apparel industry (Gugnani and Mishra 2012), and of this, 60 billion square meters (15%) will likely be wasted on the cutting room floor. ZWF patterns not only eliminate fabric waste but can reduce the length of fabric required.[3] However, while ZWF contributes to industry waste reduction, eminent ZWF designer and researcher Timo Rissanen (2013, 160) states, "Zero-waste fashion design is not 'good' in and of itself," going on to say that we need examine the fashion system it exists within as a whole in order to make meaningful change.

In response, *Make/Use* expands ZWF research to explore how users might engage with zero waste garments. Similarly to Rissanen, Kate Fletcher (with Toth-Fejel 2014) has speculated that while the average environmental impact of fashion per product may have reduced, the increasing volume of consumption has significantly eroded any gains: approximately 120 billion new garments are made every year. Consumption behavior clearly needs addressing, and one possible avenue is through the transformation of consumers into informed and engaged users. Fletcher (in Fletcher and Grose 2012) defines the "wearing and using of garments" as *use practice*, and positions it as central to the practice of garment design. Fletcher's exploration of the *craft of use* of clothing encourages designers to learn from the ways in which users "mitigate… intensify, and adapt" clothing to suit their lives. With the exception of Rissanen's *Endurance Shirt* (2014) which explored ongoing repair in zero waste menswear, the *craft of use* of ZWF has not previously been explored, and forms the research agenda of *Make/Use*.

Locating the agency: designers as facilitators, users as makers

Fletcher's notion of *use practice* challenges the existing ZWF literature, as it shifts the creative agency from the expert designer or craftsperson to the everyday clothing user, reframing use practice as a "craft" in its own right. This subsequently throws into question the role of design and the designer, in relation to the role of the user, the design process and resulting product. Manzini's 1994 call to arms, *Design, Environment and Social Quality: From "existenzminimum" to "quality maximum,"* questions designs role in a world in crisis. He calls for designers to act within three proposed consumption scenarios (1994, 40): transforming from consumption of products to "Care," "Utilization of Service," and "Non-Consumption." Design behavior, activated through these lenses, aims to instigate "a new way of

behaving or of viewing the world". In order to expand the "vision for fashion design" to engender behavioral change around "the consumption, wearing and using of garments", and subsequent systemic change in "the systems in which the wearing and using occurs" (Rissanen 2013, 160), we need to shift the role of design from the creation of products to the facilitation of social and political change.

The fashion industry is currently built around ideas of the designer as expert; the keeper of specialist knowledge that informs a creative practice. Design students are often presented with visions of the fashion designer as "somewhere between rock star and artist, designing mainly with a sketchbook and directing a group of able production people" (Blomfield and Trade 2002). While other fields have moved beyond this mentality the fashion industry largely remains locked in a twentieth-century understanding of the role of the designer. In his 1990 book *Technocracy and the Politics of Expertise*, Frank Fischer describes "…the ways in which expert knowledge and technocratic practices have become key political resources sustaining increasingly undemocratic forms of decision-making" ("Review: Technocracy and the Politics of Expertise" 1992). According to Torgerson (1992), Fischer proposes "a radical democratic alternative which would wed expertise with an active public". While Fletcher's craft of use engages with this "active public" and poses an alternative to Blomfield's technocratic "designer as rock star" model, it leaves room to explore more democratic relationship between expert and user.

Democratising the design process: tools and facilitation

Democratisation of the design process hinges on the redistribution of design knowledge and creative agency. In order to move from a technocratic to a democratic model of design, the notion of creativity must be explored from the perspective of the user. Sanders and Stappers (2008, 12) observes *Four Levels of Creativity*: doing, adapting, making, and creating. Ranging from wanting to "get something done" to the more explorative aim of expressing creativity, of importance is that "expertise, interest/passion, effort and returns grow with each level." Through this desire for creativity in ordinary life, users can become part of the design team, but "they must be given appropriate tools for expressing themselves" (2008, 12). This echoes the wedding of expertise and active public proposed by Fischer, suggesting that the role of the designer in transforming the passive consumer into an active participant in the design process is one of facilitation and scaffolding through the provision of cognitive tools.

Matt Ratto (2011) proposes critical making as a hinge between a conventional model of designer, maker and user, and an understanding of the designer-as-maker, or user-as-maker. He states that critical making focuses "on making practices themselves as processes of material and conceptual exploration… it is the making experience that must be shared." The sharing of the action, knowledge, and tools of the making process opens the way for a more democratic creative process, allowing the user to actively create

"novel understandings". The exploration of the intersection between *craft of use* and ZWF design redefines the roles of designer, producer and consumer, sharing the making process by repositioning the consumer as both maker and user, and empowering them with creative agency. Both Sanders and Fischer propose a need for tools that scaffold this experience, enabling it to generate new understandings and engender new modes of behavior.

Open design: unfinished things and wayshowing as an open system

Cameron Tonkinwise (2005), in *Is Design Finished?*, suggests that we need to reframe design entirely and stop designing mere "things". Instead, we should be designing "how things thing." He issues the challenge that we "design timely things, things that can last longer by being able to change over time" or that we design unfinished things, "things in motion"(Tonkinwise 2005, 6).

The proposal to design unfinished products is further explored by Fuad-Luke in "Ways of Making" (2009, 95) which target the over-consumer. According to Chapman (2005), stories help develop the desire to hold onto things; a notion that was tested by Fuad-Luke and Anya Herscher in a fashion context in *Half Way* (in Niinimaki 2013). *Half Way Products* are produced incomplete for finishing by the consumer, where mistakes become part of the narrative of making and owning. Workshop participants determine their level of skill and involvement and are supported to modify, make, or design a prepared garment style.[4] This approach transforms a passive relationship between the consumer and ready-to-wear garment into one where the consumer becomes active in the design and making of their garments. Another example of open garment design is the *Post-Couture* project (van Strien n.d.). Targeted at a non-fashion-specific "maker culture," their approach simplifies the making of a garment so that it requires no stitching, and provides the garment files for download and production at a "maker-space" anywhere in the world. Aimed at democratising the making process, it does not open the design of the garments to ordinary users.

A building or city can be seen as something activated by the user or inhabitant. "Wayshowing," a system of design elements that facilitate "wayfinding," is "the process of using spatial and environmental information to navigate to a destination" (Lidwell, Holden, and Butler 2003, 260). Per Mollerup's (2006) *Wayshowing: A Guide to Environmental Signage* clarifies the relationship between *wayshowing* as design output, and *wayfinding* as intended user experience. In this manner, *wayshowing* can be considered an open system that is designed to be interpreted or completed by the user. The term *wayfinding* is most commonly associated with the disciplines of urban planning, architecture and landscape design, and their intersections with visual communication design. Popularized by Kevin Lynch's (1960) in *The Image of the City*, this was expanded by Romedi Passini (1984) in *Wayfinding in Architecture*. Lynch (1960) describes

the process of finding one's way as having four phases: *orientation, route decision, route monitoring*, and *destination recognition*, while spatial cognition is aided by five key elements: *paths, districts, edges, nodes,* and *landmarks*. When successfully laid out and comprehended, these facilitate the legibility of a city, or "the ease with which its parts can be recognized and … organized into a coherent pattern" (Lynch 1960, 2). In attempting to develop an open design system, we explored the application of spatial wayfinding to the process of garment transformation, attempting to translate Lynch's city-image to one of garment-image, whereby the garment parts can be easily recognized and organized. Wayshowing/finding is generally considered in an environmental rather than object-based context, so this may seem somewhat of a leap, but as suggested by creative pattern cutter Julian Roberts (2013), a garment can be considered a space for the body to pass through. Rather than merely transposing the concept of wayshowing onto the creation of garment-as-object, the research shifts towards this notion of garment-as-space. This reveals a new, transdisciplinary, understanding of the zero waste garment that underpins *Make/Use v2*.Discussion of research

Overview

The *Make/Use v2* research outlined below was conducted through a period of in-house testing and development, followed by test workshops with volunteer participants. This shaped the format of a series of public workshops, first delivered as part of a month-long exhibition and residency at Objectspace Gallery in Auckland, New Zealand, and since, at various locations worldwide.[5] While the intent was to develop a series of standalone UMZWF patterns that could be openly shared with users, it became clear that we needed to design both the system, and the means for understanding and disseminating it. The discussion is structured around three such participatory experiences: an initial in-house test is used to set up the basic concepts and problems with using the printed pattern to create the garment form, the "Flat-to-Form" workshop illustrates the use of the *embedded wayshowing system*, and the "Your Style" workshop helps to demonstrate the further potential of the customizable *zero waste matrix*.

The collection of *Make/Use v2* prototype garments and patterns consists of seven garment forms: Crop T-shirt, Long T-shirt, Long Coat, Wrap Dress, Tube Dress, Skirt and Trousers.[6] The concepts that enable making/using are most easily illustrated in the *Crop T-shirt* (Figure 2).[7] The foundational garment used to develop the Make/Use systems, it provides a relatively low level of complexity and a recognizable garment typology. The pattern is derived from a minimal waste pattern often referred to as the Bog Coat, that can be traced back to at least the Danish Bronze age (Burnham 1973). It has been explored by numerous historians and designers over time because of its simplicity, efficiency and versatility.[8] The basic modifiable *Make/Use* t-shirt pattern was developed through *Make/Use v1* and *v2*. Beyond creating the basic t-shirt form, embedded in this pattern

Figure 2
Make/Use Crop T-shirt print on left and form shown on right. Digital File by Holly McQuillan, Photograph by Bonny Beattie.

are four possible groups of modifications (Figure 3). In combination with three choices of neckline offered, the options embedded within the *Make/Use Crop T-shirt* create 48 possible permutations from a single pattern.[9] This pattern became the testing-site for the *embedded wayshowing system*, and was the site of discovery of the underlying parametric system that developed into the *zero waste matrix*.

Initial "in-house" workshopping

User testing of the textile print as navigational system in *MakeUse v1* revealed its complexity and the need for either verbal explanation or a key to decode the instructional print elements.[10] Most elements referred to a corresponding action, such as "cut and separate" or "cut and fold back" (Figure 4). One example referred to a means of orientation: a "guide" line, indicating center front or back of the garment. Upon analysis, a lack of consistency in the visual instructions was noted, as was a lack of hierarchy. These early tests suggested the potential of the embedded instruction concept, and a need for further development, both in terms of its functionality and legibility as a system, and its esthetic as a textile print.

Initial *Make/Use v2* testing further explored the use of coded cut lines and matching symbols as clues to the "completion" of the garment. These in-team tests involved the garment-form designer presenting two other team members with a paper prototype of the Crop T-shirt pattern, with no instruction. Despite having knowledge of the basic pattern and modification concepts and being proficient in three dimensional form design, they were unable to successfully transform the paper "flat" into the intended garment "form" without additional guidance. An example of feedback

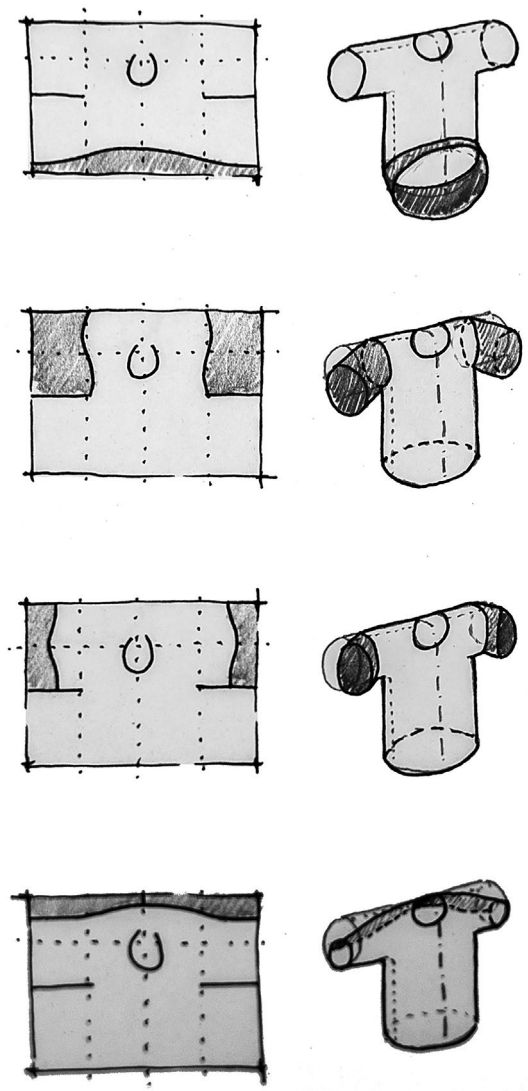

Figure 3
There are four basic modifications possible from the Make-Use Crop T-shirt print. These are: body volume rotation, armhole volume rotation, sleeve volume rotation, and sleeve taper swap. Illustration by Jen Archer-Martin.

loops and "fast failure," this test highlighted the existence of a procedural hierarchy which had not previously been visible to the ZWF expert due to it being innately, rather than explicitly, understood. This prompted a search for visual hierarchy to communicate multiple levels of instruction within the textile print, as well as attempts to clarify and articulate the underlying geometric logic.

Subsequent tests looked to find a coherent synthesis between the existing visual languages of cartography and pattern-making. Issues arose with the inherent incompatibility of coded systems that have been developed over time within specialist disciplinary fields. This may be exemplified by the dashed line, which could be variously interpreted by the different spe-

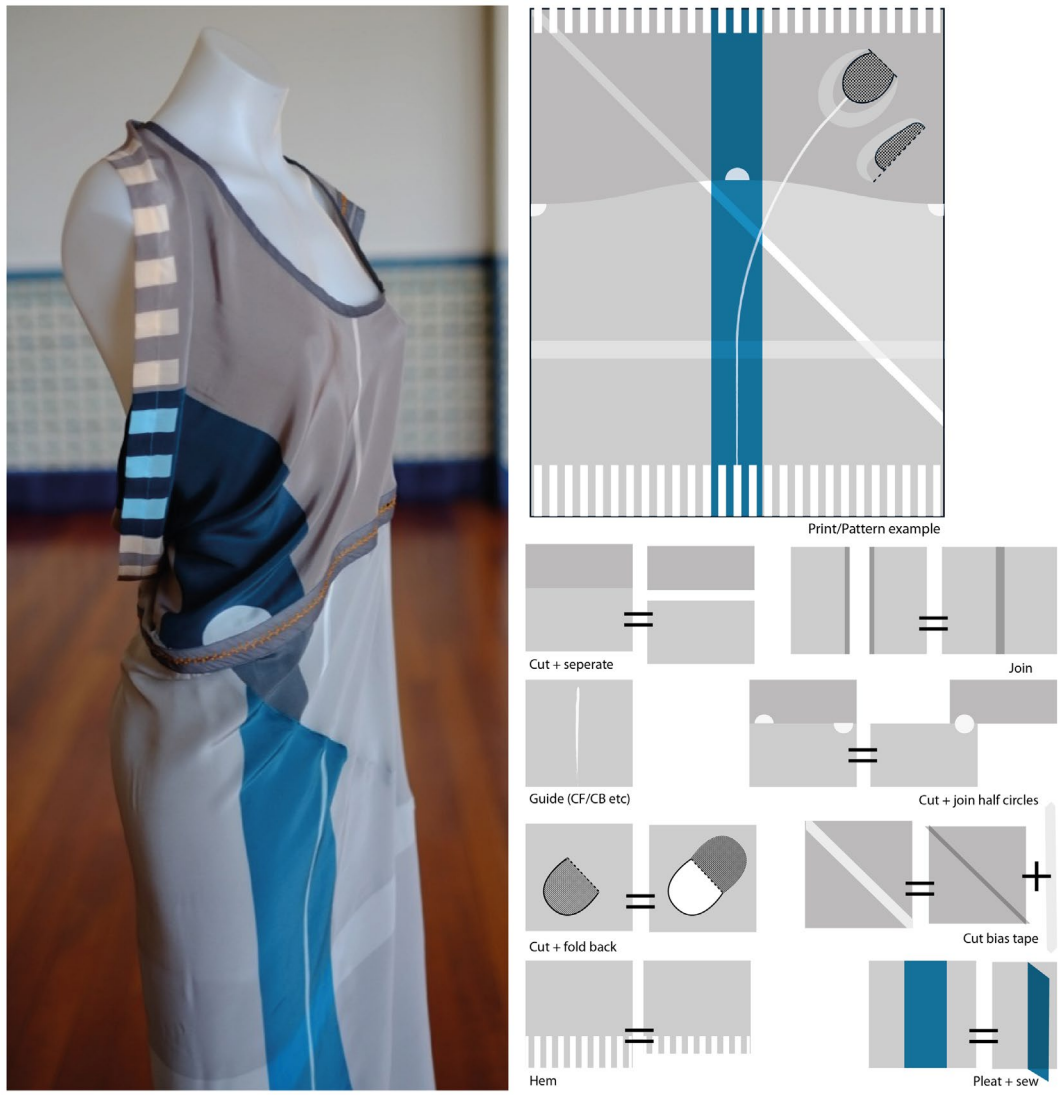

Figure 4
Make/Use v1 Tube Dress design with key demonstrates early instructional/wayshowing print experimentation. Photograph and illustration by Holly McQuillan.

cialists as a seam, fold, cut, perforation, grid line, route, or the delineation of an object "behind" or "above." While attempting to use different line types, weights, and colors to denote all of the instructions required in one pattern to create multiple possible garment forms,[11] it became clear that the inherent complexity of this codification still required either verbal explanation or a key . This was considered a failure to liberate the creative act from overly coded technocratic understanding. It became clear that

what was required was not simply a set of instructions for *making*, but a set of cognitive tools for *understanding*.

In attempting to simplify the navigational system in order to develop these tools, it was realized that the complexity resulted from both the mode of visual communication, and the design of the garment itself, including the number and nature of embedded modifications. This led to an analysis of the pattern design and modification system, clarifying the key volume-creation concept and uncovering a simple underlying organizational system. Secondary paper pattern testing confirmed that these two things helped to cognitively support successful form creation. First, visualizing the basic T-shirt as two conjoined tubes created by joining parallel edges (Figure 5), aided understanding of volume-creation as a simple wrapping from flat plane to cylindrical form. Mapping these "arm" and "body" tubes onto the flat fabric reveals the organizational system, a 12-zone matrix that anchors the pattern and textile print (Figure 6) relative to both fabric and body "zones": left or right, front or back, "sleeve," "shoulder," and "body."

These findings impacted on both the textile print design and the development of the garment forms themselves, illustrating the interdependence of the *embedded wayshowing system* and the *zero waste matrix*. The matrix underpinned the liberation of the textile print from having to communicate complex instructions, allowing the research to explore more open methods of communication that focused on affectively supporting the creative process of the maker/user.

"Make/Use: flat-to-form" workshop

With the difficulty of the previous iterations presenting a barrier to the participants in both successful completion of the task, and confidence in doing so, we sought to understand how the textile print might support the creative process both cognitively and emotionally. It was acknowledged that the fear of "getting it wrong" when decoding complex instructions, implied that the "right" answer was gate-kept by the designer. In contrast, the intent was to foster an open-ended collaboration between designer, maker/user and textile that empowered the maker/user to actively make design decisions, affording them creative agency. If the designer or expert is not present, this agency hinges on the relationship between the textile and the maker/user. The concept of wayshowing became useful here in the sense that wayshowing is a series of navigational cues or signs left in the landscape for the wayfinder to follow. This prompted the reimagining of the instructional print as an *embedded wayshowing system*.

Unlike wayfinding at the landscape scale, which may be supported by a map, the zero waste textile is both map (*flat*) and landscape (*form*). A proposed shift in focus from print-as-map to textile-as-landscape sought to offer more opportunities for intuitive wayfinding rather than instruction-following. Hiking through a landscape with different levels of perceived navigational information was adopted as a spatial analogy for

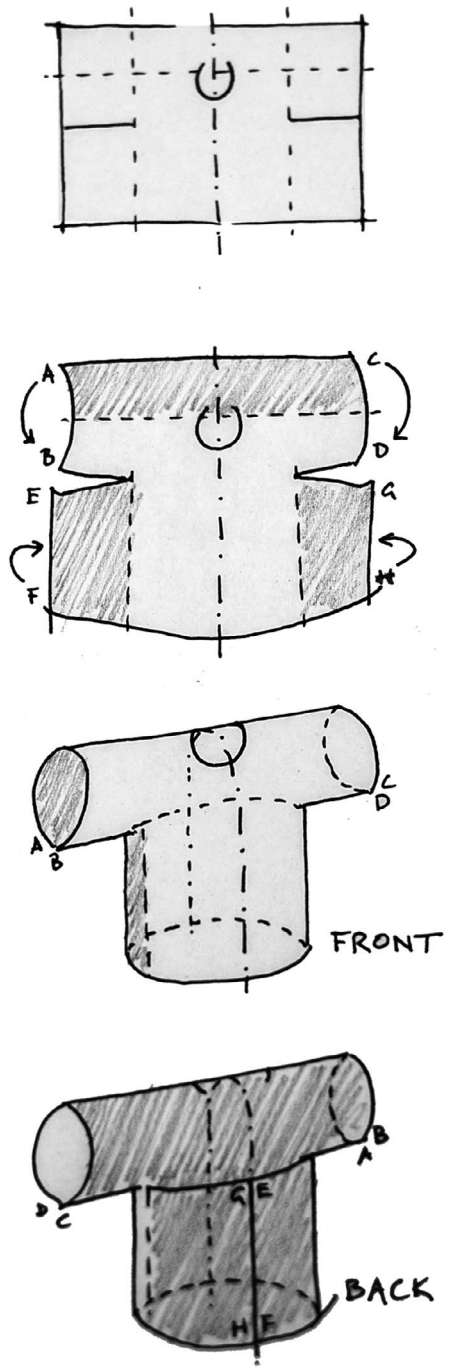

Figure 5
By making three simple cuts, two from either side of the fabric and one cut for the desired neckline the basic T-shirt form is able to be created. Illustration by Jen Archer-Martin.

visual hierarchy. At a basic level, the inexperienced hiker can follow a predefined path and signposts. A more seasoned hiker might follow less obvious paths or rely on general orientation and the occasional route marker.

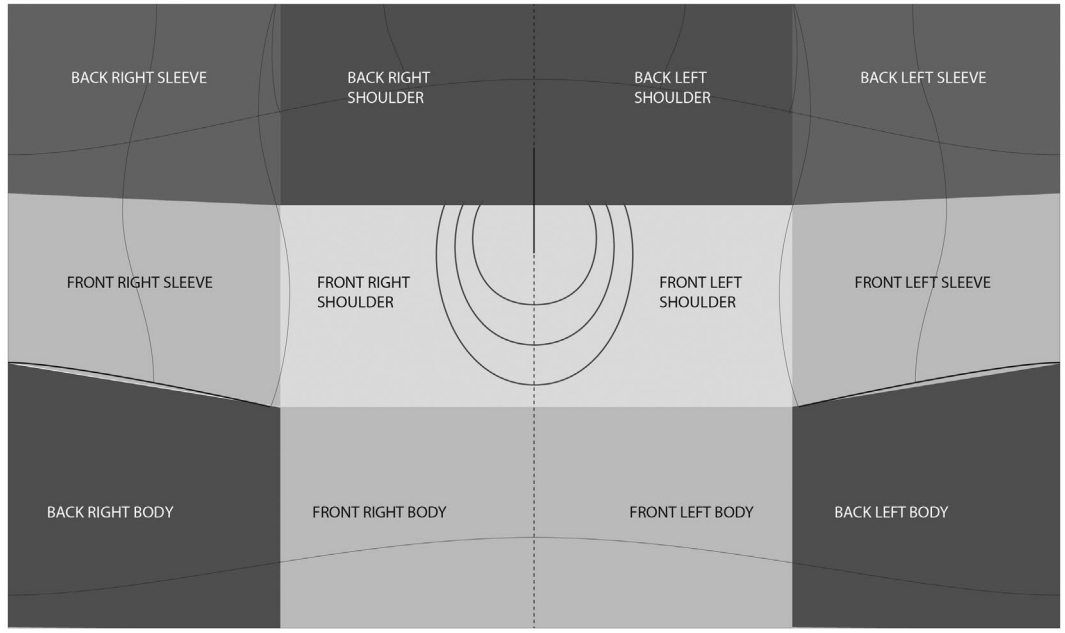

Figure 6
Twelve zone matrix with body zones mapped onto the surface. This facilitates an understanding of the relationship between 2D fabric and body for the maker/user. Illustration by Holly McQuillan.

An expert might find their own way, able to read less visible cues in the landscape. Within this fabric-landscape analogy it became possible to describe multiple levels of information that existed simultaneously, without having to be immediately visible, or explicitly understood. If not essential to the immediate creative or cognitive process, the information would remain a part of the background print. It was proposed that this system of emergent information might combat the overwhelming experience of deciphering multiple encoded instructions in the textile print.

The resulting wayshowing system borrows from Lynch (1960) and consists of four levels of emergent information—*orientational cues*, *primary paths*, *secondary paths* with supplementary *rotational cues*, and *route markers*. In the Make/Use "Flat to Form" workshop, these emergent levels were first explored haptically by making an A4 paper version[12] of the Crop T-shirt (Figure 7). After being shown a diagram of the T-shirt pattern and the finished garment, participants were invited to create a paper model of the basic T-shirt form from the printed paper. Participants were then able to use *primary paths* (clearly marked essential cut lines) to begin the form creation process. In the T-shirt pattern, only three essential cuts need to be made: two cuts that separate the fabric of each side of the "sleeve tube" from the "body tube," and the neckline (three style options were available). It was found to be helpful to describe the T-shirt as a horizontal tube for the arms/shoulders/upper torso and a vertical tube for the body and

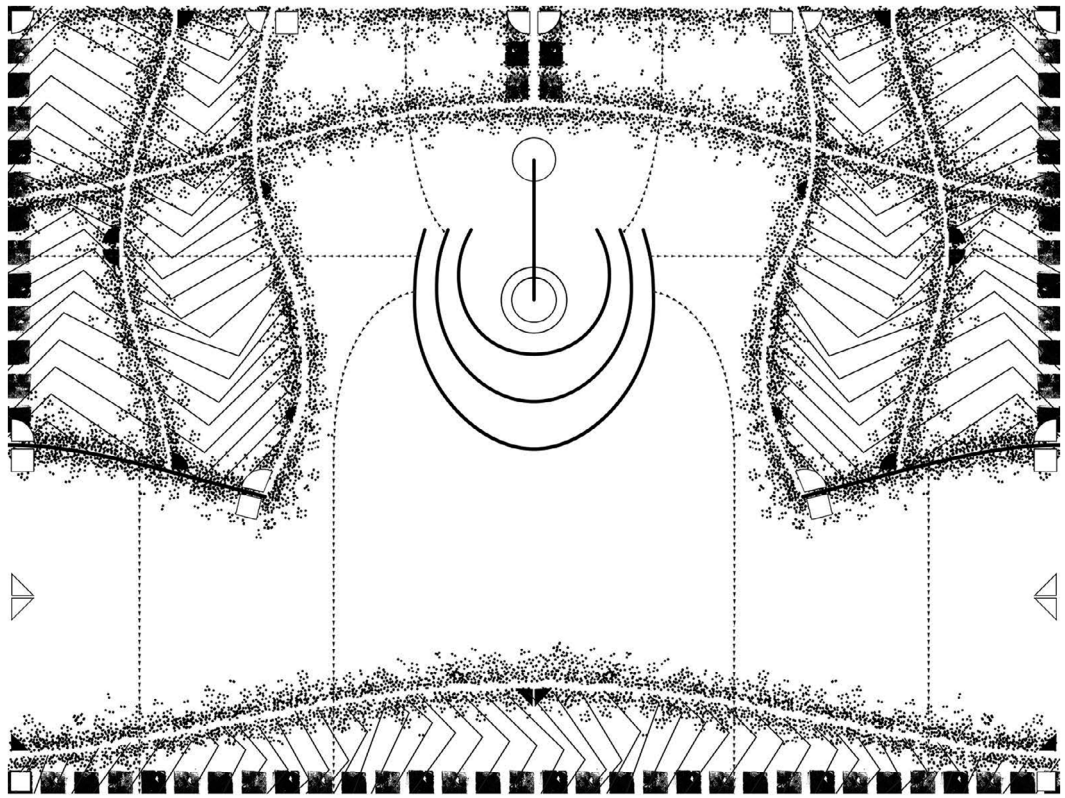

Figure 7
A A4 scaled paper copy of the textile print was provided to the participants to practice making the garment. Textile Design by Greta Menzies.

to give a brief demonstration of this concept. Two elements in the printed paper pattern further aided in the task. *Orientational cues*, including recognizable "landmarks" like the neck hole, and directional marks that suggest the flow of gravity from the high point on the body to lower or outer edges/hems, helped participants to locate the "body zones" on the flat fabric. Once participants located the neckline they were able to cognitively position the body inside the garment, guided by the gravity cues. The research has found that the latter are particularly useful in zero waste pattern cutting, where the various zones of the pattern are contained within the same piece of fabric, but in multiple orientations that can be difficult to understand until they are on the body. This combination of cues helps the maker/user to read the neckline as the high point in the pattern, combating the common tendency to read the uppermost edge as the "top."

Once this first stage of volume-creation is successfully completed, participants were introduced to the concept of volume manipulation, central to the Make/Use ZWF pattern cutting methodology. This was achieved through a brief demonstration of the concept, in which a tube cut

diagonally and rotated 180 degrees forms a bent tube. Translated into fabric, this creates more volume on one side of the tube, and lifts the hem on the other. In the same way that the delivery of this information was done in stages, the supporting navigational aids in the pattern are given visual hierarchy. *Secondary paths*, or cut lines for manipulating the volume, are expressed as edges between zones where the background print becomes denser, rather than as clearly marked paths or lines. The rotational movement required to make the modification is supported by the print, with a directional pattern of *rotational cues* such as chevrons sitting "behind" the other visual information as a background to the textile print. Participants were not overwhelmed with this information in the first step, as the secondary information is integrated with the background pattern of the print in such a way that it emerged once the participant was ready to focus on it.

Lynch (1960) describes route monitoring as supporting the route decision-making process. This is achieved in the *Make/Use* textile through the considered placement of visible symbols, or *route markers*, at points that needed to be connected in order to complete the transition to three-dimensional garment form. The lineage of these symbols can be traced to pattern-making conventions, and can be seen in proto-typical form in *MakeUse v1*. The simple symbolic system, devised by the visual communication designers within the team, used basic geometric shapes that require little decoding, and became part of a multi-modal dynamic visual system for the wider *Make/Use* project. Returning to the spatial analogy of hiking in a landscape, the symbols resemble the route markers placed at intervals along a trail—high-visibility messages of reassurance that one has not gone too far astray. Matching the symbols facilitates the creation of the garment form and provides positive visual feedback that gives the participants confidence that they are "on the right track," validating their creative decisions.

Participants had varying degrees of success with grasping the basic form creation and customization but quickly learned from each other in the workshop setting, using the wayshowing print as a guide.[13] The set of navigational cues that make up the *Make/Use embedded wayshowing system* act as scaffolding that supports the learning maker-user to explore further as their skill and confidence grows. Forming a layered visual system that takes the raw textile as its base, the cues emerge from the background of the print as required. This open-ended system acts mutually with the maker/user to build their agency, initially shielding them from complexity while gradually unlocking new understandings and more complex garment forms, rewarding those who are ready to look beyond the more basic visual guides. The requirement for explicit guidance decreases as the agency of the maker-user increases and they feel comfortable to ignore the markers and create their own garment forms, leaving the landscape open to affective interpretation. This was demonstrated in the workshop when participants were given a full-size fabric version of the Crop T-shirt to work with. While we anticipated multiple variations of the 48 possible garment permutations contained within that pattern, the openness of the system

Figure 8
An example of the variations participants produced from the same T-shirt pattern, some followed the guidelines, others deviated from planned modifications (center). Photograph by Bonny Beattie.

was further illustrated in the unplanned modifications some maker/users chose to make (Figure 8). The observation was that the participants were afforded the conceptual understanding, confidence, and "permission," not only to do, adapt, or make, but to create (Sanders and Stappers 2008, 12).

"Make/Use: Your Style" workshop

While user testing of the *Make/Use* Crop T-shirt showed that the *embedded wayshowing system* was successful in facilitating cognition and creative agency, it was clear that this success did not occur in isolation. The underlying geometric concepts that were clarified in order to both refine the system and explain how to use it began to emerge as a new way of understanding and teaching zero waste design. It became evident that this was a central innovation rather than a byproduct of the process, leading to the development of the *zero waste matrix* and a "grid and template" system (Figure 9). These were tested through a second workshop typology—"Your Style"—in which participants could bring their own fabric and customize a Make/Use pattern. In discovering this underlying logic, we found a solution to a key critique of zero waste patterns, which is the lack of flexibility regarding fabric width due to the pattern being directly

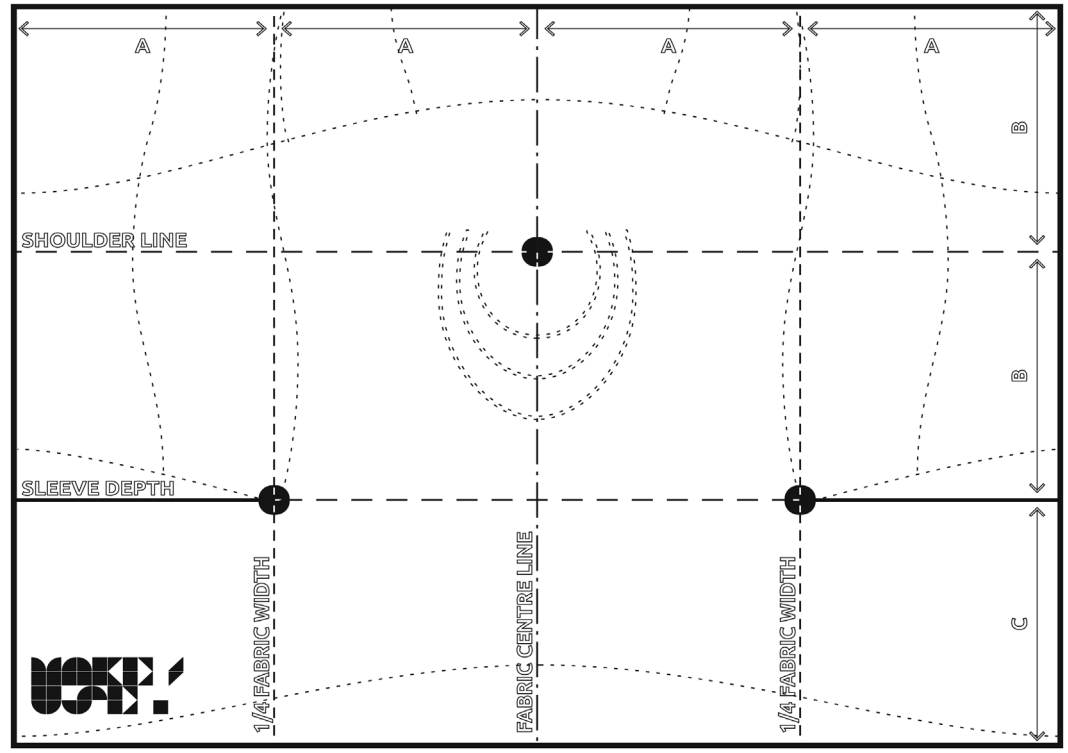

Figure 9
Make/Use Crop T-shirt grid. This works in tandem with the templates (see Figure 10) to determine placement of the garment design features (such as neckline) at the intersection of the horizontal and vertical guidelines. The guideline placement is determined by the user's fabric width, body size and designers design outcome. Illustration by Holly McQuillan.

informed by the size of the piece of fabric. In an industry in which there is no global standard for fabric width, this is problematic. The Make/Use workshop planning encountered the same issue—while fit variations were possible within a single printed pattern, the extent of these was governed by the size of the cloth, meaning that participants desiring a larger fit had to make additional modifications, such as opening the T-shirt at the front to make it a jacket.[14] If participants were to work with different width fabrics, a system was needed to easily adjust the patterns without the expert having to recreate a full custom pattern each time. This redesigning was both unfeasible in the time available, and undesirable in that it would place technocratic and creative agency back into the hands of the "expert," disempowering the maker/user.

The *zero waste matrix* might best be described as the ZWF equivalent of the fashion "block." Conventional blocks are based on a complex matrix that translates the basic 3D garment form, as it relates to the body, onto the 2D plane. Each block corresponds to a specific "standard" body size, shape, and gender. The body is divided into front and back, with joins commonly at the shoulder and side body, creating separate pieces that are

then flattened to form the block. This is then used as the base from which to generate patterns for different garment designs. This approach is limited in its consideration for the cloth used, with placement onto the fabric of pattern pieces for various designs differing in the pattern cutting process. In contrast, in ZWF pattern cutting it is the direct relationship between the "block" or pattern base and the fabric that determines the cut of the garment. While many ZWF designers exploit this relationship to great effect, the challenge of modifying a zero waste pattern to another fabric width or garment fit/size can be difficult for even an experienced pattern cutter. For Make/Use, the need to cater for both novice and expert users amplified the problem. An ideal solution would see the pattern, including embedded modifications, adjustable to suit both different sizes/fits and fabric widths.

The *zero waste matrix* was utilized during the workshops in two ways. The first was to explain the underlying geometry of the pattern, and aid comprehension of how the different zones of the flat pattern map to the garment form. The second was the development of the "grid and template" system which formed the main focus of the "Your Style" workshop. In this workshop, participants began with the same paper-modeling exercise as outlined in the first workshop. It was found that starting in this small-scale and informal way reduced the trepidation about cutting into cloth, and allowed participants to gain confidence and understanding through the benefits of the printed wayshowing system. Rather than an exercise to understand the wayshowing, this became an exercise that used the wayshowing to understand the principles of Make/Use flat-to-form volume creation. Then participants were instructed in how to adapt their own grid using custom parameters. While in this workshop, the participants were able to choose to make any garment from the full Make/Use collection, the Crop T-shirt will again be employed here to illustrate the properties of the matrix and the generation of a custom grid and garment pattern.

The 12 zones of the T-shirt pattern are defined by a 4 × 3 grid.[15] In its simplest form, four equal sections across the width of the fabric relate to the garment/body circumference (equal to full fabric width) and sleeve length (equal to a quarter of the width). Of the three vertical sections, the top two are equal and the third variable; the top two rows define the sleeve depth (the top row wrapping backward to form the back of the sleeve and shoulders), and the third, bottom, row makes up the remaining length of the garment (see Figure 9). The width parameters (fabric width, shoulder width + sleeve length, and body circumference) are thus interrelated, as are the length parameters (fabric length, garment length, and sleeve depth).[16] Working backwards, participants were able to measure their desired garment/body circumference to determine their choice of fabric width and the sleeve length relative to their shoulder width, and mark out the vertical divisions on their fabric. How long to cut the fabric was determined by measuring their desired garment length, and adding the desired sleeve depth, then using these dimensions to mark out the horizontal divisions. Participants then had a marked-out fabric "block," customized to their fabric and desired fit, on which to lay out the desired templates.

Figure 10
Templates for design features shown here are laser cut from recyclable card but can also be printed onto standard A4 or A3 paper if a laser cutter is not available. Both file types are available for download from www.makeuse.nz and include instructions for their use. Photograph by Timo Rissanen.

The flexible parametric grid is only useful if the pattern can be easily adjusted to fit it. To this end, we separated out each element of the pattern-cutting options into separate templates (Figure 10). These modular templates were tested in an analog fashion for the workshops, and are also provided in an open-source digital form. For the Crop T-shirt, six basic template sets existed, each with multiple options: necklines, body rotations, sleeve rotations (elbow), sleeve rotations (shoulder), sleeve-shoulder tapers, and sleeve-body tapers. To achieve the most basic garment form, participants selected a neckline and used the corresponding grid intersection to position it, followed by making the three essential cuts (neck hole and sleeve/body separation). Other modifications could be added as desired by locating the templates at the grid intersections. Once marked out and pre-finished,[17] these could then be activated in the initial garment creation, or at a later date. As with the printed textile version of the garments, any cut or modification can always be unstitched and "reset" in order to select an alternative. This both allows for ongoing adaptability, and relieves some perceived pressure about making the "best" choice the first time.[18]

The *zero waste matrix* proved to be a breakthrough innovation, allowing any fabric to be made into any *Make/Use* garment design with any form variation and modification applied. In the short duration of a standard six hour Make/Use workshop, participants of varying skill levels were able to design and make their own custom versions of the Make/Use

UMZWF garments. This has exciting applications beyond the workshops and is already available as an open-source system on www.makeuse.nz, along with the digital print files for the *embedded wayshowing system* versions. However, a number of limitations remain. One is that the textile print design is not yet adjustable, and so cannot be used in conjunction with the parametric grid. This is an area for further research and development. Another is the recognition that these solutions do not fully satisfy the original aim of the research, which was to encode the instructions for garment form creation into the printed textile so that a user could make and modify the garment without supplementary instructions. It is acknowledged that the majority of testing occurred in a workshop setting, where we took the participants through the key concepts and processes, and were there to troubleshoot. This does not offer a comparable situation to the proposed home user experience, where the user might access the garment patterns or order a digital printed textile through the Make/Use website, and work through the process alone. This is addressed in part by the supplementary material available on the website, which is intended to be further developed and instructional videos added. It is believed that these aids need be introductory only, and that once users understand the basic concepts they are able to find their own way through the textile-as-landscape.

Conclusion

With the fashion industry in crisis, producing unsustainable volumes of waste, zero waste garment design and construction provides obvious advantages. However, we identify two current key issues with ZWF: its perceived complexity and inaccessibility, and its inability to effect significant change when considered in isolation from consumption to use. Make/Use pursues a re-examination of the goals of ZWF design, extending its application and impact through integrating new understandings of how users might engage with zero waste garments. Borrowing from Fletcher's notion of *use practice*, we explore how people might make and modify their own zero waste garments, empowering them to engage with both the production and use of their clothing. As demonstrated by Make/Use v1, ZWF garments provide inherent opportunities for ongoing modification due to the whole cloth being retained, giving them the ability to be "reset" and remade. We initially set out to test whether this process could be facilitated by embedding multiple options for making and modifying the zero waste garment, along with codified instructions, into a pattern digitally printed directly onto the fabric. While it was proposed that this would remove the need to translate between conventionally separate elements of fabric, paper pattern, and accompanying instructions, thus simplifying comprehension, user testing revealed that complexity in decoding the various elements of the instructional print remained a central barrier to engagement, despite the overall success of the embedded modification options. Contrary to the aim of placing creative agency back into the hands of clothing users, this reinforced the perception of ZWF as technocratic.

Aiming to democratize access to ZWF, enhance user connection to the garment and increase both its functional and desirable life span, Make/Use v2 brought together a larger interdisciplinary team to explore how the printed pattern might better support users to understand, make, and modify, while simultaneously creating a desirable textile print and garment. Early unsuccessful testing of a symbol-based visual language was revealing: cognitive understanding of the process of transforming the flat pattern into garment form required more than a clever system of "encoded" instructions. For a start, relying solely on a language of lines and symbols to communicate multiple options and actions made the "reading" of that language an additional hurdle for the maker/user to overcome rather than reducing the number of cognitive leaps to be made. A better visual hierarchy was needed to guide the maker/user through the stages of the making process. Understanding the garment as a spatial form, the fabric was reconceptualized as both "map" and "landscape", and ideas of spatial wayfinding more often applied to cities was used to create a framework for embedding navigational cues. This *embedded wayshowing system* aimed to support users both cognitively and affectively, reducing intimidating visual complexity and attempting to instead support intuition. The development of the Make/Use v2 T-shirt print employed a strategy that turned a simplified logic of volume-creating "moves" into multiple layers of emergent visual information.

This printed textile was successfully employed in the Make/Use v2 workshops. Participants made essential moves to transform flat to form by following visually obvious primary cut paths, supported by a sense of orientation provided by recognizable landmarks like the neck hole, and directional cues in the print background suggesting how the fabric might fall when orientated to the body. Participants were then enticed and supported to make creative decisions about secondary modifications by looking for less obvious visual cues in the print. A relationship between the maker/user's readiness to look for these cues, and their "emergence" from the visual field of the print, was observed. Matching symbols/markers provided the reassurance required to start joining edges together to build the garment form. Together, this series of cues both cognitively supported understanding of the flat-to-form transformation, and affectively supported maker/users to feel as though they were "on the right track." Furthermore, the open-ended ambiguity of the print empowered more adventurous participants to re-interpret the options for modification beyond those provided. Rather than all participants reaching the same destination, the resulting variation of emergent garment forms evidenced the openness of the process as a collaboration between designer/facilitator, textile/facilitator, and maker/user.

Despite the success of the *embedded wayshowing system* in facilitating an empowering collaborative encounter with the textile, it was recognized that the textile print was not able to fully remove the need for verbal or other support. Test workshops prompted a rethinking of this system, not as the primary research outcome, but as a tool for

supporting initial engagement. With the community of maker/users engaging in democratic knowledge-sharing growing, it became apparent that there was a bigger barrier to the democratic application of UMZWF: catering to this diverse community was problematic while the printed textile pattern was still constrained to the dimensions of the cloth. To cater for a variety of participants, sizes, and fabric widths, the system needed to be made more flexible. The Make/Use *zero waste matrix* emerged as a solution. Translated into a grid and template system, the matrix allowed participants to modify the garment design in relation to the fabric width. In workshop testing, participants successfully created their own grid using custom parameters, then located templates for garment elements onto this grid to create bespoke ZWF patterns, with embedded modification options as desired. Beyond this proof of concept, we believe that this innovation can increase accessibility and flexibility of ZWF for the individual maker/user, regardless of skill level, and pave the way for more widespread uptake of zero waste construction in the fashion industry.

Following successfully prototyping and testing via the Make/Use workshops, both the digitally printed textile with *embedded wayshowing system* and the customizable grid and template system based off the *zero waste matrix* have been made publicly available as a set of open-source tools for User Modifiable Zero Waste Fashion (see www.makeuse.nz). However, research is ongoing. A more comprehensive qualitative study on the empowerment of the maker/user through the wayshowing system, and a quantitative study of the reduction of waste in use through the hypothesized extended life cycle, are required. The grid and template system is currently analog and lacks the visual support offered by the wayshowing system, while the textile print is not yet flexible. At present the wayshowing print acts as a "cognitive tool" that enables comprehension of the system, with people then moving on to the more flexible forms possible through the grid and template system. This points to the need for further research and development of a digital composite of both systems, whereby the parametric grid locates both garment features and print elements to generate a flexible and comprehensible "flat" from any width fabric, that can be made into a "form" for a wide range of bodies. It is at the intersection of these two systems where the research positions new territory for exploration, and forecasts development of a universal system for User Modifiable Zero Waste Fashion design.

Disclosure statement

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Notes

1. This concept for zero waste garments has been explored further in a textile context by Greta Menzies' Master of Design thesis "Conversational skins : heirloom 'pelts' that emerge and evolve" (Menzies 2015). G. Menzies was the textile designer for Make/Use.
2. Also known as a "sloper".
3. An unlined coat from Burda patterns (Burda, n.d-a) requires 250 cm of 150 cm wide cloth. While the *Make/Use Long Coat*, with a similar silhouette, requires only 150 cm of a 155 cm wide cloth. A pair of trousers from Burda (n.d-b) requires 230 cm of 140 cm wide cloth, while the *Make/Use Spiral Trouser* of a similar design requires 155 cm of 150 cm wide cloth for two pairs, or only 78 cm of 150 cm wide cloth if using a reversible fabric.
4. Fuad-Luke also proposes a model of "Modular Evolved Products" (2009, 101) where products are designed to be easily repaired.
5. Locations so far include: Dunedin, Wellington and Auckland, NZ; Los Angeles, San Francisco and New York, USA; London, UK; and Borås, Sweden.
6. See supplementary material.
7. As in all Make/Use garments, any excess neck or arm hole fabric is retained (featured as a flap or folded back and sewn to the adjacent fabric), allowing for future mending/resetting.
8. Tilke 1922; Balenciaga 1961; Telfer 2008; Rissanen 2013; McQuillan 2014 and many others.
9. Differences in fabric dimensions, placement of cut lines, volume redistribution, neckline and body shaping possibilities, color and textile print, and the potential for maker-users to create their own modifications, allow an infinite number of garment possibilities.
10. We noted other critiques, such as a high degree of difficulty finishing the edges. This was resolved in a range of ways such as painted or pre-embroidered edges through the research. These are not the focus of this paper.
11. See Bernard Rudofsky's (1947) *Are Clothes Modern,* page 146 for an early (1873) example of this approach.
12. As a cheap but inflexible proxy to cloth, participants are asked to scrunch up their paper and flatten it a couple of times to soften it so it behaves more like cloth.
13. As with the in-house testing, we found that guidance was needed in explaining the underlying geometry and sequence for a greater success rate. This is discussed in the conclusion.
14. The Make/Use Crop T-shirt for which the wayshowing print was designed will fit only a New Zealand size 8–12.
15. Seam allowances are not discussed here, but these can be allowed for in the calculations or resolved through alternative edge finishing and joining methods.
16. Adjusting the fabric width will change the body circumference, and shoulder width and sleeve length. Adjusting the fabric length and/or

the placement of the upper two divisions will change garment length and sleeve depth.

17. Prefinishing techniques explored in Make/Use ranged from simple analog processes to more complex specialty techniques and included digital embroidery, machine sewing, felting and hand painting using latex and house paint.
18. Assuming the esthetic impact of resetting is acceptable to the user.

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PAPER II

McQuillan, H., 2019. ‘Waste, so what ? A reflection on waste and the role of designers in a circular economy.’, *Nordic Design Research Journal.* Espoo, Finland, 8(8), Available at: http://www.nordes.org/opj/index.php/n13/article/view/485/456.

WASTE, SO WHAT?

A REFLECTION ON WASTE AND THE ROLE OF DESIGNERS IN A CIRCULAR ECONOMY.

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ABSTRACT

This paper discusses research currently being undertaken which addresses the interrelated volume, value and cost of waste and the responsibility designers have in its creation. The discussion utilises textile waste as an example however many of the problems that exist in the fashion and textile industry exist in other design fields, and it is possible that some of the ways of thinking discussed to address these problems will be transferrable. The paper begins by outlining the contemporary waste problem (in the fashion industry). Then utilising observations made during recent field tests – where I was invited by major brands to apply waste reduction and elimination strategies to existing designs ¬ I sketch out the impact that explicit and implicit design hierarchies and complexity have on waste minimisation attempts. Then I question if waste is actually a problem in the context of proposed Circular Economy (CE) models – after all if we have a CE then perhaps we can continue the status quo in terms of design (overproducing and generating excessive waste in production) because any waste can be put back into the cycle? Maybe the CE will let designers (and industry) off the hook? Lastly, I speculate as to what a fashion industry without waste might look like, discussing my ongoing design response to the issues raised.

INTRODUCTION

This paper discusses research currently being undertaken as part of a PhD in Artistic Design and addresses the interrelated volume, value and cost of waste, and the responsibility designers have in its creation. The discussion utilises textile waste as an example however many of the problems that exist in the fashion and textile industry exist in other design fields, and it is possible that some of the ways of thinking discussed to address these problems will be transferrable. The paper begins by outlining the contemporary waste problem (in the fashion industry). Then utilising observations made during recent field tests – where I was invited by major brands to apply waste reduction and elimination strategies to existing designs ¬ I sketch out the impact that explicit and implicit design hierarchies and complexity have on waste minimisation attempts. Then I question if waste is actually a problem in the context of proposed Circular Economy (CE) models – after all if we have a CE then perhaps we can continue the status quo in terms of design (overproducing and generating excessive waste in production) because any waste can be put back into the cycle? Maybe the CE will let designers (and industry) off the hook? Lastly, I speculate as to what a fashion industry without waste might look like, discussing my ongoing design response to the issues raised.

Things overrun our world. Many products are over-manufactured, never owned and so are waste through poor management, others are produced, bought, owned but sooner or later discarded. Many products are designed as waste, such as packaging, or waste as an inevitable outcome of manufacturing. As an example, the fashion and textile industry generates between an estimated 55 and 92 million tons (Kerr & Landry, 2017) of waste every year based on 2015 consumption figures. Within one year close to two-thirds of the material used to produce clothing becomes waste. Only 10% of this is currently recycled, with the remainder ending its life in the incinerator or landfill.

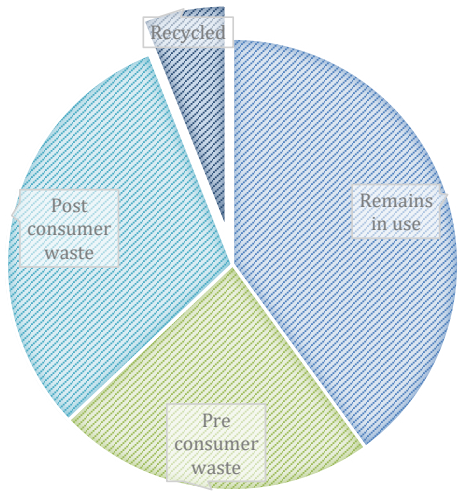

Figure 1: Raw material status within the fashion system after one year. Based on 2015 data (Kerr and Landry, 2017)

METHODOLOGY

This research program (Redström 2017) asks a seemingly simple question: What if we eliminate waste from the production of products? What could that look like in the context of the fashion industry? Employing an experimental and phenomenological approach, I have undertaken a series of iterative field tests and experiments in response to these questions, grounded by ongoing reflection (Schön, 1983) and analysis of available consumption and waste data. Through a lens which advocates for us to consider design as an act of future-making (Simon 1969, Yelavich & Adams, 2014) I have begun to craft an argument supporting the call for an alternative fashion industry.

REFLECTIONS ON DESIGN HIERARCHIES AND WASTE

The waste hierarchy asks that we first eliminate the production of waste and that all other approaches, including recycling, are secondary to this. It is common to consider waste an inevitable 'by-product' of industry and disregard the role designers play in its creation. However, it is important to remember that before it was waste, it was potential. Consider the garment: Fibre into yarn, yarn into cloth, cloth into a garment, at every stage materials are imagined and manufactured into existence – what we do with them, how we make them, how we utilise them – each step we transform them from ideas and materials with potential, to products. And waste – we design that too. If we consider design as an act of future-making (Simon, 1969; Yelavich & Adams, 2014), we have designed our reality and continue to generate the future. Nine years ago McDonough and Braungart in their seminal work Cradle to Cradle (2010) advocated for a redesign of the very notion of waste, however, our models of design, our society and industries continue to make a future consumed by both products and waste.

In this context, I was invited by two major fashion and clothing brands to work with their teams. In this section, I will discuss my reflections relating to the second, longer field test to demonstrate that when attempting to reduce waste within an existing business and production model there occurs a powerful – and lopsided – negotiation between resource waste and design outcomes.

Field Test 2: In 2016 I led a zero-waste design workshop with a large American sustainable clothing brand. In preparation for the workshop, I was asked to redesign an iconic mid-layer fleece jacket using zero waste design principles to demonstrate to the team what may be possible. I presented this design while hosting the zero waste design workshop with the product team who suggested changes to seam placement, such as moving seams slightly for reasons of function, taste or aesthetics. When making these changes, both large and small, efficiency and yield returned close to the original.

Later, the team decided to embark on another related project with me – redesigning a men's and women's technical fleece mid-layer. The project began "off calendar" meaning it would have a long development period, acknowledging the peculiar challenges this type of project faced. However, it was moved to be "on calendar" midway through the process, significantly reducing the time available to develop effective solutions. An iterative process continued back and forward for many months, with shifting explicit and implicit constraints playing an ever-increasing role in the decisions made. Despite the challenges presented through constraints, the designs progressed satisfactorily enough that the company arranged for the design and technical design team, and me to travel to one of their factories for a week of intensive collaborative work. This kind of at-factory design had never taken place in the company before, and in a short space of time, a significant amount of work and related breakthroughs were achieved. The outcome of this week was a working sample of both the men's and women's technical garments, with a significantly lower yield than the original. However once assessed by the wider team, and suggested changes to the aesthetic and fit of the design were actioned, the yield and waste were only marginally improved on what it was initially. The company is proceeding with this version of the garment. (McQuillan, 2019)

The key finding of this field test was the lived observation of the limitations that existing hierarchies of design impose when trying to reduce or eliminate waste

from the fashion design process. There exists a fundamental schism between design as an act of product creation and design as a simultaneous act of waste creation. Waste is considered a management problem that requires collection and disposal. For cut and sew garments waste is the parts cut off when making the desired/designed form and detail. It is emphatically NOT part of the design. Perceptions of fit, function, form, aesthetic and cost are considered exponentially more important. And yet, if design is not only what we design into existence, but also what we design 'away' (Tonkinwise, 2014), then the waste is also what we have designed. The problem is currently, where we only recycle 10% of textile waste, there is no 'away'.

We are content to design out adverse outcomes that do not have an impact of aesthetic, form, function, fit and cost. We use organic cotton, but only if it does not impact on cost or aesthetic. We specify for the removal of toxic dyes so long as the replacement is equally vivid and colour fast. We do not yet have a solution for non-toxic waterproofing, so we continue to use it despite its impact. Please, make it zero waste, but do not change any aspect of the form, fit, function, cost or aesthetic. We have designed the fashion system to prioritise almost all things above the environment we all rely on. The result is the world we live in now.

Through this research, I often ask myself: should 100% resource use in production be the ultimate goal? If the answer is an ideal yes, then we need to address expectations of aesthetics/fit of garments or develop new methods of design and production which eliminate waste while maintaining current expectations.

REFLECTIONS ON COMPLEXITY

In a 2017 report by the Global Fashion Agenda (GFA) (Kerr and Landry, 2017) industry workers identified the following barriers to sustainability; short-term thinking, siloed roles, resistance to collaboration, lack of company resources, among others. Contemporary industries tend to have complex supply chains, with materials sourced globally, and key actions and decisions made independently of others, often in different buildings, cities or countries, using different languages. How can we negotiate the various forces at play in the development of a design when a holistic approach is needed. A key observation from the first field test described was that the most rapid and successful period in the design and product development process was when many of the stakeholders were working together in the same space and time –when the hierarchies and silos were partially broken down.

The tightly controlled hierarchies governing who controls the design and the sequence these levers of control are used became very apparent in Field Test 1.

Field Test 1: was of short duration, lasting three days and taking place in Istanbul. I was asked by a large fast fashion company to work with a group of their freelance marker makers. The company are known for their efforts to reduce the negative impacts of their garments; however, they are a brand where high-volume, low-cost garments dominate. I worked with teams of marker makers on a specified existing dress design, exploring a range of approaches and small changes to the design in order to dramatically improve garment yield and reduce waste, without change of silhouette or critical details. In this context, we developed three different possible outcomes, one of which reduced yield for the planned style by 26%, by adding a single seam. These modified garments and markers were costed by the company, however, as the savings they would make on material yield, were outweighed by the extra cost of sewing the additional seam – because their cloth was so inexpensive – they were not implemented. (McQuillan, 2019)

The marker makers in this field test were experts at making pattern pieces fit efficiently into a lay plan, often performing much better than computer software. However, they had no contact with the designers or pattern cutters in this context. So any insights they had as to waste and yield reduction via changes to the pattern or design had no avenue for communication. This field test also speaks to a particular way of thinking that dominates our capitalist society and industry. Even if a design can be made more efficient in terms of material use, it needs to save money overall to be considered viable. So, how much fabric do we need to save for it to be 'worth' the human effort and financial cost?

When using a conventional production process, particularly within a high volume, low-cost context, reducing yield and improving waste does not seem a valuable investment in time and resources – especially if the material cost is not a significant part of the cost of a garment. The changes required to the profoundly ingrained system are too significant for them to be worthwhile unless there is motivation outside of a financial imperative. This observation is supported by an examination of Runnel et al. 2017 report on textile waste. Despite advocating for a somewhat radical rethink of the role and value of textile waste in the industry, the report still only attempts to address waste once it is made, not the prevention of its production through design. This is perhaps because doing this impacts on design systems, hierarchies in both design and production and potentially garment aesthetics.

I wonder: To what extent are industry and consumers willing to change?

REFLECTIONS ON THE CIRCULAR ECONOMY AND WASTE

If we have a circular fashion system then does that mean we can continue to overproduce and produce excessive waste in production because the waste can all be put back into the cycle?

Humans are impacting on the geological record to such an extent that the International Geological Congress in 2016 designated that we are now in the Anthropocene, despite the fact humans only account for about 1/10000th of the world's biomass (Bar-On, Phillips. & Milo, 2018). Yet the dominant business-led discourse around 'radical' developments such as the circular economy and circular textiles on the surface seems to suggest that there is little need to modify wider behaviour of consumers and business models because the 100% recycled circular economy will save us from climate oblivion. However, Fellner et al. (2017) and Brooks et al., (2017) argue that such simplistic notions of recycling solving our problems – even if we achieved a theoretical 100% recapture of materials – is flawed. The 2017 study by Fellner et al. examined what level of greenhouse gas (GHG) emissions reduction we might expect if we recycled 100% of the materials used across a wide range of industries: plastic, aggregates, iron, steel, aluminium and paper/board. They found that even with a theoretical (and impossible) 100% recapture and recycling rates we would only generate a 1.6% reduction in GHG emissions. This is because the industries examined already recycle at relatively high rates, the materials are often in permanent (or near permanent) use, so material throughput is low, and growth is still very high, so replacing new with recycled material will not come close to meeting the increase in demand. The report concludes that growth in material use needs to flatten and stabilise.

A NOTE ON DATA

Getting reliable data on the volume of waste generated by the fashion industry is notoriously difficult – a reality exemplified by the fact that the Kerr and Landry's report seems to suggest we discard significantly more garments (92mt p/a) than we consume (62mt p/a). Perhaps the authors have conflated the fashion and textile industries when reporting on waste and not when calculating consumption. Additionally, the Global Fashion Agenda who commissioned the report is in part funded by garment giants Kering, ASOS, Nike and H&M, which could be argued as being a conflict of interest. Most garment companies do not keep reliable records of textile waste (Runnel et all 2017), and there is no clear categorisation of types of waste or what is done with it. In many cases, companies have little information about what happens to production waste as they do not technically 'own' it, and only have a moral responsibility for it. With these limitations in mind, I have calculated the theoretical recycling shortfall c based on the 62mt p/a consumption figure and adds 35% to account for pre-consumer waste, as is indicated in the GFA report (Kerr & Landry, 2017).

TEXTILE WASTE AND THE CIRCULAR ECONOMY

Fellner et al. (2017) do not discuss the fashion and textile industries (though they could be included in some of the figures used for plastic and even potentially paper). However utilising the figures provided in the GFA report (Kerr & Landry, 2017), we can extrapolate figures to illustrate the textile and fashion story. Assuming a theoretical 100% recapture and recycle rate at both pre and post-consumer stages, the fashion industry would be almost 33.5million tons p/a short of recycled material to maintain even current levels of consumption, assuming both zero growth and no improvements in efficiency in production. This shortfall is mainly because people hold on to 54% of their garments year to year (Kerr & Landry, 2017).

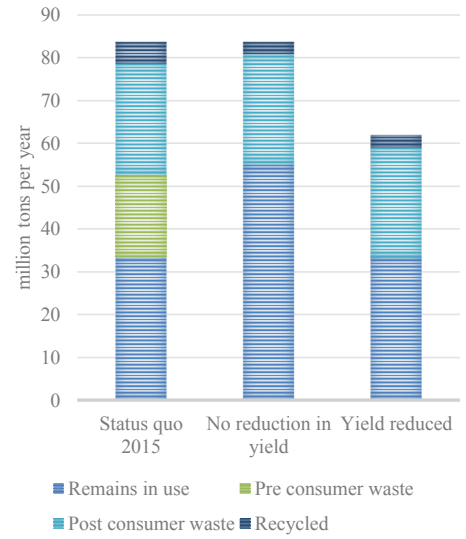

Figure 2: Comparison of material status after one year, assuming zero growth and no rebound effect.

Between 35% (Kerr & Landry, 2017) and 25% (Runnel et al. 2017) of the raw materials used to produce garments becomes waste at the factory. An average of 15% (Rissanen, 2013) is generated at the design stage via the pattern cutting-to-marker making process, and the remainder is end-of-roll, selvedge waste, and other yarn waste. Zero waste through design can lead to a reduction in waste while maintaining yield, or both a reduction in yield and a reduction in waste (before meeting a theoretical minimum yield). If we achieve a theoretical 100% utilisation of raw materials two entirely different outcomes are possible depending on how we do this. For example, if we currently need 200cm of cloth to make a dress but only utilise 160cm (20% waste), but we redesign the pattern or production

method to make the same style utilising the full 200cm, without generating waste but without a reduction in yield – then this will maintain overall total demand. It also drives an increase in the need for virgin materials (a theoretical increase of 21,7 million tons per year) because of the resulting increase in a recycled material shortfall. If instead, we make the same dress utilising only the 160cm needed to make the style (the theoretical minimum yield) then we will reduce demand of recycled material while maintaining demand for virgin materials, assuming we maintain current levels of consumption (Figure 2). Should we, therefore, disregard the reduction of waste without the reduction of yield as a strategy for zero waste? Under theoretical 100% recycling rates yes, however, we do not have that, and it is not likely to ever be the case. This strategy will remove significant volumes (up to approx. 8.3 million tons per annum at the 2015 rate of consumption, see Figure 3) of waste from landfill and incineration, however under a theoretical 100% recovery and recycle scenario the goal shifts to reducing yield while reducing waste.

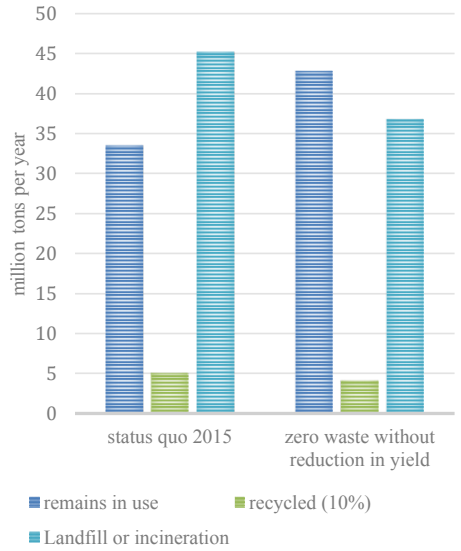

Figure 3: Impact of zero waste (without reduction in yield) on textile waste volume at current recycling rates.

If consumption increases, which it is expected to do so (from 62 million tons per annum in 2015 to 102 million tons per annum in 2030) then the benefits to be gained from achieving theoretical minimum yield in production increase further (Figure 4). However, growth in virgin material demand is still clearly a problem.

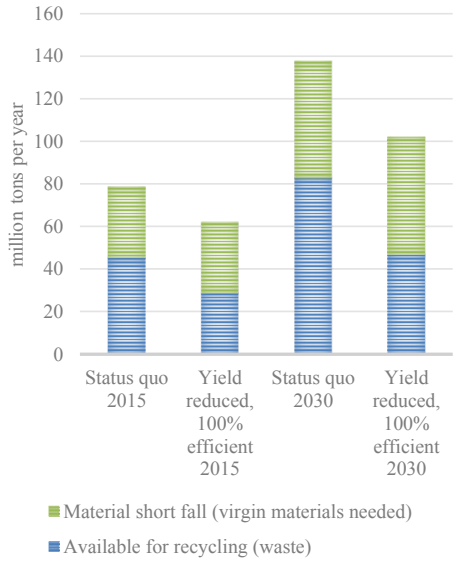

Figure 4: Material demand and shortfall over time, assuming 100% recovery and recycling.

At a theoretical 100% recovery and recycling rate, the key driver for the demand of virgin material use becomes how long people use their garments and its relationship to growth in consumption. If people hold on to their garments (without using them) while also increasing consumption (hoarding), then the demand for virgin materials increases as the material available for recycling cannot keep up with demand driven by growth. However, if people reduce consumption because they hold on to their garments and use them (slow garments, Figure 5), then demand for virgin material is moderated. Alternatively, if people speed up the flow of products through their lives and we can capture and recycle 100% of these products, and there is no growth in demand as one garment is made for every garment recovered. In this scenario, more recycled materials will be available and less virgin materials required.

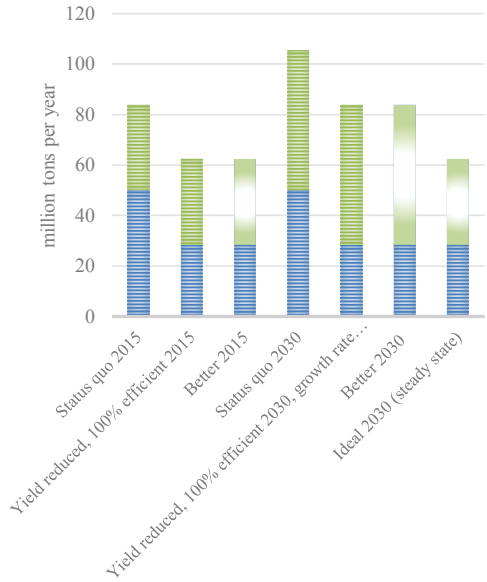

Figure 5: From status quo to better to ideal.

So, we need a multi-pronged approach. First, we need to reduce the amount of material needed (aiming for theoretical minimum yield) to make the garments. Secondly, we need to be able to achieve as close to 100% recapture and recycling rates as we can. Thirdly, we need to eliminate the hoarding of garments, and instead have two distinct kinds of garments (Peters, G. et al. 2018): those that are designed to last, that do not drive consumption increases because they are repaired, cherished, reused, lent, on-sold – these are the only garments (if any) we should consider making from virgin materials. Also, fast '1:1 garments'; which move through the fashion cycle rapidly, providing their own raw material to be reborn, therefore meeting their own demand for recycled material. Lastly, ideally, we need to flatten growth in material use to achieve a steady state economy.

A NOTE ON THE 'REBOUND EFFECT'

It has been observed that increases in efficiency often increase production and consumption, as the raw materials saved through efficiency become drivers for growth – a phenomenon called the 'rebound effect'. "Invariably… efficiency in production processes have been used by the businesses… to save on costs so as to be able to produce and sell more. In fact, what we call economic growth is the long history of the diversion of efficiency gains into production increases." (Grosse, 2011). There seems to exist hope for a perpetually expanding market fed by ever decreasing raw material consumption.

During the field tests I often reflected at the companies motivation for increases in efficiency, it is impossible perhaps for a company operating in a neo-capitalism to view efficiency gains as anything but 'guilt-free' raw material for more production and therefore growth. The potential problem, however, is that without a limit on growth our notion of a circular economy will always be, in fact, an ever-increasing spiral requiring ever more virgin inputs.

FUTURE-MAKING

"The best way to predict your future is to create it." Abraham Lincoln

It makes sense that business is reluctant to disrupt the status quo after all industry has been benefitting at the expense of the environment and many humans for hundreds of years. A progression of efficiency savings in labour (first through the division of labour and more recently automation), and extraction has fostered a business model for the garment industry which is so complex, global and entrenched that change on almost any level seems infeasible. However, change we must. CE "is not a "more of the same" approach…[it] has the potential to understand and implement radically new patterns and help society reach increased sustainability and wellbeing at low or no material, energy and environmental costs." (Ghisellini, Cialani, & Ulgiati, 2016). The future we need (as a self-realised choice and not catastrophic collapse) can seem thoroughly fantastical. The point is that we need radical change – either it happens to us or we design it ourselves.

This research seeks to illustrate what a future alternative model of design and production for woven textiles might be in response to the question: What if we eliminate waste from the production of products, and what could that that look like in the context of the fashion industry? The remainder of this paper seeks to explore some of the approach taken so far.

ZERO WASTE COMPOSITE GARMENT WEAVING

Building on my tacit (Polanyi, 1966) knowledge gained from past experience and in response to the field tests outlined earlier I began to explore the edges of zero waste design practice. Based on my experience attempting to design within the tight framework provided in the field tests it became clear there was a need for a holistic approach, and that the fundamental design of the textile was underexplored as a method of reducing waste for woven textiles.

A key critique of zero waste fashion design is the perceived difficulty in controlling the exact outcome. A holistic approach is required where a careful negotiation

is made between the various competing goals of a product. A fundamental limitation is the rectangular form of the cloth at odds with the curved form of the human body. This perhaps explains why many zero waste garments are voluminous or boxy in form – controlling details and silhouette in the context of rectangular cloth can be difficult.

In response, I experimented with designing both the textile and the form in a simultaneous design process (Townsend, 2003). This enabled me to find the 3D potential in what most designers consider a 2D material. Treating the loom as a kind of 3D printer for woven textiles, "composite garment weaving" (CGW) is defined by Piper and Townsend (2015) as the simultaneous design, and production, of woven textile and garment. This way of working has existed for knitted garments for many years first through fully fashioned knitting and later whole garment knitting, but woven garments are made utilising a method called Cut and Sew.

Cut and Sew is the primary method of garment creation for both woven and knitted garments within the industry. It has been adopted by industry because it enables the various actions of garment creation to be divided into separate steps (the division of labour). However, it is a complex, time consuming and resource intensive practice. This method of production contributes an average of 43% of the waste generated at production due to inefficient and entrenched design and pattern cutting processes. This research critiques cut and sew as an appropriate production method in the context of the circular economy.

In contrast, CGW (like its cousin whole garment knitting) hybridises and automates many of the various actions needed to make a garment – form and detail are materialised with textile. Existing explorations of composite garment weaving include Issey Miyake and Dai Fujiwara in A-POC (1999 - present), and recent explorations of composite garment weaving by Anna Piper (Piper and Townsend 2015), Jacqueline Lefferts (2016) and Linda Dekhla (2018). Other models which disrupt cut and sew for knitwear have begun to be explored by London based Unmade, and Knit for You (Adidas, 2017) with onsite, on-demand whole garment knitting of garments that have been partially designed by the user. Seamdress' by Kate Goldsworthy and David Telfer (2013) explored circular economies, mono-materials and laser-etched garments reducing the steps and materials required for garment production. 3D printed garments are an area of increasing interest, and more work is needed for the outcome to have a cloth-like feel.

By situating the majority of garment production processes in a single automated action and location – ideally, in an on-demand, distributed model close to end-users – production and transportation emissions are reduced and over-production limited. Additionally, it makes possible the re-shoring of production – reversing the decades-long process of 'offshoring' the waste and labour abuses which occur in conventional production.

None of the current examples of CGW fully explore the potential for CGW to generate recognisable forms while reducing or eliminating waste for woven garments. As discussed previously there is a clear need to reduce the yield required to manufacture garments, eliminate (or at least drastically reduce) waste of all kinds (including weaving waste and overproduction) in the context of the CE. It is in this territory that my work has been focussed so far.

Figure 6: The design process occurs primarily in the digital software CLO3D.
https://vimeo.com/user42375475/review/311307753/8f2247db1e

CONCLUSIONS AND ONGOING RESEARCH

Design in the context of a circular economy should ideally adhere to the following: Reduce yield to the theoretical minimum while reducing or eliminating waste in overall production. Products need to be able to be recycled easily, so we can achieve as close to 100% recapture and recycling as we can. We need to design two distinct kinds of products: those that are designed to last, that do not drive consumption increases because they are repaired, cherished, reused, lent, on-sold: And '1:1 products; which move through the use cycle rapidly, meeting their own demand for recycled material.

My design responses to these demands are beginning to take form. The use of the t-shirt archetype enables me to explore the possibilities for recognisable form creation utilising a radically different design and production method. The zero waste CGW t-shirt shown in this example was designed almost entirely utilising digital software (CLO3D), which would theoretically enable an on-demand design model for consumers where the garment is digitally tailored to fit. It is then woven on a digital jacquard loom and cut so that the embedded layers, details and 3D form of the t-shirt expand out from the 2D woven cloth.

Figure 7: Video showing the weaving and cutting for the tshirt.
https://vimeo.com/user42375475/review/311307665/fb5719ed3b

All of the examples made so far are woven from 100% cotton to avoid hybrid materials which are more difficult (or sometimes impossible) to recycle, and with further development will require no stitching (which is usually a polyester-cotton blend). Further research will include developing more variation in the creation of form, surface, edges, and details. Variable yarn weight will be explored to potentially eliminate the need for adhesives in production and to control the density (for durability and drape) of the cloth across the loom width.

WASTE, WHO CARES?

So what is the effect of eliminating waste from the design of the products we make? It is clear that we are facing a waste problem that requires we transform our industries and that the scale of the problem is vast and designers cannot continue to behave as though it is only a management and recycling problem. We need to understand that aiming for 100% resource use in production needs to be part of our goals. To achieve this, we need to either address expectations of aesthetics/fit of garments or develop new methods of design and production which eliminate waste while satisfying needs and expectations – or perhaps both. However, 100% efficient resource use cannot be our only task. McDonough and Braungart (2010) critique the waste hierarchy – reduce, reuse, recycle – as the logic of death and argued that we must find a way to design for abundance. Their argument is that growth isn't in and of itself wrong, only the way we do it and that the things society and industry tends to want to grow like product sales and dividends – unless also tethered to the finite environmental (and social) limits of our planet – are the very things that can make abundance for all impossible to achieve.

The complexity of the fashion industry mirrors the complexity of many design-led industries. Our ingrained ways of working, particularly the silos and hierarchies are barriers to meaningful change. Designers need to act as translators and facilitators, enabling better communication to improve the status quo and providing a clear creative vision for what the future might look like. We have work to do so that the products we design are the right kind of products, able to be recycled, and repaired, at the right time. We need to design to prevent the creation of waste in the first instance while reducing the total material needed to make them and meeting our needs. The circular economy will not save us from climate disaster unless we employ its mechanisms well and creatively. We need to utilise all the tools at our disposal to transform the ways products are made and the system they exist within so that once technology catches up with our design dreams, we are ready and waiting.

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PAPER III

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Hybrid zero waste design practices. Zero waste pattern cutting for composite garment weaving and its implications

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Abstract: This practice-based design research explores methods of eliminating textile waste through utilising zero waste pattern cutting to expand the outcomes possible through composite garment weaving and speculates as to the implications for the wider industry and society. Employing a hermeneutic phenomenological approach, I tested known strategies in the context of industry and responded with new emergent strategies to the challenges that arose. The findings that emerged from the iterative design practice, and surrounding discussions and reflections, inform the experimental design work that follows. It is this experimental 'future-making' that is the focus of this paper, which outlines foundational pattern cutting theory and methods for an emerging field – composite garment weaving – as well as findings relating to the impact and use of technology in the fashion industry while bringing into sharp relief the inherent conflicts that exist within the fashion system.

Keywords: Zero waste design, Composite garment weaving, Technology, Circular design, Sustainable fashion

1. Introduction

Typically, 15%-25% (Rissanen, 2013; Runnel et al., 2017) of the cloth needed to produce a garment is wasted due to deeply entrenched and complex conventions of design, pattern cutting, and production practice, all of which are reinforced by dominant and problematic business models. The combination of a massively globalised and fragmented industry, and fear of a loss of competitiveness if the realities are revealed (Ditty, 2015), leads to a general lack of transparency in the fashion industry. In a recent 2018 report by Fashion Revolution, the highest transparency level achieved was 144.5 out of a possible 250 points (Ditty, 2018). The demonstrable opaqueness of the industry makes comprehending the scale of the waste problem and then addressing it a herculean task, so most strategies have been applied only on a small scale. The inclination to want to scale up these, and other innovative sustainable strategies are understandable. However, this may fail to address the underlying consumption model which is responsible for many of the problems we face (Brooks et al. 2017).

It may seem we should write off the large-scale globalised model as a destructive one, but to do so would neglect to address areas of the industry that negatively impact on people and planet at a considerable scale. Perhaps we should look to brands who produce intentionally slowly and holistically, utilising 'fiber sheds'[1], local production and natural dyers. The garments they produce are hand-made by those who have the skills to make themselves or bought from the skilled by those who can afford to pay for them. However, it can be argued that this small-scale approach fails to impact on the wider production and consumption issues the industry faces. Probably the best holistic solution to the problems we are facing in the fashion industry is addressed through circular design, assuming we apply it holistically, at all stages of the fashion cycle and not only at fiber recycling. Simultaneous respect for (re)use of resources and at least a flattening of consumption and production will be required to address the problematic waste issue we are facing – requiring us to not only change the way we use and discard materials, but the production methods we employ.

2. Aim

Hybrid zero waste design is a design approach that operates at the intersections of practices, and through it aims to reduce or eliminate waste from production while revealing new expressions. In this case, the intersection is between fashion and textile design and takes a simultaneous design approach (Townsend, 2004) where we realise in tandem the textile structure and garment/3D form. This practice is not merely concerned with designing objects or forms, but also the systems that this hybrid practice operates within. I agree with Tim Marshall (in Yelevich and Adams, 2014) who takes the view that design cannot act in isolation of the complex social, economic, and environmental issues that envelope it. Furthermore, this research exists (as perhaps all design should) in a precarious, and political space (Fry, 2010) – our current situation demands that we "confront an unavoidable choice: we either support the status quo or we chose a path of change." (Fry, 2010, pg 1)

2.1 From field test to future making

The aim of these fields tests was to explore the limits and opportunities of zero waste fashion design practice in the context of the fashion industry and aimed to develop viable, manufacturable garment outcomes for two large garment design and producing companies. Employing a hermeneutic phenomenological approach, my research program (Redström 2017) takes the form of iterative 'field tests' within relatively tight design frameworks – where the initial constraints were set by the 'field' in which the tests took place. The findings that emerged from the back and forward iterations of the field tests and surrounding discussions and reflections (Schön, 1983) directly and indirectly inform the experimental design work that follows, it is this experimental 'future-making' (Simon 1969, Yelavich & Adams 2014) that will be the focus of the second half of this paper.

3. Research Methodology

The beginning of this research involved two field tests, of different durations and goals, both within large garment companies which have sizeable globalised supply chains and operate within the

[1] Fiber sheds are a network of farmers, ranchers, land-managers, designers, ecologists, sewers, knitters, felters, and natural dyers, spinners and mill operators that have defined a strategic geography to work and create within. (*Fibreshed*, 2018)

conventional fashion system, predominantly producing using “cut and sew”[2] methods. I set out with the original intention to develop ‘successful' products for these companies so that I could then report on my success in my PhD so others – be they designers, companies or researchers – might learn from my experience. In this section I will outline the nature of the field test and how they progressed, later reflecting on the experience, and outlining how this spurred my research in a somewhat unexpected direction.

3.1 Field Test One outline: Large high street clothing brand

The first field test was of short duration, lasting three days and taking place in Istanbul. I was asked by a large fast fashion company to work with a group of their freelance marker makers[3]. The company are known for their efforts to reduce the negative impacts of their garments; however, they are a brand where high-volume, low-cost garments dominate. I worked with teams of marker makers on a specified existing dress design, exploring a range of approaches and small changes to the design in order to dramatically improve garment yield and reduce waste, without change of silhouette or critical details. In this context, we developed three different possible outcomes, one of which reduced yield for the planned style by 26%, by adding a single seam. These modified garments and markers were costed by the company[4], however, as the savings they would make on material yield, were outweighed by the extra cost of sewing the additional seam – because their cloth was so inexpensive – they were not implemented.

3.2 Field Test Two outline: Large sustainable clothing brand

The second field test was of much longer duration and for a very different garment brand. In 2016 I led a zero-waste design workshop with a large American sustainable clothing brand. In preparation for the workshop, I was asked to redesign an iconic mid-layer fleece jacket using zero waste design principles to demonstrate to the team what may be possible. I presented this design while hosting the zero waste design workshop with the product team who suggested changes to seam placement, such as moving seams slightly for reasons of function, taste or aesthetics. When making these changes, both large and small, efficiency and yield returned close to the original.

Later, the team decided to embark on another project with me – redesigning a men’s and women’s technical fleece mid-layer. The project began “off calendar” meaning it would have a long development period, acknowledging the peculiar challenges this type of project faced. However, it was moved to be “on calendar” midway through the process, significantly reducing the time available to develop effective solutions. An iterative process continued back and forward for many months, with shifting explicit[5] and implicit[6] constraints playing an ever-increasing role in the decisions made. Despite the challenges presented through constraints, the designs progressed satisfactorily enough

[2] Cut and Sew garments are constructed using patterns to cut garment pieces from an existing roll of cloth (knit or woven), and then sewn on a sewing machine. The process is time consuming, complex and wasteful compared to fully fashioned knitting for example.

[3] Marker maker takes the provided garment pattern and works with specialised marker making software to achieve the most efficient layout of the pattern of fabric for production. They have to consider the full-size range, volume of the production run, cutting table size, fabric behaviour (shrinkage for example), and directional print or grainline. They do not generally have input into the design of the garment, except in exceptional circumstances (where the garment pattern pieces are too large for the fabric width for example).

[4] This is where the total cost of the garment is calculated in detail, including all material use, trim and thread use, the time required to manufacture the garment.

[5] Factors which were able to be easily communicated and answers found – such as fabric width, size and grading requirements, limitations of manufacturing equipment

[6] Factors which were much more difficult to articulate – such as ‘house style’ or the hierarchy of what was important in a given design.

that the company arranged for the design and technical design team, and me to travel to one of their factories for a week of intensive collaborative work. This kind of at-factory design had never taken place in the company before, and in a short space of time, a significant amount of work and related breakthroughs were achieved. The outcome of this week was a working sample of both the men’s and women’s technical garments, with significantly lower yield than the original. However once assessed by the wider team, and suggested changes to the aesthetic and fit of the design were actioned, the yield and waste was only marginally improved on what it was initially. The company is proceeding with this version of the garment.

4. Reflection – The desire for change without change

4.1 The value of fabric waste

A key finding in Field Test One was that when using a conventional production process, within a high volume, low-cost context, reducing yield and improving waste is not a valuable investment in time and resources if the material cost is not a significant part of the cost of a garment. The changes required to the profoundly ingrained system are too significant for them to be worthwhile unless there is motivation outside of a financial imperative. The business model constrains meaningful improvement and change.

In the process of working through Field Test Two, I had conversations with the wider team at the company regarding textile use and waste. I discussed with textile designers and material developers the possibility of specifying fabric width but this was considered infeasible. At times I found it compelling to attribute a value to the waste generated, but due to trade agreements, effectively the company only has a moral responsibility for the waste, this is a responsibility they take seriously but can be challenging to implement. In general, information about the volume of waste generated by the production of garments, the actual markers, yields and patterns used are closely guarded by many factories. They profit off the difference between what they quote and what they use, and when margins are tight, this revenue can be important. Waste it seems in an inbuilt component of the fashion industry.

4.2 Hierarchies in design and production

Field Test Two revealed that this kind of work cannot be rushed, and requires holistic approaches and partnerships from all stakeholders involved. It is of note that the most rapid and successful period in the design and product development process was when many of the stakeholders were working together in the same space and time. It is essential that design language is confirmed and articulated, and production limitations known and challenged – such as what aspects of the design and production are negotiable, what is not – and when the designer, line manager, pattern cutters, production managers and technicians are working together these can be more easily addressed.

The conflict between the holistic requirements of a zero waste design process which is situated in design aesthetics and production simultaneously (and so requires a balance and understanding of both), and the siloed, hierarchical and linear design process the company was used to working with was another clear roadblock. There seemed to be a lack of understanding of the spatial reality of a given garment design using conventional production methods – both company’s wanted the design to remain the same, but for it to somehow take up less space – change without change. But zero waste design in not magic, and cannot be considered merely a design or pattern cutting technique. You could say it *enforces* a holistic way of working which in many ways is unlike the conventional fashion design system. The field tests can be seen as both a failure of my zero waste design

approaches to adapt to the industries rules and a testament to the inflexibility of the industry, a failure to change even when acknowledging the need to change. Despite these tensions, this research does demonstrate that zero waste design, when implemented into the wider industry, can enforce a different way of thinking, allowing us to ask different questions and potentially fine alternative solutions.

A key finding in the field tests was the realisation of the degree to which the constraints of industry prevent meaningful and responsible innovation. Extensive reflection has led to me questioning the relationship and hierarchies between fabric and garment within the design process. This questioning takes place through an experimental iterative process, where I was able to combine a newfound understanding of the digital jacquard loom, with my prior tacit (Polayni 1966) and explicit knowledge in the field of zero waste garment design. This has revealed the beginnings of foundational pattern cutting theory and new methods for an emerging field – composite garment weaving – as well as findings relating to the impact and use of technology in the fashion industry.

5. Conceptualisation – Future making aesthetics, production and economies

Simon (1969) and then Yelevich and Adams (2014) have worked to highlight design as an act of future making. They argue that as designers 'make' the future through products, services and interactions, design is intrinsically social and utterly political, and therefore our actions as designers need to consider what kind of future we are making in doing this. The following section explores three avenues for considering the practice outlined in the remainder of the paper as future making.

5.1 Aesthetics and Production: Pattern cutting for Composite Garment Weaving

A common criticism of zero waste practice is the perceived lack of aesthetic control the designer has, this was raised in discussions with staff at the two field test companies – and it does require a more nuanced negotiation between 3D form and 2D pattern than conventional fashion design practice where the 3D almost always completely controls the 2D pattern. Though in practice it is rarely this straightforward – it is usually taught that pattern cutting is in service of the design sketch, and so the process of sketch to pattern to garment is clearly established. For most fashion designers the behavior of the textile is understood concerning its existing aesthetics and structure. Textiles are selected based on criteria – such as knit or woven, weight, handle, drape, colour, and print – to best serve the intended design. The vast majority of designers do not and cannot specify its construction. Additionally, most designers consider textiles to be two-dimensional structures, a single plane that in its simplest form can be hung as a screen, or perhaps manipulated into a 3D form to cover a chair, or make a dress.. However, what if we considered the creation of woven cloth as additive manufacturing for garment production? We more easily do so for knitted materials, but the same is true also of woven materials and forms. Our existing shallow understanding of the relationship between textiles and form limits the ways in which designers could transform our industry and built environment. I question how technology has and can further shape form-making, following some of the lines of inquiry forged by the work of Issey Miyake and Dai Fujiwara in A-POC (1999 - present), and recent explorations on digital composite garment weaving by Anna Piper (Piper and Townsend 2015), Jacqueline Lefferts (2016) and Linda Dekhla (2018). This reshaping of form-making has the potential to future-make the structure of the industry itself, and through that our social fabric.

5.2 Digital Crafting

Thomsen (in Yelevich and Adams, 2014) argues that understanding the behavior of the real material is augmented by the opportunities afforded by their digital representation (increase in variation and design complexity for example). "The term digital crafting suggests the intersection between digital design tools and the capacity for precision, variation and control within the craft tradition" (in Yelevich and Adams, 2014, p.61). By modifying their structure, we can discover new behaviors for existing materials, and use digital tools to expand on the possibilities this new understanding offers designers. The use of 3D modeling software is already having profound impacts on the representation of garments in the fashion industry[7], however, how can it impact on the design process, outcomes, and systems in which designers operate[8]? This research utilises 3D design software extensively, enabling the design of highly complex woven garments, even though the designer (me) had little existing understanding of weaving or weaving software. New technology can act as a conduit between fields – such as fashion design and textile weaving – which need to be able to communicate better, but lack the language needed to conceive of new forms and methods at the intersection of practices and fields of knowledge.

5.3 Economic Models – Circular design, Scale and Social Impact

Cut and sew manufacturing is a complex, time, body and material intensive process – and the most commonly used for garment production. In a conventional manufacturing model, the actions needed to produce a cut and sewn garment are divided up into an assembly line in large factories requiring many workers to produce a single garment in a largely un-automated process. Models which disrupt this have begun to be explored by London based Unmade, and by Adidas, in their 2017 "Knit for you" popup shop and factory. Both examples utilise interactive software to enable consumers to participate in the design of their garments and onsite whole garment knitting to produce the garment designed on demand. Reducing the steps required to produce garments, and in some cases eliminating many of the hand finishing processes involved, my practice builds on 'Seamdress' by Kate Goldsworthy and David Telfer (2013) which explored circular economies, mono-materials and laser-etched garments. By situating the majority of garment production processes in a single location – ideally, in a distributed model close to end-users – transportation emissions are reduced, and end users can witness the process of making garments.

It is important to consider the potential impact that this kind of automation will cause on the economies and livelihoods of current garment workers. The International Labour Office (2017) discusses these impacts in a report titled *New Automation Technologies and Job Creation and Destruction Dynamics 1* – making clear the potential benefits and costs they foresee with increasing automation. They estimate that as soon as 2030, 47% of all work in the US, and 89% of sewing machinists are at high risk of being replaced by robots and other automation techniques and that if these costs are not addressed in a timely way, the repercussions are severe. Any new development can have consequences those that develop them do not foresee or care to mitigate.

One way of ensuring new technologies do not have unforeseen impacts is, of course, to not use any. Favoring a transition back to slow, human-scale, labor-intensive, cottage industries, proponents advocated for natural dyeing, hand weaving and knitting, and home sewing of simple garments. A kind of 'change by changing back', these models seek to undo many of the technological and aesthetic changes wrought by the industrial revolution but like automation are not without negative

[7] The use of Clo3D by Balmain for their advertising using the world's first digital supermodel is an excellent example of this.
[8] For more on this see Siersema, I. (2015) 'The influence of 3D simulation technology on the fashion design process and the consequences for higher education', in *Proceedings of Digital Fashion Conference 2015 Digital Fashion Society*.

impacts[9]. In response to Jamer Hunts (in Yelevich and Adams, 2014) critique of the "blindingly" "convoluted" scale of industry, I agree with Kamenetzky (1992) who argues for an economic model which is human in scale. Like Kamenetzky I do not advocate for a wholesale return to 'primitive' technologies "whose operation required large amounts of human energy" – I instead aim to help make a technologically driven future which reduces the scale of the industrial complex required to produce woven garments which would previously be 'cut and sewn' – a kind of high-technology-meets-cottage-industry model (see figure 1).

Hybridising the actions needed to make a garment (or chair, or building) enables me to produce innovative garments, both recognisable and radical. The approach could enable a circular model of production – produced with a single material and fibre, embedding details which are often glued (interfacing) or stitched (most commonly using polycotton thread) to the cloth. Eliminating the majority of the waste from the manufacture of the garments, reduces the energy needed to capture and recycle these fibres. By prototyping ideas to proof of concept stage utilising currently available technology, the digital, industrial jacquard loom, I propose and begin to materialise a future – first clearly articulated by Miyake (1999) – where engineered cloth/garments are produced primarily on the loom, on demand, potentially proposing new technological developments[10].

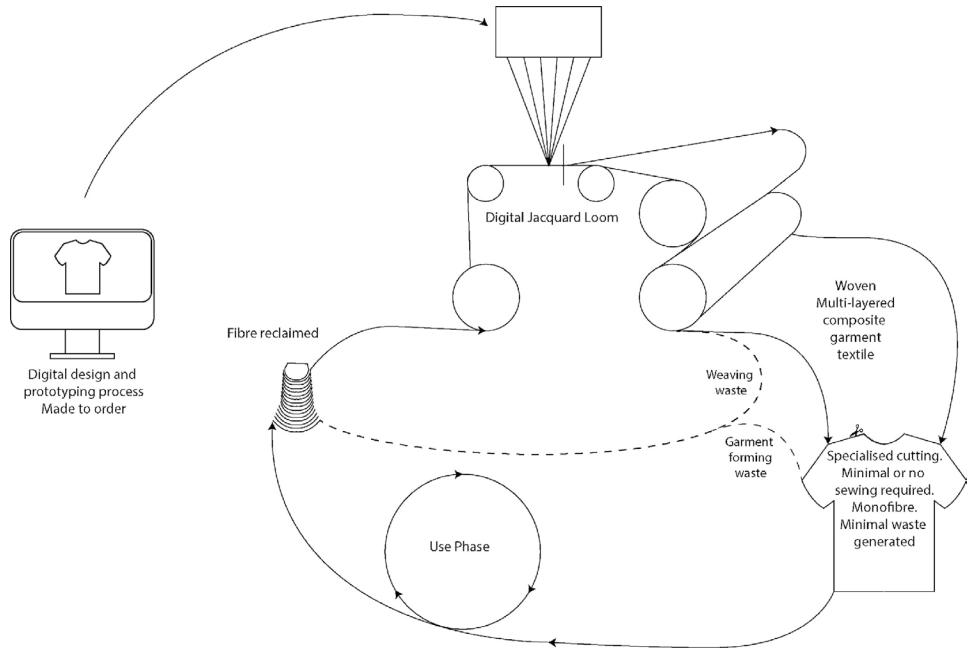

Figure 1. Theoretical circular model for hybrid zero waste composite woven garments.

[9] There are examples which prove small scale does not always mean only looking backward. Yoshiyuki Minami of Manonik (Minami, 2018) perhaps provides a good example for small scale with forward-thinking change – his work explores new methods of form making through weaving utilising small-scale and local processes – simultaneously significantly slowing and shrinking the scale of the industry while developing new methods of making garments that result in new forms.

[10] Such as highly sensitive automated cutting equipment.

6. Active Experimentation

T-shirt form

The next section explains my design process and workflow for designing the 3D form of a T-shirt, translating it to weave-able 2D structure, in order for it to once again be made 3D. I chose a T-shirt because it is difficult to achieve utilising existing zero waste pattern cutting techniques in a recognisable form. I explore the T-shirt form in three iterations, presenting it in detail for the first iteration, and subsequently exploring the sequence of limitations and possibilities that arise through iteration two and three.

6.1 T-shirt Iteration One – Stacking layers

To design the first iteration of the T-shirt, I utilised Clo3D and the basic T-shirt pattern available through the software. The use of existing conventional patterns was an attempt to achieve an understood and expected form, however, it also caused an inherent front/back flattening of the body form because a conventional T-shirt pattern consists of a front and back joined at the shoulder and sides. Despite the use of these conventional patterns, they gave a clear and identifiable place to begin the design process.

Woven fabrics produced on a loom are almost always rectangular. I am accustomed to working with this limitation due to my experience with zero waste pattern cutting, however, the possibility of creating space in the weave was not a technique I had been able to explore before. I stacked the pattern pieces *into* the textile's layers (see figure 2), woven so that when cut and separated, can create a shaped 2D pattern from a rectangular 2D textile[11]. The front and back are overlapped at the shoulder seam as shown in figure 2.1, and the sleeve pattern is placed overlapping in the same area so that a maximum of three layers[12] is needed in the woven structure. Due to the use of 3D software, I could easily see the impact of the placement of these pattern pieces on the expression of the 3D design. The placement was simultaneously guided by the resulting expression, the requirement that all areas of the weave be 'used' for the garment[13] and the technical considerations for weaving concerning thread density. In short, through technology I am able to design the macro structure of the textile, garment form and surface expression at the same time – no one single element consistently overrides the others.

[11] Often in the field tests discussed earlier in the paper, I wanted to be able to 'find' or make space beyond what the flat fabric could provide, and in this technique, I discovered I am able to.

[12] This self-imposed 3 layer maximum was determined based on the relatively low warp density I had available to me. The warp density of the cotton industrial jacquard loom used for these samples is 33 ends (warp threads) per cm, so when divided into three layers each layer would have a maximum of 11 ends per cm, which is considered very low for apparel textiles. With a higher density warp more layers would be possible.

[13] So none would be cut off and discarded, as is required in zero waste design

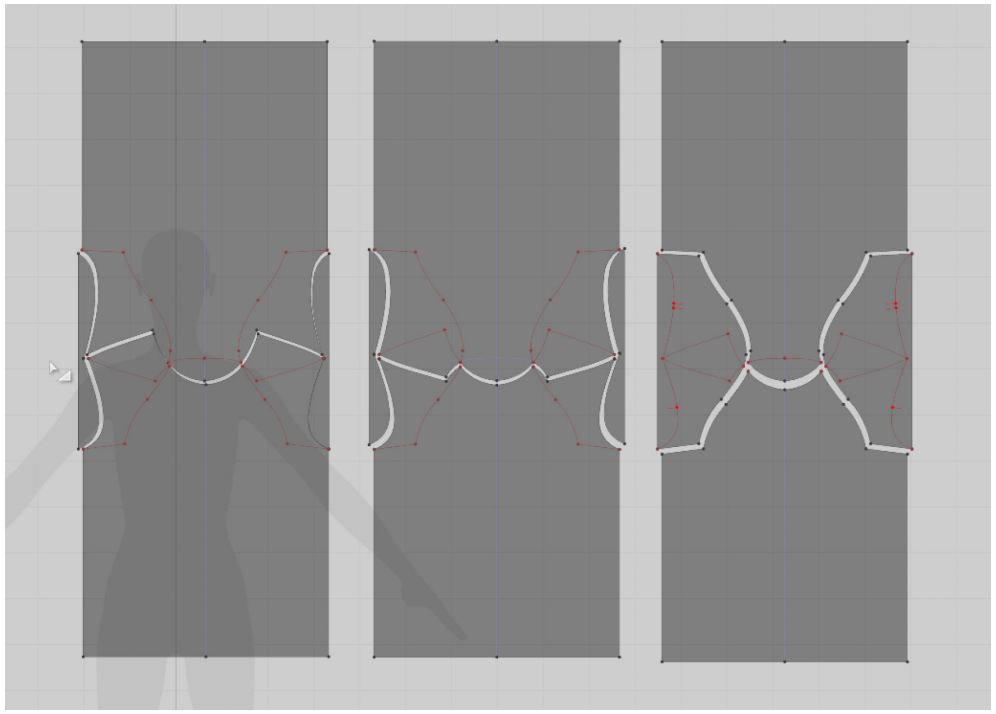

Figure 2. T-shirt Iteration Two development showing three layers that make the weave when separate and not stacked for weaving. Red lines show overlapping conventional t-shirt patterns.

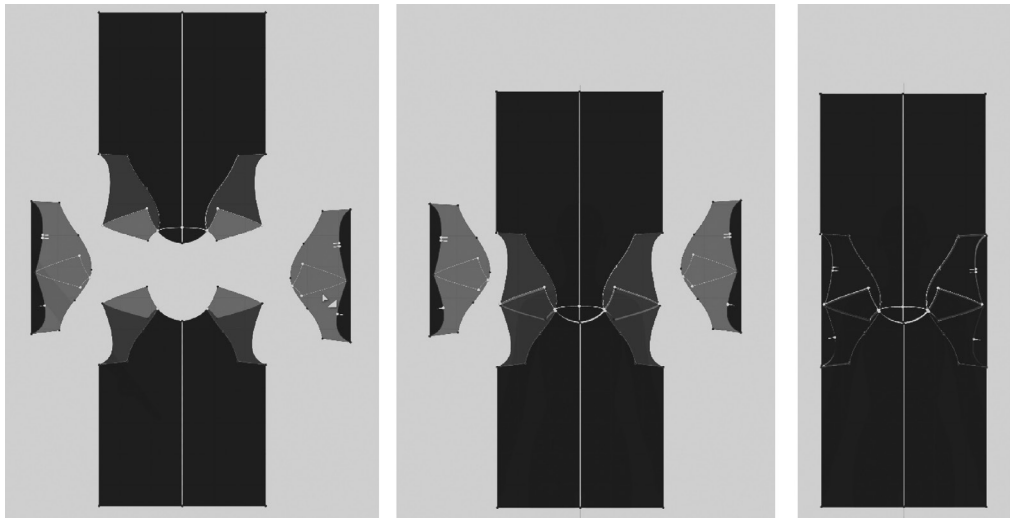

Figure 2.1. T-shirt Iteration Two development showing stacking of the three overlapping layers. Left to right: T-shirt pattern shapes (front back and two sleeves); Front and back overlapped; Front, back and sleeves overlapped (this is how the T-shirt is woven on the loom.

The three-layer ‘stacked' pattern was exported from CLO3D as a PDF and opened Illustrator. In Illustrator the three layers of patterns are sandwiched to produce a single layer, colour-coded ‘map' of weave structures or ‘bindings'. The bindings used in the research so far are simple and fall into three categories, fill, edge and cut, and all determine the relationship between the three layers. There are 16 possible binding types for these T-shirts, so there are 16 colours: this constructs the map of bindings (Figure 3), which determines both 2D space (woven) and 3D potential (form).

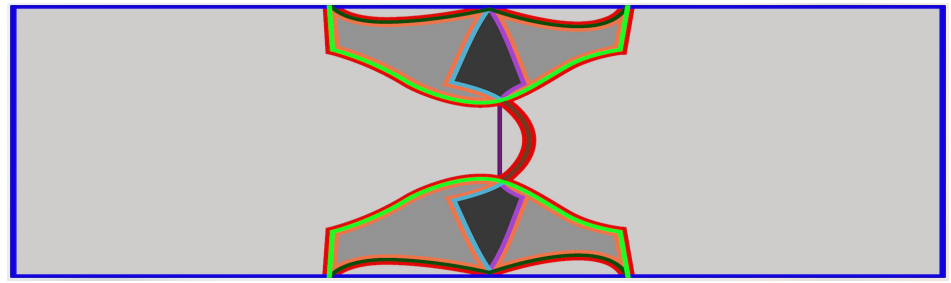

Figure 3. T-shirt Iteration One, map of bindings. Each colour defines an area with a specific weave structure and therefore a relationship to the other layers above and below. File is elongated to account for weft density.

The impact of repeat size, and weft density on the scale of the garment is important. The loom used has a 40cm repeat, and the same design must be repeated four times across the width of the textile, making a 160cm wide cloth. When I designed the T-shirt, I used a standard T-shirt pattern which is 55,5cm wide, so the repeat would ideally be this size. In order to test the concept as simply as possible, I shrunk the pattern to be 40cm wide in Illustrator, acknowledging this will result in a T-shirt with a maximum circumference of about 76cm[14] – a size which will likely only fit a child. The impact of weft density on the scale of the garment also needs to be addressed. For example, if I weave the T-shirt at a density of 50 threads per cm, then the file is scaled to ensure it is the correct length to translate pixel dimensions (which are square) to thread density (which is not). If I halve the thread density to 25 pics per cm without changing the file’s vertical scale, I will end up with a T-shirt twice as long.

The correctly scaled map of bindings is then exported to Photoshop to translate to pixels instead of vectors and check that the total pixel dimensions align with the warp density. From Photoshop I export as a PSD file to ScotWeave where I can assign specific bindings to the map colours and generate the code which the digital jacquard loom can read. The textile is woven using a different coloured yarn for each of the three layers in order to better visualise the process[15]. After weaving, I carefully cut the layers separate from each other using the floats as cut guides (Figure 4) and constructed the T-shirt conventionally. The resulting T-shirt requires the same number of sewing seams as a conventional T-shirt and has the same silhouette (Figure 5); however, it is zero waste. It becomes clear that whereas for ‘conventional' zero waste you measure yield and waste by area, with this hybrid zero waste method you need to measure yield by weight of yarn used. The T-shirt only produces a small amount of yarn waste in the auxiliary selvedge (assuming you cut it off). The surface expression of the T-shirt textile is a direct result of the process used to design and produce it and makes explicit the simultaneous design process that is undertaken[16].

[14] 40cm front and 40cm wide back, minus seam allowances
[15] Top layer of the weft yarns is white, while the middle layer is grey and bottom is black. All yarns are 100% cotton.
[16] If all the weft yarns used were the same colour visual difference of the textile would be significantly reduced.

Figure 4. T-shirt iteration one, sleeve layer cut from body. Transparency of sleeve is caused by the low weft and warp density of the loom.

Figure 5. T-shirt Iteration One is sewn using a standard t-shirt construction sequence, side seams, shoulder seams and armhole. Auxiliary selvedge shown as fringe on left side, this can be removed.

6.2 T-shirt Iteration Two – sliding layers

T-shirt Iteration Two was in response to the limitation of a 40cm loom repeat. To change the width of the T-shirt within a fixed repeat I utilised the 'stacking' layers method across the width of the body. The allowed me to 'slide' the layers further apart across the horizontal plane (Figure 6). In Clo3D I first divided the basic T-shirt front and back patterns vertically into panels and then overlapped these to fit inside the 40cm wide repeat (Figure 7). This resulted in a zero waste T-shirt (Figure 8) which requires more sewing than a conventional T-shirt, but which fits an adult and allows this design to be graded up to any size[17] where the circumference is less than about 230cm[18].

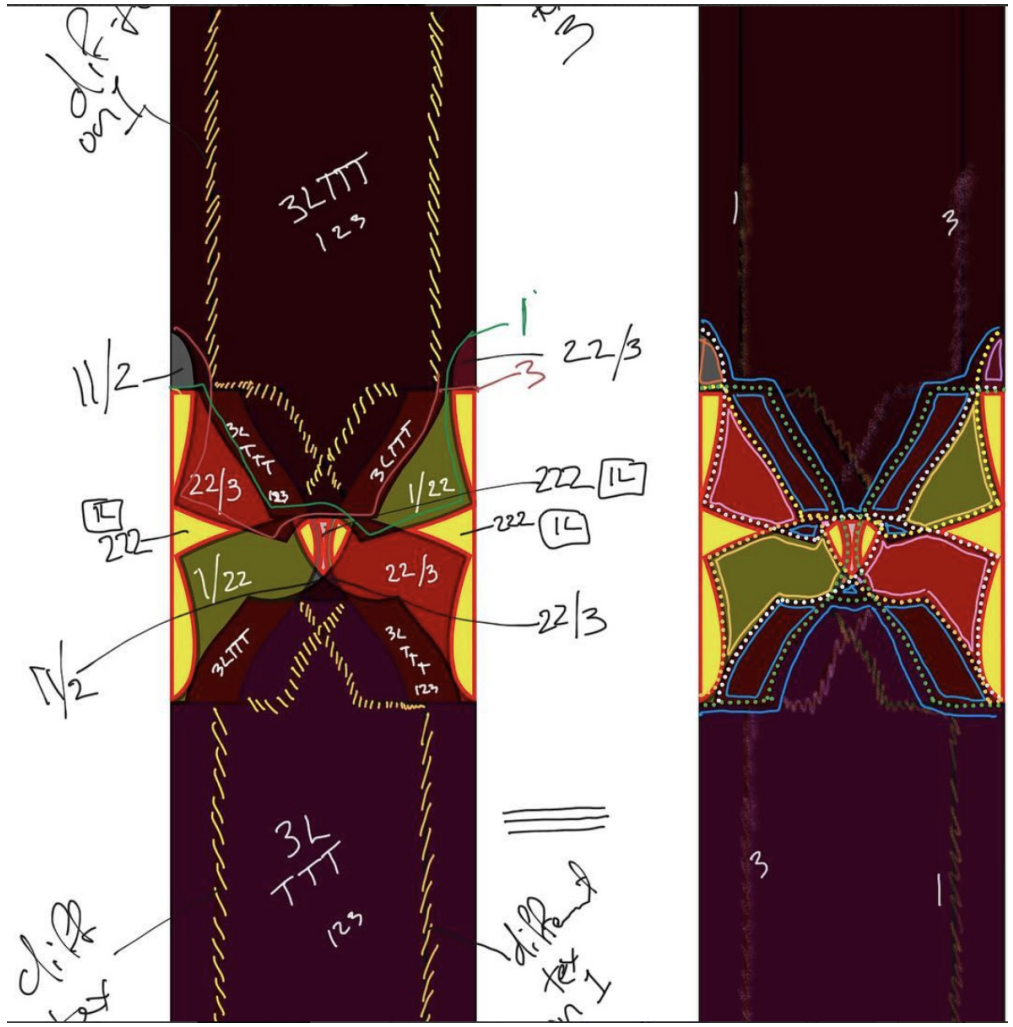

Figure 6. Planning the 'Map of Bindings' for T-shirt Iteration Two. Notation indicates relationship between layers.

[17] The resulting designs in different sizes will have visual differences to each other, a concept already proposed by Rissanen (2013) as a method to address grading problems within zero waste design.
[18] 40cm front, and 40cm wide back, multiplied by three layers, minus seam allowances

Figure 7. T-shirt Iteration Two on the loom as it is being woven, 40cm wide repeat shown

Figure 8. T-shirt Iteration Two, once cut and sewn as a 'Half' sample, actual design would be full length. Different weave structures are visible particularly on the sleeves, which are a result of the design process. More extensive sewing is required to form the outcomes generated from the sliding method.

6.3 T-shirt Iteration Three – expanding layers

I next aimed to find a method of reducing the construction required to less than for a conventional T-shirt. In Clo3D I noticed that what I thought of as 'sliding' appeared more like 'unfolding'. So using paper models first, and then moving to Clo3D (Figure 9), I conceived of a stitch-less method of embedded form making where the woven cloth has the form embedded and released when cut. Initially the 3D form of a T-shirt is flattened by cutting the side seams open so the form of the T-shirt can be flattened and then folded to conform to a rectangle for weaving. The design of the original T-shirt is modified throughout this process in order to utilise all of the available the 2D space of the textile. By designing the 3D-Tshirt-potential of the 2D textile, design elements such as the shoulder slope and armhole shape are embedded into the weave, which then through cutting, the T-shirt form is realised, with final form construction requiring only two side seams [19].

Figure 9. T-shirt iteration Three, showing expanding layers at shoulder and armhole (in light and dark grey) to enable fit and ease of movement. Only the side seams are needed to be sewn in this t-shirt, in contrast to the usual side, shoulder and armhole seams in a conventional garment..

7. Insights and Conclusion

7.1 Pattern cutting as Flattening

All pattern cutting for cut and sew garments is a process of flattening the 3D form. Zero waste design as an experimental design practice also explores what is possible when we three-dimensionally form the flat textile. The converse of utilising origami to turn flat sheets into curved geometries (Callens, S. J. P., and Zadpoor, A. A. 2018), this hybrid zero waste research takes curved geometries (in this case T'shirts) and 'flattens' them into weave-able structures. It is an iterative 3D – 2D – 2D – 2D – 3D process (see figure 10) that transforms the outcome at every step, and flattens 3D form *into* an apparently 2D textile. I am defining the interstitial space-potential in textiles – treating the textile as 3D potential.

[19] If the T-shirt was woven in 6 layers it would not require any stitching at all.

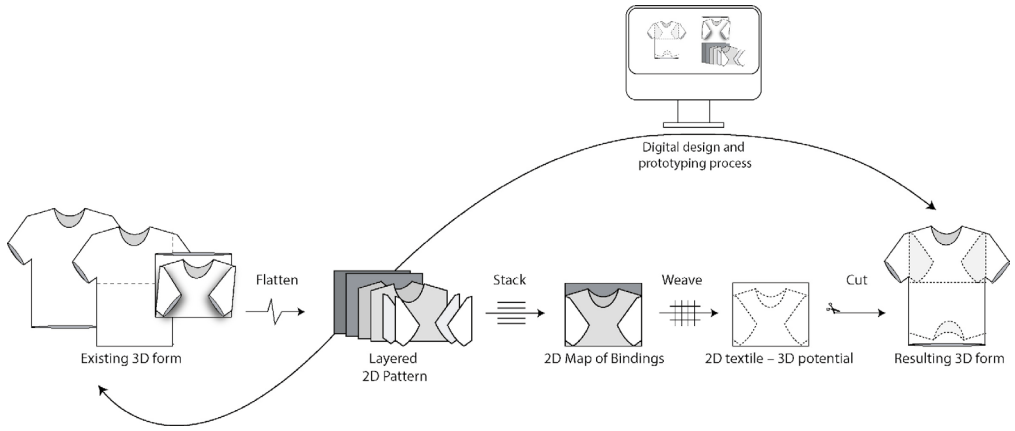

Figure 10. Proposed design model demonstrates 3D – 2D – 2D – 2D – 3D relationship, interpretation and impact. The design process is supported by a supplementary digital design and prototyping process allowing the development out complex 3D outcomes while simultaneously developing the required 2D structure.

This research presents outcomes for the human body, but they are only one set of examples. Of course this approach can be applied to many different 3D applications where we utilise woven textiles: interior furnishing (curtains and screens), furniture, spatial design, agricultural furnishings (climate screens), construction design (weave 3D building structures into flat cloth), or expanding forms used in science and technology such as folding robotics[20].

7.2 Technology – how it designs us as we design it.

It is not only the direction and method of flattening that informs and directs the expression of the form, but it is also guided by the technology utilised in its manufacture. In the case of the examples presented here the stacking, sliding and expanding techniques used directly impact on the expression of the textile surface. As the designer, I have to choose the areas where the emergence of the form should dominate the desire for a particular surface texture, or when texture and weight are more important. The direction and method the form is flattened, then further informs the textile design and resulting garment form. The design of these textile-forms is a dance between form, function and surface expression[21] which is constrained – and enabled – by the technology we use to design and produce them.

7.3 Future making for garment making

Through this research, I make examples that show how things are made while questioning why and in what context. Dilnot (in Yelevich and Adams, 2014, p. 196) argues for an ethical approach to future making asking – when designing and future building Simons (1969) "preferred" future, how do we define the ethics of this? Tonkinwise (in Yelevich and Adams, 2014) advocates for a process of intentionally designing out the things we do not need or that don't serve us – "the very active act of unmaking aspects of our locked-in world – designing things out of existence" (p. 198). In making

[20] There are other advantages – such as the ability to shipping as flat (flat pack furniture) or on a roll. The potential for the 3D forms to easily collapse back down to its flat 2D woven form can also be exploited in other areas – curtains, screens, smart textiles or even folding robotics.

[21] However at this stage many of these limitations are caused by the technology I currently have available for sampling and would radically change with changes such as utilising a higher density loom and variable yarn thickness/behaviour.

these examples it becomes clear I am not only designing something, but I am also proposing we must "design away" some of the things we already have and do.

The examples and theory explorations presented here seem situated between two seemingly opposing viewpoints within the scholarly sustainable fashion community, viewpoints which inevitably mirror the debate around wider ideas of sustainability. On the one hand, we idealise technological improvements, while we are seemingly resigned to the massive scale of the industry. There dominates a low cost, high science model of 'change without change', where industry hopes that with technological advancement in areas such as fibre recycling we can continue with the remainder of the industry as it currently operates. While on the other hand, we glorify small-scale, handcrafted garments and practices, where time and money intensive practices present a model of 'change by changing back' to how we used to do things. When invented in the early 1800s the jacquard loom was considered disruptive technology, so much so that many looms were destroyed by the workers they replaced, while the looms inventor was attacked. Eventually, society accepted the jacquard loom because of the positive change it brought to the industry. My research is 'future-making' – proposing artifacts which might exist as a result of a kind of 'high-tech cottage industry' – which suggest ways of being for designers, manufacturers and users alike.

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Holly McQuillan is a design researcher who primarily works in the field of sustainable design practice. Holly is a leader the field of zero waste fashion practice, leading workshops globally, researching, curating and designing for exhibitions and the industry. She co-authored Zero Waste Fashion Design (2016) with Timo Rissanen, and has authored or co-authored a range of articles including for Fashion Practice, and in popular media. After completing her Master of Design at Massey University in 2005, Holly was a Senior Lecturer at Massey University School of Design until 2016, before leaving that position to undertake her PhD at the Swedish School of Textiles at the University of Borås in Sweden. Her PhD explores zero waste composite garment weaving, a process which aims to fundamentally reimagine the ways in which clothing and textiles are made.