The
Garment Life Matrix

A tool for negotiating complexity in Design for Sustainability

Katrine Dalum Hesseldahl

Supervised by

Professor Sharon Baurley and Dr Bruna Petreca

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Abstract

This research project develops a new tool, 'The Garment Life Matrix' (GLM), to enable the fashion industry to shift towards a sustainable circular economy model. Fashion is a complex system, with long supply chains, and vast networks of actors and physical components participating in different parts of the system. Fashion's emissions are produced not just at the production stage, but at multiple points *throughout* the lifecycles of garments. This complexity makes it challenging for designers to identify where best to focus their efforts to conduct sustainable practice. A substantial number of strategies for Design for Sustainability (DfS) have been proposed, but the tangible impact of these on fashion design practice has been limited. A key reason for this is a lack of understanding amongst designers as to how to implement them efficiently in practice. The effectiveness of DfS strategies depends on the designer's ability to holistically consider factors which impact on a garments' sustainability and based on this understanding, select the most appropriate strategies for each case. Several tools have been developed to support designers to do this, but these do not provide sufficient consideration of crucial factors and prescribe overly granular approaches, as well as present overly complex guidance that is unsuitable for design practice.

There is a need for more straightforward and applicable support for applying DfS strategies in garment design practice. In other words, designers need a systematic approach to help them choose the most effective "tool" in the "toolbox" of DfS strategies. My project aims to redress this gap. This research project develops a tool that supports garment designers in considering and negotiating the many factors that interrelate to determine the environmental impact of garments' lifecycles.

This research project has two main contributions.

The first is the identification of a set of key factors for enabling sustainable garment design, consisting of the *primary* and *enabling factors*, and putting these factors into a relationship. The identification of these factors was based on a review of literature on DfS and DfS tools, and further established through empirical research which included two studies. Study 1, which comprised a series of interviews with consumers, investigated if/how the identified DfS-factors were affected by/affected their behaviour. And Study 2, which enriched understanding of the identified key factors by drawing in the perspective of garment industry professionals to understand if and how the identified factors were affected by/affected their practice. Findings from these studies and a supplementary review of literature were used as input for designing 'The Garment Life Matrix' (GLM) framework, which articulates the key factors for DfS and their relationship. Through a series of Research through Design experiments, the GLM framework was developed into an interactive tool, proposed as DfS support.

This leads to the thesis' second contribution: A new DfS tool and method which enables designers to manage effective selection and implementation of DfS strategies. By prompting designers to systematically consider a holistic set of DfS factors, and articulating how these correlate to affect garment's lifecycles, the GLM supports designers to competently select and combine appropriate DfS strategies for each product they are working on. The tool and method were developed and tested with garment designers through a series of action research studies. First, as support for designers to diagnose the sustainability of their current practice and pin-point relevant opportunities to improve this. Next, as support for designers to systematically select and apply appropriate DfS strategies to ensure their efficacy.

Declaration

This thesis represents partial submission for the degree of Doctor of Philosophy/ Master of Philosophy at the Royal College of Art. I confirm that the work presented here is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

During the period of registered study in which this thesis was prepared the author has not been registered for any other academic award or qualification. The material included in this thesis has not been submitted wholly or in part for any academic award or qualification other than that for which it is now submitted.

Signature: 

Date: 01.05.2023

Copyright statement

Ethics statement

Prior to undertaking any studies in this PhD research, the researcher had undertaken research ethics training. All studies described in this thesis were approved by the RCA Research Ethics committee prior to commencing and all the necessary Gatekeeper letters had been obtained and shared with the ethics committee. Before the beginning of all studies, research participants were sent an email with a Participant Information sheet and Consent form. The studies commenced once participants had signed and returned the Consent form. No participants were under the age of 18. The study followed the GDPR guidelines on privacy and data protection provided on the RCA intranet. Captured data included hand-drawn sketches and notes, video recordings, audio recordings as well as photos. Participants were informed of their rights to withdraw from the project at any time, as well as their right to withdraw their data. All digital files have been stored on the RCA's drive, and file names were coded without reference to names or other identifying words.

Before Study 2 (Chapter 5), which contained activities that required the sharing of intellectual property with industry experts, a non-disclosure agreement was signed by the participating garment conglomerate as well as by the RCA on behalf of the researcher. Before Study 3a, 3b, 4a and 4a (Chapters 7 & 8), which contained activities that required mutual sharing of intellectual property with industry partners, a collaboration agreement was signed by the two participating companies, a global swimwear brand, and Rohan Designs Ltd., as well as by the RCA on behalf of the researcher.

Ethics approval email - Royal College of Art

R

RCA Ethics <ethics@rca.ac.uk> (sent by sophie.matthews@rca.ac.uk) Wed, 15 Dec 2021, 10:30

to me, Sharon

Dear Katrine,

Many thanks for submitting your most recent Research Ethics Application Form. This has been reviewed by the Ethics Committee panel and we are pleased to inform you that, based upon the information supplied, we can approve your application and you can progress with your research.

Please note that should you make any changes to this research project, you may need to apply for further ethics approval.

Please contact us at ethics@rca.ac.uk if you have any questions about the ethics process.

Kind regards,
The Research Ethics Team

Acknowledgements

The process of this PhD project has been one of intellectual and personal development. This work was undertaken between 2019 and 2023, which was an interesting time of change in the world: The ongoing war in Ukraine, four different prime ministers in the UK, and, of course, the global COVID-19 pandemic, which have all impacted the process of this research. But most importantly, the changes in our global climate, which have grown increasingly obvious during this period, have impacted this work by motivating it.

I would like to thank the Burberry Foundation who kindly awarded me a scholarship that made this research possible, as well as my sponsors: Augustinus Fonden and Viet-Jacobsen Fonden, who have generously supported my studies here in the UK.

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I also wish to thank my colleagues at the Materials Science Research Centre at the Royal College of Art, for supporting and inspiring conversations. In addition, I would like to mention the significant support I have received from Jane Savory and Professor Catherine Dormor at the RCA whose efforts have been instrumental for this project to progress as planned, despite any administrative and COVID-related obstacles.

I want to give special thanks to the garment industry professionals from the companies who agreed to partake in this research. Thank you for your interest, and for employing your time and skills to support this research. Furthermore, I would like to thank the staff from the Nu Wardrobe and ON ROAD whose help has been invaluable for recruiting research participants.

As this project was conducted during the midst of a global pandemic, it was, for the most part, undertaken at home. The group of people who have surrounded me has often not been fellow students or colleagues, but my husband, family, and closest friends. Lucky for me, I could not have found better people to surround myself with during this time. I am thankful to my brother Mads and my parents Sus and Peter, for their continual interest and support, and for hosting me through long parts of this project on the beautiful island of Tåsinge.

Finally, I would like to thank my husband Nic, to whom I am devoted. You have been an unbelievable support throughout this project. Thank you for patiently reading, listening, challenging, and cheering me on.

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Glossary

Throughout this thesis, I use words where the meaning might not align with the common dictionary terms, and thus I here provide a glossary to specify their meaning in the context of this research.

Sustainability
The definition of the term sustainability is debated, but this thesis leans towards the following definition: the contextual and dynamic properties of systems themselves are resilient, which relates to the interactions between the environment, society, technology, culture, and economy (Faber et al., 2005; Ceschin & Gaziulusoy, 2020). This thesis primarily uses the term to describe an environmental property, and focuses less on describing social sustainability, but is based on an awareness that the two “sides” are interdependent.

Systems thinking
Systems thinking is a way of understanding and addressing complex problems by looking at the system as a whole and focusing on the interactions between the elements of the system, rather than splitting it down into its parts and addressing them separately, to understand and change the system itself (Anarow et al., 2003; Ramage & Shipp, 2009).

Circular economy (CE)
A regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops (Geissdoerfer et al., 2017).

Assemblage
From a circular economy perspective, products are always temporary; they are *assemblages*; temporary constellations of materials, components, services, etc. that have come together to form a solution for a user over a particular period (Hesseldahl et al., 2020; Petreca et al., 2022). In comparison, in a linear economic model, products are cohesive and permanent.

Enabling factors for DfS
The *enabling factors* for DfS, consist of a set of factors that are particularly influential in garments’ lifecycles, and which this thesis to be important for designers in considering design for sustainability. These factors are outlined in Chapter 4, tested, and validated through interviews with consumers and garment industry experts in Chapter 5, and further defined through a literature review in Chapter 6. The *enabling factors* are: ‘DfS strategy’, ‘Business model’, ‘Production method’, ‘Materials’, ‘Points of user engagement’ and ‘Aesthetics’.

Primary factors for DfS
The *primary factors* for DfS are factors which this research has identified as having a decisive impact on the *enabling factors*, in terms of how these factors concurrently affect garments’ lifecycles. There are two primary factors: ‘Depth of user engagement’ and ‘Use phase pace’. According to this thesis, the *primary factors* should guide decisions that impact the *enabling factors* in a DfS process to ensure efficient impact. These factors, and their decisive influence on the *enabling factors* was identified in Chapters 4-6.

Garment Life Matrix (GLM) framework
A framework which articulates the correlation between the *primary* and *enabling* factors. Each quadrant in the GLM represents a context in which the conditions for designing a garment to be sustainable are vastly different.

GLM axes
The two axes which comprise the GLM framework, present the visual articulation of the two *primary factors* ‘Use phase pace’ and ‘Depth of user engagement’ and display how these correlate.

GLM quadrant
The GLM’s structure, in which the *primary factors* are pictured on two axes in a coordinate plane, defines a possibility space within each of the GLM’s quadrants where the conditions for designing garments to be sustainable are different. Each of these quadrants represents a different segment of the garment market.

GLM tool
The GLM tool is a digital, interactive DfS tool, based on the GLM framework. The GLM tool provides DfS guidance around all the *enabling factors.* This guidance varies from quadrant to quadrant, depending on the *primary factors*. The guidance in each quadrant is provided as a *recipe* with *ingredients* as described in the following.

GLM ingredient
Each GLM *ingredient* represents a category related to one of the *enabling factors* e.g., ‘Material’ or ‘Production method’. The characteristics or nature of the guidance proposed in each *ingredient* will change depending on what GLM quadrant one is trying to design for.

GLM recipe
The GLM tool contains four *recipes,* one for each quadrant. The GLM *recipes* are collections of GLM *ingredients* that have been put together to form holistic guidance for how the characteristics of the various *ingredients* best can be combined for efficient DfS in each quadrant.

Stay or Go method
A complementary method for using the GLM tool, offers a systematic approach for designers to compartmentalise and focus their efforts in one GLM-quadrant at the time. The method guides designers to either *stay* in one GLM quadrant, or step-by-step explore what *going* to other quadrants might enable and entail.

Chapter 1

Introduction

1.1. Context of research

We are currently experiencing an environmental crisis largely caused by wasteful patterns of consumption, and the fashion industry remains one of the highest contributors. Thus, a shift to more sustainable and circular industry practices is imperative. In response, numerous Design for Sustainability (DfS) strategies have been developed, but unfortunately, there is no evidence for their tangible impact on fashion design practice (Grose et al., 2015; Fletcher, 2017; Payne, 2021). The vast scale and complex nature of this industry makes it difficult for designers to target their efforts and select appropriate DfS strategies to ensure their application will have efficient impact. As a response, the DfS field has seen a development towards more holistic approaches in recent years. However, there is still no support for garment designers which enables them to comprehend and consider the many actors and factors which influence garments' sustainability. And there is no straightforward and usable method to utilise such considerations to inform the selection and application of appropriate DfS strategies.

My research aims to address this gap by developing a new understanding of the most important factors which influence garments' environmental sustainability. Based on this knowledge, the thesis proposes that support for enabling garment designers pivot towards a systems thinking approach to consider the key factors and actors that play into garment's lifecycles, and to assess the environmental impact of their current practice and identify key areas to focus their efforts. Ultimately, the thesis aims to enable designers to systematically select and apply *appropriate* DfS strategies to ensure their specific practice has an efficient impact on industry.

1.2. Background

The fashion industry remains one of the largest contributors to climate change and pollution of our planet. It accounts for up to 35 percent of microplastics' flow into the ocean (Ellen MacArthur Foundation, 2017), and equals 4% of the global total GHG emissions (McKinsey & Global Fashion Agenda, 2020, p.3). Unfortunately, this is projected to continue: Since 2000, clothing sales have doubled (Ellen MacArthur Foundation, 2017), and global demand for garments is set to increase significantly in the coming years (Remy et al., 2016; Ellen MacArthur Foundation, 2017; McKinsey & Global Fashion Agenda, 2020). If nothing changes, the industry will use up to a quarter of the world's carbon budget by 2050 (McKinsey & Global Fashion Agenda, 2020, p.5). This rise in the garment industry is especially attributed to the phenomenon of *fast fashion*, which emerged in the 2000s, when large fashion houses pioneered new fast-paced production systems that lowered the time from design and manufacturing to retail down to as little as two weeks (Skov, 2006). Today, we see the phenomenon of *micro-seasons*, up to 52 yearly, with new trends coming out every week (Whitehead Lohr, 2014). This acceleration has changed consumer habits; across nearly every apparel category, consumers keep clothing items about half as long as 15 years ago, with consumers treating the lowest-priced garments as almost "disposable", discarding them after just seven or eight wears (Remy et al., 2016). And this is particularly problematic, as the current system of production, disposal and usage relies largely on extraction of non-renewable resources (Ellen MacArthur Foundation, 2017).

The industry must change. Aside from the many environmental reasons laid out in the above, there is an increasingly serious demand from policy makers, investors, and consumers for the industry to effect sustainable change. The Sustainable Development Goals, set in 2015 by the United Nations General Assembly and The Paris Agreement signed in 2015 by the UNFCCC nations, are both intended to support combating climate change and accelerating towards a sustainable low carbon future. This puts pressure on governments to regulate emissions, and on industry to minimise them, for the earth's temperature to stay well below a rise of two degrees Celsius (United Nations, n.d.). Furthermore, investors in the industry have become increasingly interested in the sustainability agenda, and asset owners are increasingly demanding sustainable investment strategies (Eccles & Klimenko, 2019). Finally, we see that consumers demand sustainable products, and that brands behave sustainably (Whelan & Kronthal-Sacco, 2019; McKinsey & Global Fashion Agenda, 2020; Granskog et al., 2020).

As a result, there is an increasing focus on developing more sustainable industry practices. This is not new. For decades, designers have been aware of their role in creating negative environmental impacts, and thus their responsibility for limiting them (Vezzoli & Manzini, 2008; Moreno et al., 2016; Payne, 2021). In the late 1960s, scholars such as Packard and McKibben (1963); Papanek (1971) and Schumacher (1973) first

criticised industrial design as a "harmful profession" and pointed to the responsibility of designers to use their capabilities to change the world we live in for the better (Papanek, 1971). Since then, numerous DfS strategies have emerged. The earliest of these, such as Green Design and Eco Design, are preventative. They seek to lessen environmental damage in the processes of creating and discarding products. In later years, the field has expanded to a more holistic focus (Coley & Lemon, 2009; Moreno et al., 2016).

Arguably, the most important development since the emergence of sustainable practices has been the recognition of a need for a total systemic shift towards more sustainable models of design, production, and consumption (Ellen MacArthur Foundation, 2019; European Commission, 2020; IPCC, 2014). Rather than just designing consumer products that are less bad for the environment, these approaches suggest holistic systems thinking as a more productive perspective for such a shift (Meadows et al., 1972). The proposal of a *circular economy* (CE), where the notion of waste is eradicated and all materials instead are understood as continuously looped back to be used within a system, has been widely acknowledged as an alternative strategy to achieve sustainability (Bocken et al., 2016; Webster et al. 2017; Ellen MacArthur Foundation, 2019; Goldsworthy, Earley & Politowicz, 2019; European Commission, 2020; Design Council, 2021).

Designing for a circular economy is entirely different to the current linear "take-make-dispose" model. It goes beyond the traditional design process, obligating designers to consider the product's lifecycle they are designing for as a whole (Moreno et al., 2016, Ellen MacArthur Foundation, 2017). Designing for a circular economy requires designers to understand their role as actors within a larger network. Such a systems approach encourages the development of partnerships between the many actors from different disciplines and sectors, involved at various stages of a product's lifecycle (Stasinopoulos et al., 2009). Crucially, the system also includes consumers, who play an important role. Their behaviour determines what resources are spent during the use phase, the length of the use phase, and if the product is successfully returned for reuse in material loops.

Despite the broadly acknowledged view that moving to a circular economy is an integral part of achieving sustainability, most existing design approaches have focused on two things:

1. Changing the design of the individual product as a stand-alone object, rather than as part of a larger system, whose parts need to be taken into account (Moreno et al., 2016).
2. Slowing down the use cycle of products, rather than designing products that can be reintroduced into material loops.

These approaches still follow the conventional linear "take-make-dispose" model of resource use, rather than trying to design for closing material loops (Moreno et al., 2016; Goldsworthy et al., 2019).

Some approaches which include systems thinking, such as Design for Social Innovation (Manzini, 2015), Product-Service System Design (Vezzoli et al., 2014), and Systemic Design (Barbero & Toso, 2010), have been proposed to aid development of sustainable solutions.
However, the complexity of the fashion industry as a system, with its long supply chains and vast networks of actors, complicates such approaches, and there is very little guidance for designers on how to efficiently implement them in practice (Charnley et al., 2010). Thus, there is a need for a comprehensive, systematic approach to help designers gain an overview of the system they are interacting with and the actors within it. Designers need support to help them to choose the most relevant and effective “tool” in the “toolbox” of DfS strategies.

My project aims to redress this gap and explore how systems thinking within a circular economy can assist DfS approaches in fashion design.

Researcher’s background

As a designer (industrial designer by education), I have always strived to design for sustainability. I have designed a range of services and products from private waste-sorting solutions to clothes-swapping apps, bicycles, hydroponic gardening systems, urban chicken coops and furniture solutions for a circular economy. I have spent several years educating myself and experimenting to find ways to contribute to the transition to a circular economy. Regardless, I still feel overwhelmed and unequipped for dealing with the challenge and complexity which design for sustainability - if it is to be truly impactful - presents. Thus, immersing myself deeply in dealing with this issue through this research project, was a welcome opportunity.

1.3. Research objectives

This thesis aimed to develop new support for designers to select and combine appropriate DfS strategies, to facilitate a shift towards a circular economy and ensure their efforts have an efficient, positive impact on garment sustainability.

Whereas current DfS approaches pursue a conventionally linear model, aimed at identifying and controlling only those relevant factors that pertain to the product itself, and at slowing the life cycle of a product as a stand-alone object, this thesis has proposed a shift in how factors which impact sustainability are considered and negotiated in garment design.

Based on the principles of design for a circular economy and informed by systems thinking, this was achieved by investigating the networks of dynamic and interacting parts that affect the sustainability of a product, to develop support for designers to understand how the change of one element of a product’s system can influence all the other elements in the system. This understanding has been proposed to support designers to negotiate decisions in a DfS process and enable them to design more efficiently with DfS strategies.

These research objectives were defined through a broad initial phase of qualitative exploratory research, which also helped define four research questions which guided the investigations in this research. As the project progressed, these questions have been iteratively revised to reflect insights. To give an overview of the research structure, Table 1 presents these questions in connection to the studies through which these questions have been addressed.

Table 1. Programme of research and structure of the thesis

Focus	Research Question	Chapter & Study	Objectives	Main Findings
Research Clarification	***RQ1*** *What support do garment designers currently have to design for sustainability?*	***Chapter 2*** Literature review	To critically assess existing DfS support for garment designers and identify potential shortcomings to address	- A shift to a sustainable fashion industry requires designers to take a holistic approach. - Despite a substantial amount of existing DfS strategies and tools, there is still no evidence of their impact on the fashion industry. - There is a lack of straightforward and actionable support for garment designers to take a holistic approach to design efficiently with DfS strategies
	RQ2 *How have existing DfS strategies been applied in practice?*	***Chapter 4*** Review of sustainable business cases	To investigate examples of existing DfS approaches applied in practice, and identify key characteristics of successful models	- Successful examples exist, but they struggle to scale and often employ the least impactful DfS-strategies. - Identified a set of the most important *enabling factors* for sustainable garment design
Descriptive studies 1	***RQ3*** *What are the most important design factors for garment sustainability?* ***RQ3a*** *How might these factors be related?*	***Chapter 5*** Study 1 Study 2 ***Chapter 6*** Supplementary literature review	To generate understanding of the most important factors for garments' environmental impact, and how these correlate	- Identified two factors, 'Use phase pace' and 'Depth of user engagement', as supremely influential *primary factors*, which have a decisive impact on the other *enabling factors* - Established that consideration of the *primary factors* should guide designers' decisions around the other enabling factors to enable efficient DfS - Articulation of the correlation between the *primary* and *enabling factors* in the Garment Life Matrix (GLM)
Prescriptive studies & Evaluation	***RQ4*** *How might consideration of these key design factors be structured to guide decision-making processes to enable efficient, systems-aware Design for Sustainability?*	***Chapter 7*** Study 3a Study 4a ***Chapter 8*** Study 3b Study 4b	To propose new support for garment designers to design effectively with DfS strategies	- Designed the GLM tool and complementary 'Stay or Go' method. Validation confirms support for garment designers to design efficiently with DfS strategies, through: 1) Holistic and systematic consideration of DfS factors and their relationship 2) Selection and combination of appropriate DfS strategies for each product and use-context 3) Systematic, cross-disciplinary discussion and collaboration

Question 1 *(What support do garment designers currently have to design for sustainability?)*
This question responds to the unsustainable nature of the garment industry and the lack of proven impact of existing DfS strategies, which is identified in the Background Section 1.2. This question is concerned with providing a critical assessment of existing DfS support for garment designers to identify shortcomings of existing approaches. This question is addressed in Chapter 2, which includes a literature review of existing DfS support and specifies the gap in knowledge which this research is addressing.

Question 2 *(How have existing DfS strategies been applied in practice?)*
The objective of RQ2 is to investigate and assess how existing DfS support currently has been applied in practice, and to identify key characteristics of successful models. This question is addressed through Chapter 4, which comprises a series of case studies of businesses across a range of sectors from furniture, to packaging and transport, that represents illustrative examples of successful application of DfS strategies.

Question 3 *(What are the most important design factors for garment sustainability?)*
Question 3a *(How might these factors be related?)*
The components of this question respond to the lack of understanding of the many factors that determine a garment's environmental impact, which is identified in Chapter 2, Section 2.7. These questions (3 & 3a) are addressed partly through Chapters 4-6. In Chapter 4, the review of exemplary business cases resulted in the identification of a set of particularly important *enabling* and *primary* factors for DfS. These findings are confirmed and extended in Chapter 5 through two empirical studies to investigate how these factors for DfS influence garments' lifecycles from the perspective of consumers (Study 1) and industry professionals (Study 2). Furthermore, these studies investigate how the factors correlate to affect garment sustainability. To articulate and further develop the understanding of these factors, a preliminary framework, the Garment Life Matrix (GLM), was developed in section 5.1.3. The supplementary review of literature, described in Chapter 6, is conducted to further define and build theoretical support for each of the identified *primary* and *enabling* factors, and to detail how these correlate.

Question 4 *(How might consideration of these key design factors be structured to guide decision-making processes to enable efficient, systems-aware Design for Sustainability?)*
This question responds directly to the gap in knowledge, which is identified in Chapter 2, as a comparative lack of straightforward and actionable support for garment designers to take a holistic approach to design with DfS strategies, allowing designers to negotiate the complexity of the relationship between the many factors that correlate to affect garments' environmental impact. This question is addressed in Chapters 7-8 by proposing a new tool and method for DfS, based on input from findings from Chapters 4-6. Through an action research approach (Swann, 2002) using workshops and practice-based experiments with garment designers, this tool and method is iteratively tested and developed as support for sustainable garment design.

1.4. Thesis structure

This thesis has nine chapters, and the Chapters (2 - 8) are summarised above in Table 1. Chapter 2 comprises the literature review and Chapter 3 presents the methodology that this thesis applies. The main research Chapters (4-8), except one (Chapter 6), comprise empirical studies. Chapter 4 presents the first empirical study, a comparative case study of exemplary businesses who have employed DfS strategies in practice. Chapter 5 takes a qualitative exploratory approach to investigate the most important factors for garment sustainability through interviews with consumers and focus groups of industry experts. Chapter 6 comprises a complementary literature review which refines and builds support for findings from Chapter 5. The latter provides support for the next step of research described in Chapter 7 and 8, where a new tool to support garment designers to design for sustainability is developed and evaluated. Chapter 9 presents a concluding summary, including conclusions, contributions to knowledge and future work. The main research Chapters (4-8) are summarised in more detail below.

Chapter 4: Review of DfS applied in practice

Responding to RQ2: *How have existing DfS strategies been applied in practice?*
The aim of this chapter is to investigate real-world, state-of-the-art examples of businesses which have managed to apply some of DfS strategies into their practice. This assists in understanding which strategies have been applied and how, and in determining the characteristics of successful models.
This is done through a comparative analysis of a range of exemplary business cases, which have implemented DfS strategies into their practice. Findings from this analysis allows for the proposal of a set of enabling factors which are particularly important for DfS. Furthermore, the findings from this study also indicate that two of these factors are supremely influential primary factors, which have a decisive impact on the other enabling factors. Thus, this chapter also contributes towards responding to RQ3, which was concerned with identification of the most important design factors for garment sustainability.

Chapter 5: Investigating the enabling and primary factors for DfS

Responding to RQ 3: *What are the most important design factors for garment sustainability?* And RQ3a: *How might these factors be related?*

The aim of this chapter is to build further understanding of the identified most important, *primary* and *enabling factors* for sustainable garment design, and how these are related.

This chapter presents two qualitative exploratory studies; Study 1 with consumers, and Study 2 with garment industry experts, focused on developing an understanding of the *enabling* and *primary factors'* influence on garments' lifecycles informed by the perspective of each of these groups.
Thematic Analysis of these studies resulted in further confirmation of the *primary* and *enabling factors* for DfS. Furthermore, a series of iterative Research Through Design experiments, described in Sections 5.1.4. and 5.4 confirmed and developed the understanding of the relationship between these factors. Ultimately, these experiments led to the establishment of a framework which articulates the correlation between the *primary* and *enabling* factors: the Garment Life Matrix (GLM).

Chapter 6: Refining the Garment Life Matrix elements – Additional literature on DfS factors

This chapter situates the previous empirical findings within a review of DfS literature, in order to further refine an understanding of how the ingredients (*enabling factors*) in each recipe should be configured to ensure their guidance will lead to a sustainable outcome.

The aim of the next two chapters (Chapters 7-8) to iteratively test and develop the proposed GLM framework to move towards the ultimate goal of this thesis: the provision support for garment designers to design effectively with DfS strategies.

Chapter 7: Testing the GLM as a tool for diagnosing sustainability and identifying opportunities for improving sustainability of current practice

Responding to RQ 4 *How might consideration of these key design factors be structured to guide decision-making processes to enable efficient, systems-aware Design for Sustainability?*

At the beginning of this chapter, in Section 7.1.2, the findings from Chapters 4-6 are used as input for developing a new, interactive Garment Life Matrix tool and a supplementary 'Stay or Go' method.

The two studies 3a and 4a are conducted to test and validate the ability of the new GLM tool and method to support designers in diagnosing the sustainability of their current practice and identify relevant opportunities for intervening to improve this.

These studies are run as workshops with design teams from two different garment companies. Each team is tasked with mapping their current range in the GLM framework to gain an overview of sustainability-related issues and pin-point areas or products which are particularly relevant for creating improvements in sustainable design. The GLM tool is then used to generate ideas for how the designers might approach such improvements.

Chapter 8: Testing the GLM as support for efficient, systems-aware DfS

The aim of this chapter is to test and validate the GLM framework and the ‘Stay or Go’ method as support for designers to design effectively with DfS strategies in practice.

This is achieved through two practice-based studies: Study 3b and 4b. Each study comprises a design experiment in which garment designers are tasked with redesigning a small selection of products from their company’s range to be more sustainable, while using the GLM tool and the ‘Stay or Go’ method for support. As these studies are a continuation of Studies 3a and 4a, the participants are able to bring knowledge generated in previous studies into these practice-based studies.

The prototype-outcomes from these studies serve as exemplary instances and validation of the proposed support applied in practice, and the findings which emerged from Thematic Analysis of study data served as the final test of the DfS support developed in this thesis.

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Chapter 2

Literature review

Parts of this chapter were published in:

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Design plays an important role in fashion's transition to a more sustainable model of consumption, as most of a product's environmental impact is determined during the design phase (Charter & Tischner, 2001; Ramani et al, 2010). Several approaches for DfS have been developed (Bhamra & Lofthouse, 2007; Vezzoli & Manzini, 2008; Moreno et al., 2016; Ceschin & Gaziuliusoy, 2020), but unfortunately, there is little evidence of their impact (Grose et al., 2015; Fletcher, 2017; Payne, 2021). Accordingly, there has been a call for more holistic approaches, and applying systems thinking to meet the scale and complexity of the challenges faced and facilitate a shift towards a Circular Economy (CE) (Charnley et al., 2011; Moreno et al., 2016; Ceschin & Gaziulusoy, 2020).

Such systems thinking approaches led to a reconsideration of the role of the designer, and of the consumer, in regard to creation and consumption of fashion. In a circular economy, designers and consumers are both important actors within a network of interdependent parts. Therefore, developing an understanding of how designers can consider and involve other system-actors, including consumers, is useful for enabling circularity.

Furthermore, the systems perspective that the circular economy provides also helps refine the idea of what a 'product' actually is. In the perspective of a linear economy model, a product is something cohesive and permanent. From the perspective of a circular economy model, products are always temporary; they can be defined as *assemblages* - constellations of constantly shifting materials, components and services that provide a temporary solution for a user - which accommodate the different lifecycle paces of the assemblage's components (Gregson et al., 2010; Hesseldahl et al., 2020; Petreca et al., 2022). Designers, users, and other stakeholders all play a role in facilitating these varying lifecycles. Presenting a new understanding of the role of 'designer', 'consumer' and 'product' within a circular economy puts us in a better position to be able to think about what strategies designers can implement to design efficiently for sustainability.

A systems thinking approach to circular product design allows us to consider how and when each component might best be looped back into a prospective circular system. Instead of attempting to understand the role of individual products within a broader system, it allows for a highly granular and precise approach to designing fashion products for a circular economy.

As mentioned earlier in this section, there has been significant efforts in research and practice towards developing more sustainable strategies and approaches for design (Vezzoli & Manzini, 2008; Moreno et al., 2016, Bocken et al., 2016; Ceschin & Gaziulusoy, 2020). But unfortunately, there is little evidence of their efficacy and uptake by designers in practice (Lofthouse, 2006; Stevenson, 2013; Perez, 2016; Fletcher, 2017; Payne, 2021; Farri, et al., 2022). To begin to address this gap in knowledge, this literature review aims to produce a more detailed understanding of the DfS-support currently available for garment designers. Firstly, existing DfS strategies and methods are investigated through a review of literature to form an overview of their scope, strengths, and shortcomings. Secondly, a review of a selection of existing DfS tools is conducted to determine best practice and identify potential shortcomings where these can be improved.

Below I lay out and signpost the gap in knowledge which this thesis aims to bridge. Firstly, I explain my theoretical lens of systems thinking through which I review literature, then I go through the necessary fundamental changes in the roles and relationships between designers, users and products that occur in the shift from a linear to a circular economy. Next, I lay out an overview of existing DfS and circular economy strategies and toolkits, particularly focused on fashion and textile industry approaches. I critique them and discuss which of these existing strategies might be most promising for making current practices more sustainable. I conclude this chapter by describing the gap in knowledge where current approaches are lacking.

2.1. Systems thinking as a lens

Systems thinking is defined as *"a discipline for seeing wholes and a framework for seeing interrelationships rather than things, for seeing patterns of change rather than static snapshots"* (Senge, 1990, p.59). In this literature review, I use systems thinking as a theoretical lens through which to review existing DfS approaches.

A system is defined as *"a set of elements or parts that is coherently organized and interconnected in a pattern or structure that produces a characteristic set of behaviours, often classified as its 'function' or 'purpose"* (Meadows, 2008, p.188). In design, systems thinking involves consideration of each of the elements involved in a project, how these relate to each other and the surrounding environment, and importantly, how the system will change over time (Design Council, 2021). An important aspect of systems thinking is *leverage points*. Donella Meadows (2008) describes the notion of *leverage points* as *"places in the system where a small change could lead to a large shift in behaviours"* (2008, p.145), and lists six of these crucial places to intervene in a system, ranked in order from least to most effective as shown in Figure 1.

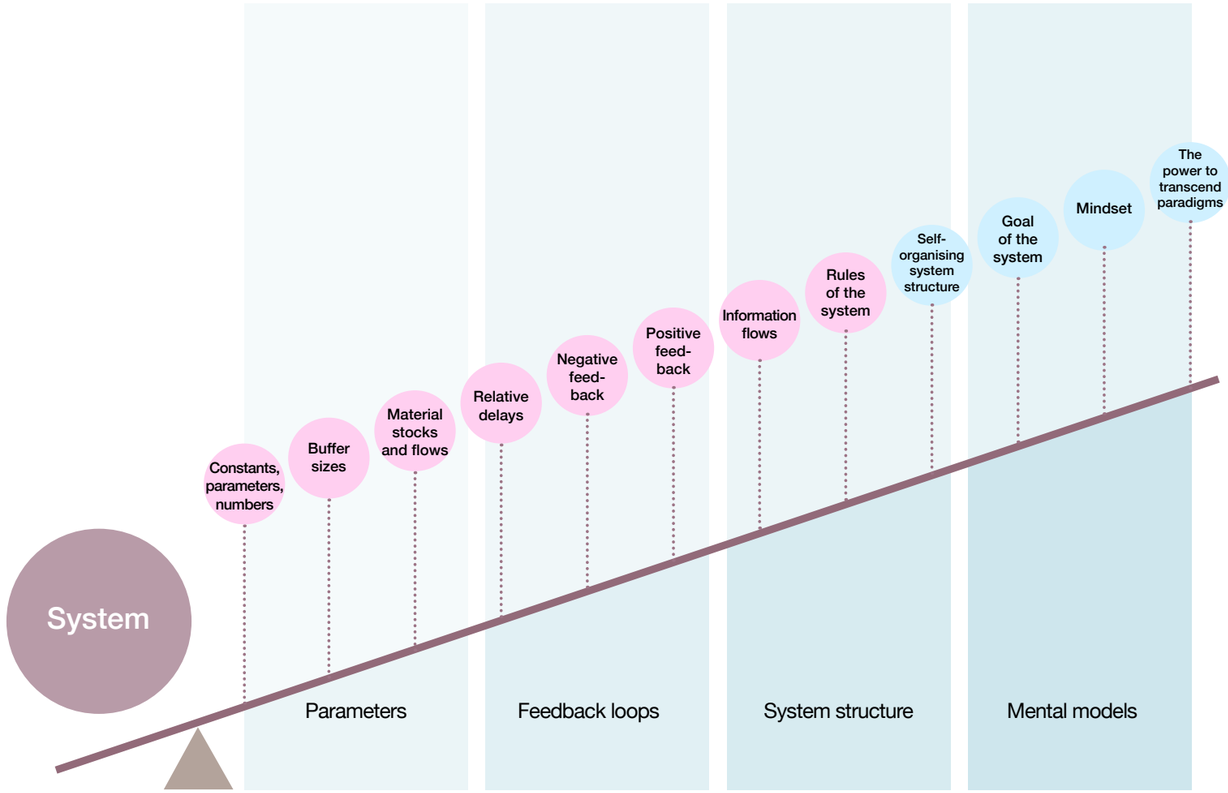

Figure 1. Donella Meadows' (1999) leverage points
(Diagram by Katrine Hesseldahl, adapted from Abson et al. 2016)

Leverage points are extremely useful for designers to better understand their own place in a system, and, importantly, for identifying useful places in the system they can intervene to have a positive and sustainable impact. As we shall see below (Section 2.5.1.), DfS strategies can also be assessed according to which leverage points they focus on and consequently, the scale of systemic impact a strategy achieves.

At a smaller scale, leverage points can also be identified within products themselves to support a circular economy: as described above (p.31) products in a CE are 'assemblages' - constellations of constantly shifting materials, components and services that provide a temporary solution for a user, the lifecycles of which are concurrently facilitated by designers, users, and other stakeholders. In other words, a product can be seen as a system in itself, with leverage points that can be identified and addressed to impact outcomes. Furthermore, understanding products as assemblages acknowledges that their components age at different paces and contain their own inherent lifecycles (Brand, 1999). Thus, a systems thinking approach to circular product design allows us to consider how and when each component might best be looped back into a circular system.

The benefits of employing systems thinking to enable a more sustainable society has been described by a body of scholarship (Meadows et al.,1972; Senge, 1990; Brand, 1999; Anarow et al., 2003; Seiffert & Loch, 2005; Rockström et al., 2009; Coley & Lemon, 2009; Charnley et al., 2011; Ceschin & Gaziulusoy, 2016; Raworth, 2017).

Several authors have also argued for the importance of employing systems thinking in promoting sustainable fashion production (Fletcher, 2007; Hethorn & Ulasewicz, 2008; Niinimäki, 2011; Armstrong & LeHew, 2011; Niinimäki & Hassi, 2011; Fletcher et al., 2012; Earley & Goldsworthy, 2015; Cataldi et al., 2017; Kozlowski et al., 2018). More recently, Alice Payne (2021, p.15-20) proposed a useful analysis of the fashion industry as a complete system composed of three facets:

1. 'Fashion-as-culture'
   (the symbolic meanings that are held in the clothes we dress our bodies with),
2. 'Fashion-as-industry'
   (the technology and labour it takes to construct them),
3. 'Fashion-as-change'
   (the changing norms and trends in response to the mood of the time).

These facets provide a helpful overview and understanding of the entwined elements and networks within the fashion system.

There is a further important aspect to Payne's systems thinking approach to fashion. Building on Fry (2009) and Willis (2006), Payne states that fashion design isn't just the practice of designing physical objects. It is also the design of "weightless", immaterial objects: the intangible style elements and narratives related to brand, trend, and style (Payne 2021, pp.123 -140). These immaterial design properties predicate the material product itself and influence the pace at which a product, and the components within it, will change. Understanding how these "weightless" elements are inextricably linked with the physical side of garments, allows the designer to make more sophisticated interventions in designing for sustainability.

2.2. The role of the consumer

A consequence of looking at the fashion garment from a systems perspective, as an assemblage that involves a complex network of actors, is that the role of the user becomes more important to the identity of the product itself; a user's behaviour can be seen to have a direct impact on the nature and function of the product. From this perspective, the divide between users and designers is to some degree blurred. Understanding how users can contribute to the lifecycle of a fashion product has a direct impact on its design and can motivate a shift towards circular design practices. I shall discuss this relationship in the following sections, focusing first on the role of the consumer, and then that of the designer.

This systems thinking approach requires us to see the production and consumption of fashion garments not as a one-way transaction, but rather the result of a complex system with a network of actors who "*work together to 'design' the objects and processes of fashion"* (Payne, 2021, p.13). Everyone participates in the fashion system, whether they know it or not. The simple act of getting dressed in the morning is unavoidably a "fashioning" of oneself in relation to societal group, culture, and time (Bruzzi & Gibson, 2000). Users act in the fashion system by wearing a garment, but also in more implicit ways, for example, by sharing garments via social media, deciding whether and where to acquire a garment, styling it, deciding how/ if to care for it, and, eventually, how/when to discard it.

Thus, the consumer plays an important role in a systems approach to designing fashion products for a circular economy, in which products are understood as 'assemblages'. In this context, the user is an important actor in ensuring that the product is successfully transferred between these cycles of use. The user plays an important role through other interactions such as repair, reuse, recycle, remanufacture, and take-back systems. Once a product has reached the end of a cycle of use, its materials can be potentially disassembled and moved to form other products in a new lifecycle, with a new user. This approach can be further refined if we look at the different paces of the various components of a fashion product, and the ways in which the user engages with these components. This can happen at all stages of the recycling hierarchy - from repairing an item, reusing an intact product component, to recycling the materials by handing in the textiles to be processed for its fibres to be woven into the fabric of an entirely different product.

From a systems perspective, there are a series of leverage points during a user's experience of a garment where they can participate, and these points need to be designed to offer the optimal conditions if we want users to participate. It is particularly relevant to consider users as important network actors in the fashion system: the speed and success of this industry is driven by consumers' desire to express identity. It is exactly through the intangible, "weightless" design objects related to brand, trend, and style (as described by Payne, 2021) that users can be engaged; the value of a fashion product becomes a result of "meaning making", instead of only being embodied in the physical product (Hussain et al., 2020). The value that a fashion garment can offer relies on the participation of consumers who *"actively rework and transform symbolic meanings encoded in advertisements, brands, retail settings, or material goods"* (Arnould & Thompson, 2005, p.871).

Considering users' role as actors in garments' lifecycles in a circular economy doesn't necessarily require the consumer to become a dedicated, conscious, intentional participant. Rather, it is simply an aspect for the designer to consider, taking into account the level to which she can rely on the consumer to be interested in participating, to determine whether to a) encourage and enable more engagement, or b) build easy

and implicitly sustainable choices into the product, and thus place the responsibility for its circularity upon the surrounding system. Whilst scholars such as Fletcher (2012) and Wastling et al. (2018) argue for a more active and conscious role of the consumer within a sustainable and circular system, there is a further layer to this narrative. Recent studies such as Armstrong et al. (2016), and Maldini et al. (2019) have detailed how the increased emotional involvement of the consumer in a product's lifecycle does not necessarily lead to more sustainable outcomes. Chapman (2021) argues that consumers only have the capacity to engage meaningfully with a fraction of the products they own. This should prompt a reconsideration of the role of the consumer in sustainable design. Determining the "right" amount and/or type of user engagement during a product's lifecycle will depend on a broad range of factors connected to the wider system along with, and beyond, the individual user's desires, needs and skills - such as the garment's business model or the production system it sits within.

2.3. The role of designers in a circular economy

The role of the designer has become complicated in the 21st century. The role of production has shifted from the 20th century factory assemblage model to an emerging logic of hobbyists and makers, who play a significant role in the creation of product value, particularly within the context of circular design. The user can now play an integral role in the design of a product, and this challenges the conventional identity of the designer as primary creator. Coley and Lemon state: *"more innovative and sustainable solutions increasingly require the integration of multiple stakeholders with an expansive array of knowledge and expertise*" (Coley & Lemon, 2009, p.3).

This trend has led to an emphasis on *co-design*, a human-centred design approach, which stresses the close interaction between user and designer and brings the user into the design process as a contributing player (Sanders & Stappers, 2008). Ezio Manzini describes this shift in design practice succinctly, referring to the notions of *expert design* and *diffuse design*. *Expert design* is defined as performed by those who have been trained as designers. On the other hand, *diffuse design* can be performed by everybody (Manzini, 2015, p.37). For co-design to work, it requires professional designers to be willing to share control over the project (Sanders & Stappers, 2008).

Focusing on fashion, Payne frames fashion design as *"the chain of decisions leading to a fashion object"* (Payne, 2021, p.8), and describes how these decisions are made by networks of different actors. Similar to Manzini, Payne (2021) separates out professional designers as a distinct group but looks more broadly at all the other actors in the system, in order to propose a flattening of the term 'fashion design'. This also means

including the designed object itself as an object that acts and contributes to the design process, alongside human actors.

The increasingly complex relationship between user, designer and product necessarily has an impact on the nature and function of the product itself; a higher number of actors and inputs wish to change the product from a standalone, linear entity to one that is more iterative and complex; in line with the above description of products in a circular economy as 'assemblages'.

Systems thinking theorists such as Findeli (2001), Sanders & Stappers (2008) and Tonkinwise (2015) map out the shift from the classic, causal model of the design towards a concept of design that is aware of its role within a larger, dynamic network. The function of the designer is thus equally the encouragement and coordination of various stakeholders, users, co-creators, and other designers, as much as the creation of the product itself. Conventionally, designers set out to identify problems and then develop a finished solution. From the perspective of systems thinking, this is not possible: a product is continually changed by its context and user.

From looking into the current and emerging role of designers wanting to contribute to a circular economy, I now turn to review the strategies and guidelines designers currently have available to support them.

2.4. Design for Sustainability - from components to systems

Designers are recognised as playing an important role for sustainability at the beginning of the process of developing a new product, determining technological, social, and environmental costs (World Commission on Environment and Development, 1987; Graedel et al., 1995).

In the 1960s, Packard & McKibben (1963), Papanek (1971), and Schumacher (1973) were some of the first scholars to criticise industrial design as a "harmful profession" (Papanek, 1971, p.ix), and point to the responsibility of designers to use their capabilities to create positive change. Since then, a large number of strategies for sustainable design practice have been developed. Scholars such as Moreno et al. (2016), Bocken et al. (2016), and Ceschin & Gaziulusoy (2020) have produced extensive reviews of existing DfS approaches. An important tendency, observed by these scholars, is that DfS approaches have broadened in scope over time, from a focus on minimising environmental impact of product-parts to more holistic, long-term, and large-scale systemic transformations. First, strategies such as 'Green Design' and 'Eco-design'

emerged to help designers create products that are less harmful for the environment (Brezet & van Hemel, 1997). Later, in the 1990s, 'Sustainable Design' was introduced; this approach started to include social issues such as designing to address human needs and socially responsible sourcing and manufacturing (Bhamra & Lofthouse, 2007). These early strategies have two key things in common: they focus primarily on preventative approaches, and they follow a linear pattern of take-make-use-dispose consumption. Over the last fifty years the field has developed significantly towards a more holistic concept (Ceschin & Gaziulusoy, 2020), to the point where the need for designers to consider the whole lifecycle of products is a *"consistent theme in the literature*" (Kozlowski et al., 2019, p.1). In the early 2000s Braungart & McDonough (2002, p.62) criticised Green Design and Eco-design approaches for being inefficient, as they were based on a linear model of consumption and didn't include considerations beyond the use phases such as recovery and re-use of materials. Instead, they, along with other thinkers such as Stahel (1994) and Benyus (2002), proposed the idea of a *circular economy*.

A circular economy

The circular economy (CE) can be defined 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"* (Geissdoerfer et al., 2017, p.766).

To enable a circular economy, McDonough and Braungart (2002) proposed the 'Cradle-to-cradle' approach, in which outputs from one system (waste) become inputs (resources) for other systems. They split the system of resource flows into two cycles; the *technical cycle*, where inorganic or synthetic materials are continually used in closed loops, and the *biological cycle*, where organic nutrients are either returned for direct reuse or decomposed to become nutrients for the wider system (Ellen MacArthur Foundation, 2017). The concept of these two types of cycles is relatively straightforward, however, there is a hierarchy that governs how materials are best circulated: interventions that prevent waste altogether have the highest priority, followed by reuse, and the least desirable method for circulation is energy recovery through incineration of waste or landfill (DEFRA, 2012; Payne, 2021). As Webster et al. state, a CE approach *"aims to keep products, components and materials at their highest utility and value, at all times"* (2017, p.16). Webster et al. define the value of materials both as their economic value and their ability to be used again, either directly in the same product or as part of a new one. Hence the related CE concepts of 'upcycling' and 'downcycling', which refer to whether materials are converted into something of higher value (upcycling), or whether their quality is reduced over time to be used in lower-value products (downcycling) (Webster et al., 2017).

The link between sustainability and CE not always clear (Kirchherr et al., 2017; Geissdoerfer et al., 2017; Corvellec et al., 2022); some scholars argue that the idea of closed loops can be used to excuse the continuation of current fast-paced unsustainable consumption patterns under the pretence that as long as it is "circular" we can consume as much as we desire (Moreno et al., 2016; Blum et al., 2020). This is problematic, as it is almost impossible to avoid leaks of material out of the "closed loop" system (Mavropoulos & Nielsen, 2020). Finally, from a systems perspective, even if designing for a CE fundamentally alters the economic system, it is still not addressing the higher systemic leverage points (Meadows, 2008): the system's goal and the overall paradigm under which the system functions remains continued economic growth (Schröder et al., 2019; Corvellec, et al., 2022). Regardless, the circular economy still stands as a relevant economic reality to strive towards, and it is considered a key principle for industrial and environmental policies all over the world (Winans et al., 2017; Camacho-Otero et al., 2019; Völker et al., 2020; European Commission, 2020; Corvellec et al., 2022).Yet it is important to acknowledge some of its most important limitations, and I take these into account when developing new support for DfS in fashion.

2.5. Existing support for DfS - Strategies and tools

The theoretical foundations of moving to a more sustainable fashion industry have now been established: the need for taking a holistic, systems-aware approach and moving towards a circular economy, and how the role of consumers and designers will have to change to facilitate this. Establishing how designers might go about implementing these changes in practice is the real challenge. As established by several authors (e.g., Baumann et al., 2002; Knight and Jenkins 2009; Bovea and Pérez-Belis, 2012; Connor-Crabb, 2017; Payne, 2021), many strategies, methodologies and toolkits have been developed to enable garment designers to design for sustainability, however, these are not being implemented in industry.

In this section I shall therefore review literature on existing support for DfS, with a particular focus on those strategies and tools that are relevant for garment designers. Firstly, in section 2.5.1., I provide an overview and discussion of existing DfS strategies according to their potential 'level of innovation' (described in the following section). In section 2.5.2, I review literature on existing DfS tools, and in Section 2.5.3, I critically review a selection of existing tools and guidance for designers to implement these strategies in practice.

2.5.1. Existing DfS strategies

As mentioned, a wealth of DfS strategies has been developed since the 1960s. These strategies have been reviewed and categorised by many scholars (Vezzoli & Manzini, 2008; Bhamra & Lofthouse, 2007; Clark et al., 2009; Go et al.,2015). The review in this thesis draws particularly on the work of Moreno et al. (2016), Bocken et al. (2016), and Ceschin and Gaziulusoy (2020), who have done extensive literature reviews of existing strategies and developed useful taxonomies and frameworks to describe these. This review draws a great deal of its terminology and structure from Bocken et al. (2016) who use the terms ‘slowing’, ‘closing’ and ‘narrowing’ loops (originating from Stahel, 1994, 2010; and Braungart & McDonough, 2002) to categorise strategies according to the mechanisms by which resources flow through a system. Furthermore, this review uses Goldsworthy et al.’s (2019) notion of ‘longevity’, which differentiates between approaches for ‘product longevity’, that focus on extending the life of products to get as much use from them as possible, and ‘material longevity’ that focus on multiple loops of efficient reuse of materials, as a way to structure circular economy design thinking in a comprehensible way.

Most existing DfS strategies have been developed for or within other design disciplines than fashion (Payne, 2021). Regardless, many have been discussed and applied in the context of fashion by a range of scholars such as Fletcher (2008), Parker and Dickson (2009), Gwilt (2014), Kozlowski et al. (2018), Goldsworthy et al. (2019). The work of these scholars has served as helpful support for understanding the potential for these strategies to impact change in the fashion industry. Thus, despite this thesis’ focus on the fashion industry, the strategies included in this review are more general strategies, applicable across all fields of product and industrial design. However, each of these strategies have been analysed from the perspective of how they might be implemented and support designers to improve sustainability in the fashion industry.

To enable a systematic review of DfS strategies, and to understand their potential impact on the fashion industry, this review draws on the ‘DfS innovation framework’ (shown in Figure 2), originally created by Ceschin and Gaziulusoy (2020) to support the analysis of the various DfS strategies from a systems thinking perspective. The DfS innovation framework organises DfS strategies on four “innovation levels”, according to the scale of systemic impact.

These four levels are:

1) Product level, which aims to improve existing and/or develop novel products.

2) Product-Service System level, which entails a more holistic perspective to include consideration of the processes of production and consumption, i.e., how the industry is organised and how consumers act within it.

3) Spatio-Social level, where product-level innovation and sustainable business models are combined to impact on the structure of the industry in itself

4) Socio-Technical System innovation level, the highest level where the entire system (of fashion) is transformed.

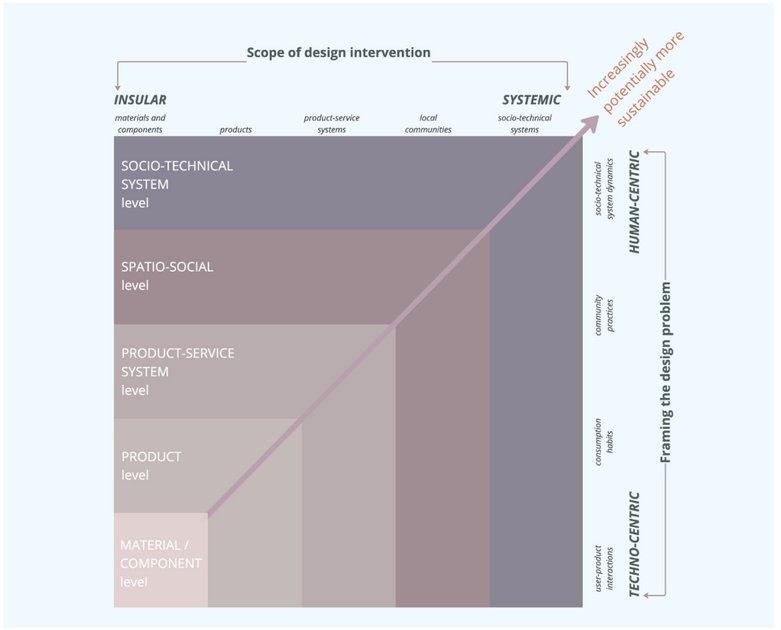

Figure 2. The DfS innovation framework
(Diagram Katrine Hesseldahl, adapted from Ceschin & Gaziulusoy, 2020)

In the DfS innovation framework, these various levels are illustrated as concentric squares (as seen in Figure 2) which demonstrates that the “lower” innovation levels are embedded within the “higher” ones. Importantly, this supports the understanding that DfS strategies overlap and interrelate to support each other, and that product-level innovations are also essential for enabling the “higher” levels of systems transformation. Similar to Meadows’ (2008) ‘leverage points’ in systems thinking, this categorisation of strategies is helpful for envisioning where, and at which level, designers are interfering in a system when utilising a certain DfS strategy.

The review is condensed to a short summary in Table 2 below. This table provides a summary of each DfS strategy and related approaches and indicates the estimated level of innovation (referring to Ceschin and Gaziulusoy [2020] framework). The full-length review of DfS strategies with sources can be viewed in the **appendix Section A1.**

Table 2. Summary of DfS strategies

Strategy	Description	Application in fashion design	Innovation level
Design for material longevity **The DfS strategies in this category focus on multiple loops of efficient recovery of materials.**			
Design for *closing* loops	Capturing and returning resources to the biological cycle system to become a nutrient for the wider system. **Related strategies:** Design for biodegradability, Design with healthy/smart processes and materials.	· Biodegradable garments · (F-ABRIC by Freitag) · (Shoes by OAT)	**Material / Component & Product**
Design for *narrowing* loops	Reducing resource consumption throughout the product lifecycle. **Related strategies:** Design for light weighting and miniaturising; reduction of production steps, waste and energy consumption; on-demand, localised production.	· Lightweight materials/constructions · Mono-material · Minimal seams (fused/welded) · Zero-waste pattern cutting · Digital knit machine (Kniterate)	**Material / Component & Product**
Design for *multiple* loops	Keeping products and components in direct reuse for as long as possible through multiple cycles, with a focus on retaining the highest possible value. **Related strategies:** Design for upcycling, recycling, remanufacturing, dis-/re-assembly, (if unavoidable) cascading.	· Modular garments · Removable adhesives/stitches (Smart Stitch heat-dissolvable thread) · Reusing components in new garments (Patagonia Worn Wear) · Digital ID / protocol tag	**Material / Component & Product**
Design for product longevity (*slowing* loops) **Strategies in this category focus on extending the life of products through physical and emotional durability.**			
Design for physical durability	Designing products to withstand wear and tear through durable and/or upgradeable structure and materials. **Related strategies:** Design for maintenance and repair; Design for upgradeability and flexibility	· Simplifying garment structure · Removing/reinforcing weak/high-abrasion areas · Modularity (removable seams/attachments)	**Material / Component & Product**
Design for emotional durability	Designing products that foster long-term, emotional connections and satisfaction for users. This could be through features in the product itself or approaches that engage users at points throughout the product lifecycle i.e., pre-acquiring/ in-store, production, upgrading, maintenance and repurposing. **Related strategies:** Co-design, participatory design, and Design for sustainable behaviour, which focuses on supporting consumers to adopt sustainable behaviour and abandon unsustainable behaviours.	· Limited edition items · Customisation, co-production (Digital customisation, trims, dye) · Aesthetics either classic/timeless or versatile and upgradable · Designing in capacity for memories and personal stories (“poetic touches”) · Designing pleasurable maintenance rituals.	**Product & Product-service system**
Design for dematerialisation	Focus on getting maximum usage from minimal material input, usually through a shift from consumer-ownership to shared use of products (swapping, renting, sharing). **Related strategies:** ‘Design for product-service systems’ (PSS) - A combination of tangible and intangible components, put together to form the best possible solution for the user.	· Rental platforms (By Rotation, Hurr, Rotaro) · Swapping communities (NuWardrobe) · Subscription service (Vigga baby clothes) · Online stylist service (Stitch Fix)	**Product-service system**
Design for the appropriate lifespan	Designing fit-for-purpose products whose material longevity fit the length of their use phase. Requires designers to think holistically about how and for how long a product will be used. **Related strategies:** Design for different lifecycle speeds	· Focus on both the functional and symbolic value a garment will hold for the user. · Paper dress by Goldsworthy et al.(2019): Designed to be worn twice, them composted	**Product**
Whole-systems design	Addressing problems holistically as opposed to focusing on one aspect at a time. Entails change to both production and consumption norms and requires the combination of multiple strategies at different innovation levels. Design of industrial systems as well as the products within them. Requires collaboration between multiple stakeholders across several disciplines, likely over long periods of time. **Related strategies:** ‘Systemic Design’, ‘Industrial symbiosis’, ‘Design for the entire value chain’, ‘Transition Design’	· ‘Queen of Raw’- matches sellers of unwanted fabric with buyers through blockchain technology.	**Spatio-social & Socio-technical system**

Discussion of existing DfS strategies

The review of DfS strategies reveals many existing strategies which offer ways to achieve sustainability by intervening on all levels of innovation, from the improvement of individual product components to changes at the level of socio-technical systems. However, most of these reviewed DfS strategies were identified as intervening at the lower material/component or product level. Only a few approaches were identified as supporting innovation beyond the product-level; namely, approaches such as 'Design for emotional durability' and 'Whole-systems design' which take human-related aspects of sustainability into consideration. It is important to remember here, that the lower-level strategies are not less useful. Rather, as stated above (p.41), DfS approaches overlap and interrelate to support each other, and the lower, product-level innovations are necessary for enabling the higher socio-technical levels of innovation.

Despite numerous available strategies, there is in fact currently no empirical evidence that these DfS strategies have had tangible impact on the fashion industry (Short et al., 2012; Grose et al., 2015; Fletcher, 2017; Maldini & Balkenende, 2017), and little evidence to show any wider adoption of these by designers in practice (Lofthouse, 2004, 2017; Stevenson, 2013; Perez, 2016). It is certainly possible (as we shall see in the review of DfS practice-examples in Chapter 4) to find examples of DfS strategies applied in practice, but the industry is struggling to adopt sustainable innovations at scale (Abdulla, 2019; Farri et al., 2022; Cornbleet et al., 2023), and fails to implement high-level, holistic approaches (Payne, 2021). In line with this observation, the review of existing DfS strategies in the above section predominantly revealed strategies which interfere only at the lower product- and component-focused levels of innovation. This might be because development of more holistic, human-centric design approaches aimed towards transitioning socio-technical systems only began around 2010 (Ceschin & Gaziulusoy, 2020). The limited implementation of higher-level approaches is problematic in regard to reaching the goal of enabling a sustainable and circular garment industry; lower-level approaches, if applied individually, only lead to incremental changes that are not developed without a long-term perspective in mind (Byggeth & Hochschorner, 2006).

Furthermore, in examining existing DfS strategies, this review observes an almost one-sided focus on approaches for enhancing longevity of garments. This group of strategies is broadly deemed as the most effective, but, unfortunately, as argued by Goldsworthy et al. (2019), the use of long-life materials can lead to garments lasting far beyond their actual use-time, potentially ending up as environmental damage over hundreds of years as landfill. Here, the proposed concept of 'Design for appropriate lifespans', and the idea of considering multiple speeds within a garment's lifecycle, proposed by Goldsworthy et al. (2019), is interesting, as it challenges the current emphasis on longevity by focusing on extending the life of materials as well as whole garments. The notion of considering lifecycle speeds in design acknowledges the complexity of the current fashion system and can thus support designers to consider their practice beyond the singular product

to include the entire lifecycle and system it sits within. Designing garments to age at a "suitable pace" requires a deep understanding of a number of human-related factors such as users' behaviours, their relationships with different garment types, and how this affects/is affected by the physical design characteristics of garments. Considering such an array of factors in a DfS process is complex and, as Connor-Crabb (2017) and Kozlowski et al. (2019) state in their reviews of existing DfS approaches for fashion design, this is a common barrier for strategies being implemented in practice.

Finally, as Payne (2021) notes, in her critique of existing DfS strategies used in fashion, designers in large-scale, mainstream fashion companies usually don't have the strategic power to implement systems-scale strategies. Most design briefs come with built-in constraints such as a specific production method, price point and materials, which makes it difficult for designers to feel that they can take action towards DfS (Earley et al., 2016; Payne, 2021). Instead, Kozlowski et al. propose that, for designers, *"sustainability must be approached in manageable pieces",* for them to gradually move towards a bigger systems thinking vision, to work within a *"duality of a very specific focus embedded within a systems thinking big picture lens—moving within the two"* (Kozlowski et al., 2019, p.16). Thus, lower-level DfS strategies are valuable and necessary components for enabling the higher-level approaches. This is emphasised by Ceschin & Gaziulusoy, who state that *"addressing sustainability challenges requires an integrated set of DfS approaches that span various innovation levels"* (2020, p.158).

The task for designers, then, is to identify DfS strategies that are relevant and complimentary, and to combine these to enable higher levels of systemic impact. In the next section, existing design tools, developed to support designers to navigate such selection, combination, and application of DfS strategies, are critically examined.

2.5.2. Establishing criteria for analysing tools for sustainable fashion design

The previous section showed that numerous DfS strategies exist, but also revealed significant limitations and problems with their implementation in garment design practice. To help designers make the leap from theory to practice, and efficiently implement DfS strategies, several tools have been developed. This section examines existing theory and texts on DfS tools, before critically reviewing a set of existing DfS tools for fashion design.

In this review, the term 'tool' is used to describe what Baumann et al. describe as a *"systematic means for dealing with environmental issues during the product development process"* (2002, p. 415). Tools are a popular vehicle for communicating complex, theoretical knowledge to designers in industry through visual formats to facilitate practice (Connor-Crabb, 2017). In the field of DfS, many tools with varying formats

(cards, frameworks, compendiums, checklists, guidelines, software etc.) and scope has been developed to support designers to implement DfS strategies. In fact, a study by Baumann et al. (2002) which examined tools for ‘green’ product design, led to the identification of more than 150 tools.

However, despite the large number of existing DfS tools, it is a frequently observed issue in literature that these are not being implemented in industry (e.g., Baumann et al., 2002; Knight and Jenkins, 2009; Bovea and Pérez-Belis 2012; Connor-Crabb, 2017; Kozlowski et al., 2019). To investigate this issue, several authors (e.g., Baumann et al., 2002; Byggeth & Hochschorner, 2006; Lofthouse, 2006; Bhamra & Lofthouse, 2007; Knight & Jenkins, 2009; Bovea & Pérez-Beliz, 2012) have conducted critical reviews and categorisation of existing DfS tools. Despite the focus on this issue in design, only two sources were identified who focus specifically on design tool implementation in the context of fashion design: Connor-Crabb (2017), who examines tools for sustainable fashion design through interviews with the tool developers to determine barriers and opportunities for tool use; and Kozlowski, Bardecki and Searcy (2019) who develop a new framework for analysis of DfS tools - the ‘Sustainable fashion innovation framework’ -which is used to conduct comparative analysis of a number of DfS tools to determine their “fitness for purpose” - i.e. their ability to support and enhance sustainable fashion practice. These critical reviews of existing DfS tools, including those looking at product design more generally, but particularly those focused on tools for the fashion industry, facilitate the identification of a number of shortcomings, which contribute to their lack of implementation in design practice. These can be categorised into two overarching shortcomings:

On the one hand, DfS support (a) can tend towards a narrow focus on functional, mechanistic aspects of design, neglecting important factors such as human-related aspects (e.g., user behaviours, emotional attachment, aesthetics, norms, and trends), and factors which are not directly part of the design of the garment, such as business models and supply chain infrastructure.

This narrow focus ultimately leads to DfS tools which only offer guidance for incremental product-level innovations, rather than more complex system-level innovations, as this requires designers to consider a broader set of factors for DfS. This tendency is described by Byggeth and Hochschorner (2006) who state that *“important aspects, from a sustainability perspective, are often missing in the tools (for example social and economic aspects together with ecological aspects), which can lead to incremental changes without the long term in mind”* (p.1429). The recognition of the need for tools to support designers to provide holistic guidance for DfS is echoed by Lofthouse (2006), Wever and Vogtlander (2014), and described in particular depth by Kozlowski et al. (2019) in regard to DfS tools for fashion. In their analysis of DfS tools, Kozlowski et al. (2019) specifically looked for the ability to support high levels of innovation as a key criterion for their “fitness for purpose”.Therefore, in this study, the tools which encourage

consideration of a broad spectrum of sustainability aspects such as aesthetics and cultural norms, were seen as better able to support high level innovations, and thus more able to support and enhance sustainable fashion practice. A key finding from this study was the overwhelming tendency for existing DfS tools to limit guidance to approaches that lead to product-level innovation, and a clearly evidenced lack of tools that can support higher levels of innovation.

Besides enabling designers to achieve higher levels of innovation, support for holistic consideration of DfS factors which includes human-related aspects is particularly important for designers working in fashion: sustainability in fashion is particularly dependent on intangible and aesthetic aspects which are inextricable from the material product itself, and aspects which other areas of design, e.g., industrial design, might be less reliant on. This is also demonstrated by Kozlowski et al. (2019) in their construction of a framework for analysing DfS tools in fashion: Kozlowski et al. detail the need for expanding traditional models of sustainability, which tend to focus on three dimensions (‘environmental’, ‘economic’, and ‘social’) (Herath & Rathnayake, 2019), by adding ‘aesthetic’ and ‘cultural’ dimensions. Furthermore, as discussed above (p.35), Payne explores at length how the design of fashion is as much the design of immaterial, “weightless design objects” (2021, pp.123 -140) as physical garments. detailing how aspects of fashion design such as brand story, trends and style determine the material product and its lifecycle. These human-related aspects are particularly necessary for designers to consider when attempting to implement DfS strategies such as designing for emotional durability (Chapman, 2005), or designing garments to have an ‘appropriate lifespan’ (Goldsworthy et al., 2019) where its material longevity fits the length of its use phase, which requires designers to think holistically about how and for how long the garment will be used, as well as the functional and symbolic value it will hold for the user. Furthermore, strategies related to collaborative consumption of garments are entirely reliant on designers to consider norms, habits and users’ emotional barriers (Belk, 2014). However, as established by Byggeth & Hochschorner (2006), Bovea and Pérez-Belis (2011), and Kozlowski et al (2019), the tendency for existing DfS to overlook these crucial elements means that there is a lack of adequate and suitable support for fashion designers.

On the other hand, (b) where DfS support does aim to address a broader range of DfS factors for the designer to consider, the result is often overly complex and difficult to both understand and implement as a designer.

As Kozlowski et al. describe, there are in fact tools in existence which include a broad range DfS factors; however, these tools “fail to fully take the complex idea of sustainability and simplify it into clear digestible resources and actions” (2019, p.4). Kozlowski et al. go on to describe how existing tools often will provide plenty of information and numerous suggestions for strategies, but that they lack the “how-to” component to implement these strategies in practice. As a result, the designer is left

feeling overwhelmed, *“unsure as to where best to start, and how to be most effective”* (Stevenson et al., 2011, p.4), with little idea of which strategies most suitable for their project to implement, in which order, and how to implement them (Kozlowski et al., 2019). This lack is critical because, as Ceschin & Gaziulusoy describe, effectively addressing sustainability challenges requires designers to combine DfS approaches which are complementary and appropriate for each project. However, without an understanding of the many factors which play into garments’ lifecycles, it remains difficult for designers to determine which DfS approaches will be most appropriate in each case.

Authors such as Bovea and Pérez-Belis (2012), Knight & Jenkins (2009), Lofthouse (2006) Connor-Crabb (2017) and Kozlowski et al. (2019) attribute this issue to a lack of suitable communication, in which the information is present in the tools, but is not effectively presented. These authors describe how existing tools fail to convey information in a way which is suitable for the designer to implement. Kozlowski et al. (2019) propose that tools must “speak the language” of designers, which they connect to features such as being intuitive and visually based. This is in line with several authors (Baumann et al., 2002; Gómez Navarro et al., 2005; Eskandarypur et al., 2009) who describe that the best way to present information to designers is through graphics rather than text. Lofthouse (2006), who conducted a research project to understand the type of requirements that designers have of eco-design tools, proposed that tools should provide a combination of information, inspiration, education, and guidance. In the field of sustainable fashion design, Connor-Crabb (2017) and Kozlowski et al. (2019) also identify the visual appeal of tools to be one of the key factors which affect their uptake. Connor-Crabb states that an “attractive veneer” is particularly important for designers *“as they work primarily in the aesthetic sphere”* (2017, p.84).

Kozlowski et al. also point to the importance of tools to be “*targeted to how designers work”* (2019, p.16), and propose that sustainability should be explicitly integrated into fashion design processes and practice which, as they describe, *“does not necessarily follow an orderly process”* (2018, p.195). Scholars such as Dormer (1997) and Diffenbacher (2013) detail how fashion designers move iteratively between multiple media and stages of ‘idea’, ‘concept’ and ‘design’, rather than following an ordered linear process from concept to production. As designers move through their process, they also move between working and communicating through 2D (sketching), 3D (draping), mood boards and sample creation. This process, where designers use prototyping, mood boards and sketches to progress their thinking, is also referred to with the term ‘designerly thinking’ (Cross, 2011). In this way, as Sinha observes; *“creativity is a kind of problem solving, and fashion design is a problem”* (2002, p.3) for fashion designers. Thus, to “speak the language” of designers, DfS tools must fit into, or perhaps enhance, processes which are iterative and creative. However, as the above has shown, there is still a lack of DfS tools which can do this while still offering sufficiently detailed information for holistic consideration of the many factors involved in DfS.

Finally, another crucial aspect which needs to be considered if high level innovation approaches are to be implemented in practice is other stakeholders in the system of the garment or product. As broadly agreed in literature (Coley & Lemon, 2009; Wever & Vogtlander, 2014; Ceschin & Gaziulusoy, 2020; Brown et al., 2021) higher level innovation approaches cannot be reached by designers working in isolation but requires them to collaborate across disciplines and layers within an organisation. However, as detailed by Brown et al. (2021) in a study focused on developing a tool for collaboration around circular-oriented innovation, there is a lack of support that facilitates collaboration which, again, can be linked to the complexity and lack of practical guidance in existing tools. Furthermore, Wever and Vogtlander stress the importance of communication and collaboration around DfS across company levels, because, as they state: *“the leadership of the company management plays a crucial role in successful implementation”* (2014, p.10).

Criteria for sustainable garment design tools

Based on the texts reviewed in this section, it is possible to define a set of criteria which tools ideally should fulfil to be able to provide efficient guidance for garment designers. In summary, DfS tools should:

1. Be suitable for the way designers communicate and work (i.e., be visually appealing and suitable for use in iterative processes)

2. Enable designers to engage in cross-disciplinary collaboration around DfS

3. Enable holistic consideration of DfS factors (i.e., mechanistic and tangible as well as human-related and intangible; at the scale of the product as well as the business models and supply chain infrastructure)

4. Enable designers to select and combine appropriate DfS strategies

2.5.3. A critical review of existing DfS tools for garment designers

This section presents a critical review of a selection of existing DfS tools for garment designers. This review was deemed necessary for two reasons: firstly, to supplement the small number of sources which review DfS tools as support for garment designers. Secondly, to explore the degree to which existing DfS tools fulfil the four established criteria for sustainable garment design tools to be efficient support for garment designers, to further define and evidence the gap in knowledge which this thesis addresses.

The DfS tools reviewed in this section were identified through a broad search of literature and collections by scholars such as Baumann et al. (2002), Bhamra & Lofthouse (2007), Byggeth and Hochschorner (2006), Connor-Crabb (2017), Kozlowski et al. (2019), and Ceschin & Gaziulusoy (2020), as well as websites of organisations and NGOs. This search revealed a large number of tools developed as support across design more generally, but only a small number developed for designers in the fashion industry. This review mainly investigated tools developed for garment designers, but also included tools, such as the LiDS Wheel, which are broadly adopted by designers more generally.

Table 3. Reviewed DfS tools

Tool	**Source**
Higg Index	Sustainable Apparel Coalition (n.d.)
LiDS Wheel	van Hemel, with Brezet (1998)
TED's 'TEN	Earley and Politowicz (2010)
Sustainable Design Cards	Hasling and Ræbild (2017)
reDesign Canvas	Kozlowski et al. (2018)
Circulator	H&M Group (2021)
Circular Design Speeds guidelines	Goldsworthy et al. (2019)

The Higg Index

Sustainable Apparel Coalition (n.d.)

The Higg Index is widely used in the apparel industry for measuring environmental impacts of garments from initial extraction of materials to final disposal using a life cycle assessment (LCA) framework. LCA is a widely recognised method to use data to quantify the environmental impact of products (Bhamra & Lofthouse, 2007). This data-driven tool is particularly useful for the beginning of a design process, as well as evaluation and benchmarking once new solutions have been proposed. It is unavoidable to note here, that this tool recently has been under sustained criticism for favouring fossil-based materials and potentially having ties to companies in fast fashion (Tabuchi, 2022).

When assessing the degree to which the Higg Index tool fulfils the four criteria of efficient DfS tools identified above (p.49) it becomes clear that this tool has a limited focus on quantifiable facts related to environmental assessment - not further guidance of designers. For example, regarding the first criterion of being suitable for the way designers communicate and work, the information provided by this tool is complex, lengthy, and will often require expert facilitation to "translate" into actionable guidance for designers (Kozlowski et al., 2019).

Regarding the second criterion, the Higg Index can provide an objective, clear starting point for collaborators to agree upon and perhaps return to for benchmarking. However, due to its limited focus on environmental, mechanistic aspects of sustainability and complex format, it does not as such enable collaboration throughout a design process. In summary, this tool does one thing - assessment- well, but should be used in conjunction with other, more holistic, tools to be truly useful for designers. The tool's narrow focus on the environmental, strictly quantifiable dimensions of DfS and lack of consideration of human-centred aspects, naturally also makes it insufficient for the third DfS tool-criterion related to holistic consideration of DfS factors.

The Higg Index does not fulfil the criterion of enabling the selection and combination of appropriate DfS strategies as this tool focuses purely on assessment and does not as such propose DfS strategies. This tool is efficient for benchmarking, and for establishing where in a product's lifecycle the bulk of environmental impact is produced, and thus where intervention can have the best effect. However, it offers no support for designers to link insights from assessment with selection of DfS design strategies to make them actionable in practice.

The LiDS wheel

van Hemel, with Brezet (1998)

The Lifecycle Design Strategies (LiDS) Wheel is a popular tool for qualitative assessment of a product to pinpoint aspects of a product's design that should be improved to become more sustainable (Wever & Vogtlander, 2014). The tool works as a form of qualitative benchmarking by providing a visual framework (the "wheel") in which a product can be mapped and compared to its alternatives through eight steps ("spokes"), which each represent a factor for product sustainability. Products are ranked from zero to five on each step to create an overview of how well the product is performing in each.

In terms of the degree to which the LiDS wheel fulfils the four established criteria of efficient DfS tools, this tool, at least partly, lives up to most of them: first, the comprehensible, visual wheel-format of this tool and the limited amount of written information is a clear strength, making it suitable for the way designers communicate and work. Secondly, the LiDS wheel tool also performs well when it comes to the second criterion related to support of collaboration: the visual "wheel" format, in which a product can be mapped, allows the tool to serve as a central framework which *"both the company's managers and the development team can use* [...] *as a tool to visualize a product's current, desired, and achieved environmental profile"* (van Hemel, 1998, p.43). Once a new product has been proposed, the tool can also be used to make qualitative comparisons with previous or competing products. Thus, the LiDS wheel enables a shared vision for collaborators, or, as van Hemel describes it: *"a plan of action which ensures that all members of the product development team know exactly what aspects will be aimed for"* (van Hemel, 1998, p.43).

When it comes to the criterion of enabling holistic consideration of DfS factors, the LiDS wheel only fulfils this partially: the eight aspects ("spokes") of the LiDS wheel encourages designers to consider a broad spectrum of factors from the product component level to product system level, which makes this tool a strong starting point for a holistic approach. However, it neglects human-related aspects of DfS. The tool barely includes consideration of users; apart from suggesting a reduction of resources used during a product's use phase, the LiDS wheel remains largely focused on optimisation of the product and its components.

When looking at the fourth DfS tool criterion, related to a tool's ability to support designers to select and combine appropriate DfS strategies, it provides a quick, visual way for designers to assess a product's sustainability and identify relevant focus-areas to improve its design. However, as Wever and Vogtlander argue in their critique of the tool: *"the importance of each aspect relative to the other aspects is not known, which can easily lead to too much focus on the wrong aspects"* (2014, p.11). Essentially, this tool suggests many useful DfS approaches, but doesn't indicate when to use a particular approach, or how these might be combined.

TED's TEN

Earley & Politowicz, (2010)

This tool comprises a deck of ten cards, which each represent a strategy for reducing environmental impact of textile design, production, use and disposal. The tool aims to educate and inspire designers to make more innovative and informed decisions when designing for sustainability. TED's TEN, originally created by Rebecca Earley and Kay Politowicz (2010), has been developed and refined over several years and tested in the practice based 'Textiles Toolbox' project, led by Rebecca Earley (Earley et al., 2016).

This tool is particularly fit for living up to the first of the fourth identified criterion for efficient DfS tools related to providing information, in a way that is suitable for designers for the following reasons: firstly, because it, in line with recommendations from literature (Baumann et al.,2002; Lofthouse, 2006; and Connor-Crabb, 2017), keeps the amount of written text to a minimum, using short descriptions of each approach. Secondly, because of its card format which, according to literature (Wölfel and Merritt, 2013; Kozlowski et al., 2019) is a particularly popular format amongst designers. The card-based format allows designers to take a "gamified" approach, which seeks to transform contributors *"from relatively passive "participants" into "players" who are proactively involved and mentally engaged"* (Earley et al., 2016, p.115). The deck of cards is specifically designed to be used collaboratively and played in workshop activities, which naturally qualifies it to fulfil the second DfS tool criterion related to enabling cross-disciplinary collaboration. This ability of the TEN cards to support collaboration around DfS is not inherent in the cards themselves, as it relies on the activities in which the cards are played. A range of such activities, which encourage group discussions, gameplay and role-play formats, have been developed as part of the Textiles Toolbox project.

When it comes to the criterion of enabling holistic consideration of DfS factors, the TEN tool includes a significantly broad set of DfS aspects. The cards represent a spectrum from product-centric strategies, such as design for disassembly and use of bio-based materials, to localisation (i.e., tailored solutions for diverse user needs, produced locally and at a small scale, and post-use services at the local and regional levels [Dogan & Walker, 2008]), as well as higher level strategies related to dematerialisation through product service systems, localisation, and design activism.

There is only one of the four identified DfS tool criteria which the TED's TEN only partially fulfils: the ability to support designers to select and combine appropriate DfS strategies for the particular garment and use-context. The TEN cards can be used in activities, such as 'Lead Cards' (Earley et al., 2016), which support designers to identify strengths and interest areas of their current practice, however, such activities will not enable designers to determine which strategies might be most appropriate to optimise efficient DfS in the case of each garment.

Sustainable Design Cards

Hasling and Ræbild (2017)

The Sustainable Design Cards were developed by Karen Marie Hasling and Ulla Ræbild as part of a research project carried out between Design School Kolding and industry partner Kopenhagen Fur. This card-based tool presents 29 approaches to sustainable design, one on each card, with a particular focus on supporting garment designers to enhance garment sustainability through increased longevity.

The Sustainable Design Cards fulfil the first of the four criteria for DfS tools concerned with being suitable for the way designers communicate and work. Similar to TED's TEN, this tool also keeps written information rather short. Furthermore, the cards each have one side dedicated to graphics. The graphics visually positions each cards' approach within a "compass" of design for longevity approaches (in a triangular spectrum between functional, technical, and emotional approaches), as well as symbols indicating which part of a garment's lifecycle the strategy can impact. Thus, in line with Lofthouse's (2006) recommendations for DfS tools (cf. p.48), the cards in this tool provide a combination of information, inspiration, education, and guidance for design for product longevity.

For similar reasons as TED's TEN, this tool is also suitable for enabling collaboration around DfS, and thus fulfils the second DfS tool criteria. This is particularly evident from reports on how the cards were developed and tested in collaboration with industry. In interviews conducted after design completion, the industry partner, Kopenhagen Fur, described finding the cards useful for them to *"understand themselves, within the organization, and to disseminate to external stakeholders"*. Furthermore, the cards had served as a dialogue tool which had enabled them to understand *"how the designers had implemented approaches to product longevity in the design process"* (Hasling & Ræbild, 2018, p.169).

This tool fulfils the third criterion related to enabling a holistic approach, for despite its one-sided focus on design for longevity approaches, it nonetheless allows focus on a broad spectrum of factors. The cards propose a spectrum of approaches in considering the technical, functional, and emotional aspects that arise throughout a product's lifetime, and encourage designers to work across the product lifecycle to consider various aspects including material, production, transport, use and recovery. However, this tool tends to focus on DfS approaches for product-level innovation. It also proposes strategies at the product-service system level such as rental models and design for local manufacturing, but does not reach the highest innovation-levels, like TED's TEN (the other card-based tool) does by proposing power shifts through design activism. Finally, this tool only partly fulfils the criterion of enabling selection and combination of appropriate DfS strategies. Despite providing suggestions for interlinking strategies, the cards do not provide case-specific guidance for designers to assess when to use which strategies to achieve the most effect towards a sustainable outcome.

The reDesign Canvas

Kozlowski et al. (2018)

This tool was developed for supporting designers to build sustainable fashion brands, with a particular focus on micro-sized enterprises (less than 10 employees). The tool is included in this review as, according to Kozlowski et al. (2018), small-scale entrepreneurs represent a significant and growing portion of the fashion industry. The target group for this tool is clearly reflected in its format, which is adopted from the well-known Business Model Canvas by Osterwalder and Pigneur (2010). Like the original Business Model Canvas, the reDesign canvas *"resembles a painter's canvas, preformatted with a set of building blocks which form the basis of the canvas"* (2018, p.195). The 12 "building blocks" of the canvas represent themes and challenges that a design entrepreneur would face in the process of building a sustainable fashion brand. Each building block contains a series of prompting questions which should be addressed in relation to each theme.

This tool was developed to address a similar gap in knowledge as this thesis; namely, that existing DfS tools for fashion are: *"too complex, overly conceptual, require experts to apply"* and *"fall short in holistically supporting sustainable fashion design entrepreneurial practices"* (Kozlowski et al., 2018, p.194). Thus, it is specifically developed with the intention of fulfilling the first of the DfS tool criteria: Providing guidance that is suitable for the way designers communicate and work. This is partly achieved through the canvas format, which allows designers to visualise and compartmentalise consideration of DfS strategies in a singular space, which, according to Kozlowski et al. encourages *"a non-linear, iterative design thinking practice"* (2018, p.197). However, in opposition to the recommendation in literature on DfS tools that the best way to present information to designers is through graphics rather than text (Baumann et al., 2002; Eskandarypur et al., 2009; Goméz Navarro et al., 2005), this tool remains entirely devoid of graphics and rather densely filled with text.

This tool was described by Kozlowski et al. as useful for *"collaboration between the designer and key stakeholders"* (2018, p.199), and thus addresses the second criterion for efficient DfS tools. The original Business Model Canvas, on which this tool is based, is widely successful amongst entrepreneurs, designers, and developers (Stenn, 2016; Sparviero, 2019) exactly because it is useful for collaboration between stakeholders. It allows users to think through the various elements of a business, to "record" these thoughts in a way that can easily be communicated, and once filled in, can serve as a central framework which designers and other collaborators can return to, to discuss new iterations (Stenn, 2016). However, in the case of the reDesign canvas reviewed here, it is possible that the text-heavy presentation of information, which isn't optimal for communicating to designers, also might provide an obstacle for other stakeholders and thus collaboration. Furthermore, it is worth noting here, that the reDesign Canvas, to the author's knowledge, has not been tested in practice, but through semi-structured

interview-sessions with industry experts. Kozlowski et al. themselves address this in their report, and state that the tool would *"benefit from more use and feedback"* (2018, p.206).

When it comes to the third DfS tool criterion of enabling holistic consideration of DfS factors, this is also described as an important goal for this tool, but only achieved partially. The tool's 12 "building blocks" represent themes which span broadly across aspects such as 'Design & Smart Material Selection', 'Sustainable Supply Chain' and 'Innovative & Sustainable Business Models'. However, as most of the other tools reviewed here, it is limited when it comes to including human-related aspects. The reDesign canvas does include consumer behaviour as an important factor for garment sustainability, but this "building block" only prompts consideration of the relationship between business and consumer: it proposes approaches for how a business can influence consumption and disposal behaviours but pays little attention to the relationship between garment and consumer and how this should impact the choice of DfS strategies.

Finally, this tool is also insufficient for the criterion of enabling designers to select and combine appropriate DfS strategies: the tool proposes a large amount of useful prompting questions and DfS strategies in each 'building block', but it does not help designers draw meaningful links between strategies or provide guidance on which strategy to use in each case to be as efficient as possible.

The Circulator

H&M Group (2021)

The Circulator was developed by multinational clothing company H&M in collaboration with the Ellen MacArthur Foundation. It is a visual framework, which *"guides product teams to make better design decisions and create more circular products"* (H&M Group, 2021, p.12) through a four-step process. The Circulator framework sits within a compendium with instructions, information material, case-study examples and a supplementary 'Product purpose matrix' framework.

The Circulator framework lives up to the first of the four DfS tool criteria by being visually clear and comprehensible. As a first step, the designer is encouraged to establish the "product purpose" of the garment being designed by mapping it into the "Product purpose matrix", according to estimated lifespan and frequency of wear. As a result of this process, the designer will determine whether the garment they are designing is in the 'light', 'mid' or 'heavy' product purpose category. Then, the designer can look in the framework to discover suggestions for relevant DfS strategies and material-types related to the "product purpose" of the particular garment. By using different-sized dots, the Circulator indicates the relevance of each strategy - the bigger the dot, the more the material or design strategy should be prioritised. In fact, this feature of the tool relates directly to the fourth DfS tool criterion: that tools should *enable designers to select and combine appropriate DfS strategies.* By specifying the "product purpose" as a key step, the Circulator can provide garment-specific guidance to enable selection of appropriate materials and DfS strategies, to ensure the outcome is as sustainable as possible.

However, despite providing guidance for selecting appropriate DfS strategies, the tool has shortcomings when it comes to providing holistic guidance (the third of the established DfS tool criteria). The booklet in which the tool sits clearly states the intention of taking *"a more holistic perspective"* (H&M Group, 2021, p.6), but in fact provides guidance that is limited to the product in itself. This tool provides very little guidance related to aspects of the further system surrounding the product, such as production methods or business models. Furthermore, the user's role in the garment's lifecycle is neglected; the assessment of 'product purpose' doesn't really include consideration of the user's role or emotional relationship to the garment beyond wear and tear. And, despite this tool being developed for the fashion industry, there is very little mention of how factors of trend and aesthetics might play into how, and for how long, customers will use the garment.

Lastly, when it comes to meeting the DfS tool criterion of enabling stakeholder collaboration (criterion no.2), this is only met partially by the Circulator: as described above, this tool was designed specifically for product teams, and it is certainly possible to imagine that the Circulator could serve as a useful framework for group discussions in workshops. Regardless, the Circulator, and the compendium it sits within, does not provide instructions or a description of how the tool might be used collaboratively. Instead, the compendium states: *"we've kept the criteria in each strategy quite general so they can be applied broadly. It's up to each team to interpret and determine how they can be applied to their product group"* (p.28).

Circular Design Speeds guidelines

Goldsworthy et al. (2019)

This tool was developed as an outcome of the four-year Mistra Future Fashion 'Design Theme', led by Dr Kate Goldsworthy from University of the Arts London. This practice-based project, entitled 'Circular Design Speeds', also described above in relation to the DfS strategy of 'Design for appropriate lifespan'(cf. p.42), focused on designing "ultra-fast" and "super-slow" design prototypes. The project concluded with proposing a set of three guidelines for circular fashion design; one for 'fast' garment lifecycle speeds, one for 'slow', and one for stakeholder collaboration, and these are reviewed here.

When observing the guidelines' ability to fulfil the first DfS tool criterion, related to providing information in a way that is suitable for the way designers communicate and work, a few significant shortcomings emerge. Firstly, contrary to recommendations from literature, which stresses the need for visual rather than written information (Baumann et al., 2002; Gómez Navarro et al.,2005; Eskandarypur et al., 2009), these guidelines are, as the name implies, lists of written recommendations placed in tables. Despite the lack of graphics, the information is presented in a concise and logical way, e.g., guidance for 'slow' is kept separate from guidance for 'fast', which makes the suggested DfS approaches more comprehensible. It is worth noting here that these guidelines were proposed as part of a project which also produced a number of visualisation tools ('Lifecycle Sliders' and the 'Speedcycle') to help stakeholders understand and discuss speeds within a product's lifecycle phases. These visual tools are not directly connected to the guidelines and are thus not reviewed here.

This brings us to the second criterion related to enabling designers to engage in cross-disciplinary collaboration around DfS. One of the three guidelines was specifically aimed at focusing on collaboration between stakeholders. However, due to its format, which consists purely of bullet points with recommendations, they do not in themselves enable collaboration. They do bring awareness of the importance of collaboration for moving to a circular economy, interdisciplinary collaboration, and suggestions for effective methods.

When it comes to enabling holistic consideration of DfS factors (criterion no.3) these guidelines, like most other tools in this review, tend to focus on technical and mechanistic aspects of DfS. The 'Circular Design Speeds' report. which describes the large-scale project from which these guidelines were generated (Goldsworthy et al., 2019), shows that the creators of these guidelines certainly have been working with human-related aspects and intangible factors. Regardless, these aspects have not fully transpired to the guidelines; despite mentioning strategies such as design for emotional longevity, and pointing to the importance of considering users behaviours, they do not provide support for how to implement such aspects in DfS practice.

Finally, this tool is one of the only tools in this review, which can, at least partially, live up to the fourth tool criterion of enabling designers to select and combine appropriate DfS strategies. This ability is particularly evidenced by the fact that the tool's guidance on the various DfS aspects (i.e., design strategies, materials, services, manufacturing technologies) *varies* depending on one factor: garment's lifecycle speed. By defining one supremely important factor (speed) and specifically recommending DfS approaches according to this factor, these guidelines assist designers to quickly distinguish between relevant and irrelevant approaches to employ in each case. Furthermore, by placing approaches into overarching categories of 'slow' or 'fast', to specify how either product longevity ('slow' guidelines) or material longevity ('fast' guidelines) can be approached, designers are further enabled to draw links between compatible approaches.

Summary

On the basis of a review of literature on DfS tools (pp.44-45), Section 2.5.2. established a set of four criteria which DfS tools should fulfil to be able to provide efficient guidance for garment designers. This Section (2.5.3) has presented a review of seven existing tools for sustainable fashion design based on their ability to fulfil the four established criteria for efficient DfS tools. The findings from this review are visualised in a heatmap (a plotting technique often used in science to reveal patterns in data [Gehlenborg & Wong, 2012]), in Figure 3 below, and summarised the following sections:

Figure 3. Heatmap of Reviewed DfS tools according to the four criteria

Criterion 1: Facilitating designers' communication and work (i.e. providing a visually appealing format which can support iterative processes)

As visible in Figure 3, most of the reviewed tools did, at least partly, live up to this criterion; many were visually appealing and provided information through rich graphic content and moderate amounts of text. Here, the card-based tools (TED's TEN and Sustainable Design Cards) stood out positively as they, through their interactive format, encourage a "playful", iterative approach for designers. In contrast tools such as the Higg Index, the Circular Design Speeds guidelines, were deemed less suitable for use by designers due to either their complexity (Higg), and/or less engaging text-based formats.

Furthermore, it emerged, that the framework-based tools (e.g. The LiDS Wheel or the Circulator) which allow designers to visually map their own practice, are also particularly suitable for garment designers for two reasons: firstly, they help designers understand their own practice, and secondly, because they provide a visual anchoring point to which they can return as they move iteratively through their design process. This point leads us to the next criterion, as these attributes of framework-based tools also can benefit collaboration around DfS.

Criterion 2: Enabling designers to engage in cross-disciplinary collaboration around DfS

Most of the tools in this review have been developed with the intention of enabling collaboration around DfS, however, some were more suitable for this than others. The framework-based tools in this review, the LiDS Wheel, and the ReDesign Canvas, were deemed particularly useful for enabling designers to collaborate with other stakeholders. Specifically, because the visual mapping of a project, which can be conducted collaboratively in a workshop, enables a shared understanding, or "language", which is "recorded" in the visual framework. Frameworks can remain a shared point of reference which designers and other collaborators can return to, and base cross-disciplinary discussions on. However, the two framework-based tools in this review, are both limited by not fully living up to other of the identified DfS tool criteria, such as by providing information in a way that isn't entirely suitable for designers or neglecting human-centred aspects of design. Despite not providing a common framework for collaborators to return to, and discuss, the card-based tools (TED's TEN, Sustainable Design Cards) were also deemed particularly useful for collaboration, as these can be 'played' in workshops. It is worth noting here that both the frameworks and card-based tools rely on workshop activities and, most likely, a facilitator to be able to support stakeholder collaboration.

Criterion 3: Supporting holistic consideration of DfS factors

Only one of the reviewed tools, TED's TEN, enabled holistic consideration of DfS factors across a broad spectrum of aspects from product-scale, mechanistic aspects, to human-related, intangible aspects, and systems-scale aspects like business models, supply chain infrastructure and societal norms.

Most of the remaining tools (e.g. The LiDS Wheel, the reDesign Canvas, the Sustainable Design Cards, the Circulator, the Circular Design Speeds guidelines) certainly do include a broad range of factors but lack consideration in two main-areas: Firstly, these tools tend to have a narrow focus on the functional, physical features and mechanistic aspects of design. Most of the reviewed tools neglect consideration of human-related aspects such as consumer behaviours, aesthetics, or users' relationship to garments. This is critical, as established in section 2.3, the sustainability of garments in a circular economy is often contingent on consumers' behaviours throughout garments' lifecycles; how and for how long they will be used, and whether the garments will be returned for it to be reused in new products. Therefore, it is problematic that the consideration of users in existing support for DfS generally is neglected, or in the most advanced cases, still limited to focusing narrowly on the very beginning of a garment's lifecycle through co-design approaches, with the one goal of extending the lifecycle through enhanced emotional engagement. Secondly, in line with the findings from Kozlowski et al. (2019) these tools tend to focus on approaches which support lower product- and product-service systems-level innovation, rather than higher systems levels.

Criterion 4: Enabling designers to select and combine appropriate DfS strategies

Most reviewed tools did not live up to this criterion, in fact, none of them properly managed to provide guidance which can enable designers to select and combine DfS approaches which are complementary and appropriate for each garment and its use-context. Despite this lack, some tools (TED's TEN, the Sustainable Design Cards, the reDesign Canvas) did provide useful pointers to compatible approaches. However crucially, they do not help designers to assess which approaches will be more relevant than others, depending on the particular garment and how it will be used. Only two tools did in fact describe a relationship between the various DfS factors and indicate how approaches might be navigated using this knowledge: the Circulator visualised a relationship between garments' "product purpose" and specifically relevant design strategies and materials. the Circular Design Speeds Guidelines also showed a relationship between the factor of garment lifecycle speed and specific design strategies, production methods and materials. However, these tools, as established under Criterion no.2, only provide guidance around a limited spectrum of DfS factors. Thus, designers still lack a tool which can draw links between a holistic set of factors which affect garment sustainability, to provide guidance on how they can use such considerations to inform their choice of DfS strategies.

To conclude, this review of tools for sustainable garment design has generally confirmed findings from previous literature which showed two key shortcomings of existing DfS support: a) Insufficient consideration of factors and an overly granular approach, focused on functional and mechanistic aspects, and overlooking the equally important intangible aspects of design, and b) An overly complex understanding and presentation of design factors that does not effectively communicate ‘theoretical knowledge’ to designers, and does not support designers to collaborate with other stakeholders.

2.6. Conclusion and gap in knowledge

This review of literature was conducted to develop an understanding of the requirements needed for design to contribute to a shift from a linear- to a circular fashion system, and to detail how designers are currently supported in their efforts to contribute to this shift. The shift to a circular economy requires a different understanding of several key aspects of garment design.

One particular point of interest that was discussed above (Section 2.2.) was the importance of the role of the consumer in the shift from a linear to a circular economy, and the increased possibilities and responsibilities of the consumer in a product’s lifecycle. In a circular economy, an increasingly complex role of the consumer in product design emerges, as well as the increased importance of a consumer’s physical and emotional engagement with products throughout their lifecycle in a circular economy. The ways in which consumers behave and interact with products are crucial for closing material loops, especially at certain points in the lifecycle where the product needs “help” either to extend its use phase (e.g. reuse, maintenance or repair) or to enable its components to move on to form new product assemblages (e.g. remanufacturing or materials recycling). The role of consumers thus becomes one of greater responsibility. Complementary to this, the review also showed a change in the role of designers, to becoming more collaborative and broader in scope. This indicates a blurring of the roles of designers and consumers and the need for establishing beneficial relationships between the multiple stakeholders involved in garments’ lifecycles .
However, as revealed in the review of current DfS tools, there is currently a lack of support which enables designers to include consideration of users’ engagement in DfS solutions, to assess how their involvement best can support garment sustainability.

Another important shift in design within a circular economy is an understanding of the product itself. Whilst a linear economy model can be said to move from consumption to disposal, a circular economy encourages the materials of a product to be reintroduced into a ‘closed-loop system’. This requires an awareness of the different properties of each component that comprises the product (understood as an ‘assemblage’ of its parts), and an awareness of how these various components might be best reused in new

contexts, or the best ways in which these components might be responsibly disposed of. In contrast to current consensus amongst DfS approaches, longevity isn’t necessarily the aim of the game. A more sophisticated understanding of how to reintroduce the components of a product into a circular ‘closed-loop system’ is needed.

As the literature review also observes, there is a clear affinity between DfS within a circular economy and systems thinking theory. Systems thinking encourages a holistic approach and a consideration of the links and interactions between the elements in a complex organisation or structure. For a designer, this means the encouragement and coordination of various stakeholders, users, co-creators, and other designers, *as much as the creation of the product itself.* Encouraging designers to apply systems thinking clarifies both the importance of the role of the designer in a circular economy and can suggest best practice for product design in a specific context.

This literature review then turned to survey the existing strategies and tools for DfS currently available to designers. As this review shows, there are many strategies and tools for DfS already in existence. However, crucially, these approaches fail to recognise the necessary changes to designers’ practice that have to occur within a shift to a circular economy (viz. The relationship between designer and consumer; attention to the components of products; understanding product design within a system). Broadly speaking, existing strategies and tools for DfS prescribe action within a product’s lifecycle at two specific levels: at a product-level, (i.e. a change to components or materials), and/or to interfere with a system that surrounds the product, such as changing a business model, or a supply chain configuration (e.g. collaborative consumption, distributed manufacturing, or designing resource flows so that waste from one production process becomes an input for another). This review has observed a general evolution in DfS towards implementing the second type of higher-level strategies to tackle the scale and complexity of the challenge of climate change (p.37).

This is undoubtedly a positive trend, but whilst a number of DfS approaches do acknowledge the complexity of designing for a circular economy and the need for a holistic, whole-systems approach, it has been observed (Baumann et al. 2002; Stevenson, et al., 2011; Bovea & Pérez-Belis, 2012; Kozlowski et al., 2019) that these existing forms of support are exceptionally complex and difficult for the designer to implement. There is a lack of executive guidance for designers to determine which DfS strategies constitute the best practice for a specific context and for a specific purpose. These approaches do not sufficiently enable designers to comprehend the array of factors that affect a product’s sustainability. There appears to be a lack of straightforward guidance for selecting and applying the right strategy at the right time.

Two major points of concern were identified regarding existing forms of DfS support for garment designers:

a. They provide insufficient consideration of factors and an overly incremental approach, focused on functional and mechanistic aspects, and overlook the equally important intangible aspects of design.

b. They have an overly complex understanding and presentation of design factors that do not effectively communicate ‘theoretical knowledge’ to designers, and do not support designers to collaborate with other stakeholders.

This review has revealed the need for a fundamental change in the way designers should work if they wish to contribute to a shift to a sustainable fashion industry. For such a shift to be realised, it requires designers to work in new, more holistic, user-centred, and collaborative ways, however, there is a clear lack of guidance which enables them to do so. Therefore, it is the primary goal of this thesis to develop support which can empower designers to efficiently select, combine and employ DfS strategies.

To conclude, this critical review of existing support for sustainable fashion design revealed the following gap in knowledge:

There is a lack of straightforward and actionable support for garment designers to take a holistic approach to Design for Sustainability -specifically, to enable them to:

i) *negotiate the multiple factors that affect garment sustainability, and*

ii) *instrumentalise this knowledge to select, combine and employ appropriate DfS strategies for the particular garment and its use-context.*

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Chapter 3

Methodology

The review of literature conducted in Chapter 2 revealed that despite a substantial amount of existing DfS strategies and tools, there is little evidence of their efficacy and uptake in garment industry practice. This lack of impact can be ascribed to a discernible lack of straightforward and actionable support for garment designers to design efficiently with DfS strategies. The insufficiency of existing DfS tools for garment designers can be attributed to two main shortcomings: the first is an insufficient consideration of factors that influence garment sustainability and an overly granular approach, focused instead on functional and mechanistic aspects, and overlooking the equally important intangible aspects of design, particularly relevant to the fashion industry (cf. p.35 [Payne, 2021]). The second is an overly complex understanding and presentation of design factors that does not effectively communicate theoretical knowledge to designers and does not support collaboration with designers and other stakeholders.

The research methodology in this thesis has been developed to identify particularly influential factors for sustainable garment design and generate an understanding of how these factors correlate to impact on garments' lifecycles. The investigation of these factors is conducted to enable the achievement of this thesis' main goal: To develop new applicable support for garment designers to negotiate these key factors and instrumentalise this knowledge to select, combine and employ appropriate DfS strategies for the particular garment and its use-context.

3.1. Overview of the research methodology

As established in Chapter 2, practising efficient DfS means taking a holistic, systems-aware approach, which inevitably requires designers to "look at a problem as a whole; take multiple factors into account and utilise relationships between different parts of the problem" (Charnley et al., 2011, p. 172). Thus, rather than simplifying, I needed a systematic approach to manage complexity. For this reason, this thesis takes a design research approach, which is "the investigation of how materials, ideas and systems operate and intersect in the processes and objects established by design" (Crouch & Pearce, 2012, p.xii), to investigate the most important design factors and their correlation, in order to propose a new tool for supporting systems aware, efficient DfS.

In this thesis, empirical studies informed the development of a new DfS tool and supplementary method to support garment designers to design efficiently with DfS strategies.

3.1.1. Using design thinking to navigate complexity

As a designer, working iteratively, using practice-based experiments, and visualising processes is a natural approach to generating and analysing knowledge. Therefore, the approach of Research through Design (RtD) (Frayling, 1993; Koskinen et al., 2011; Stappers & Giaccardi, 2017), which employs methods and processes of design practice to generate new knowledge, was used through all phases of this research. Methods of visualisation, such as Mind Mapping (Hannington & Martin, 2012) were used for "zooming out" and creating an overview of complex correlations between the numerous factors which impact on garments' sustainability. The visual maps, once created, allowed for a more tangible understanding of these systems, and transformed them into a format that could be communicated and tested with designers. At the same time, these visual maps also allowed for distilling, "zooming in", and making sense of these contexts. This method of visual maps was frequently used to enrich 'Thematic Analysis' (Braun & Clarke, 2006), which was the most-used method for analysis in this thesis.

Thematic Analysis is a method for analysing qualitative data, which offers a thorough, methodical way for researchers to go through data to identify relevant patterns and themes. This thesis follows a set of guidelines developed by Braun and Clarke (2006), which suggests a series of steps for the researcher to follow when conducting Thematic Analysis. This description is inspired by Petreca's (2016, p.171) concise report on these steps:

1. Familiarising with the data by reading study transcripts and noting down ideas

2. Generating initial codes by systematically going through the data. According to Braun and Clarke, codes *"identify a feature of the data (semantic content or latent) that appears interesting to the analyst"* (2006, p. 88)

3. Searching for themes by clustering the codes to form potential themes. According to Braun and Clarke, *"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"* (2006, p.82)

4. Reviewing themes to ensure they reflect the entire dataset

5. Defining and naming themes to "*refine the specifics of each theme, and the overall story the analysis tells"* (Braun and Clarke, 2006, p. 87)

6. Producing the report supported by selected quotes.

In this thesis, the Thematic Analysis was complemented by visual thinking and mapping methods to support synthesis and systematic analysis of data. e.g., the method of 'Affinity Diagramming'; a method for clustering observations and research-backed insights into meaningful categories and relationships. As well as 'Mind Mapping'; a visual thinking tool for organising a problem space or topic to understand it better (Hannington & Martin, 2012).

This research aimed to generate understanding of the networks of numerous dynamic and interacting parts that affect the sustainability of a product, to develop support for designers to understand how the change of one element of a product's system can influence all the other elements in the system. This is aligned with the Design Research Methodology (DRM), which combines *"the development of understanding and the development of support"* (Blessing & Chakrabarti, 2009, p.5), and thus the DRM (described in the following section) was chosen as the overarching methodological approach.

The DRM was complemented by a selection of methods: the most important factors for DfS were investigated through a comparative case study (Goodrick, 2014) of exemplary business cases which have employed DfS strategies in practice. These factors were further investigated through two qualitative exploratory studies. Study 1 consisted of a series of consumer interviews, confirmed, and enriched the understanding of the identified factors' influence on the lifecycles of garments informed by consumers' perspectives. Study 2 validated and refined these factors' importance by drawing in the perspectives of garment industry professionals through a focus group-session. Findings from these studies informed the next phase of developing design support, where an Action Research (Swann, 2002) approach was taken, to design a new DfS tool and method, enabled by methods of visual mapping and prototyping. Finally, the proposed tool was tested and validated through design workshops and development of garment prototypes.

3.2. Research framework

The chosen methodological framework, the Design Research Methodology (Blessing & Chakrabarti, 2009) follows a process of four phases:

1. ‘Research clarification’, which includes a literature review and empirical studies to focus the research
2. ‘Descriptive studies 1’, where the key factors for design are investigated
3. ‘Prescriptive studies’, which emphasises the development of support for DfS
4. ‘Descriptive studies 2’, in which the proposed support is tested and evaluated.

The manner in which the research questions have been explored through these project phases is shown in Table 4. As visible in Table 4, many of the chapters and studies overlap between research phases. This is intentional, as the research was developed through an iterative flow; insights from the various studies were taken forward through studies to inform continuous iteration of the focus of the research, as well as giving shape to the proposal of the new DfS tool and method.

To provide an overview of how this research has developed through the project’s phases, the methodology has been structured in layers: ‘Research questions’, ‘Chapters & Studies’; ‘Outcomes’; ‘Data collection methods’ and ‘Data analysis methods’. Each layer is described below, and the methods used are introduced briefly, but not described in further detail, as each study’s methodology will be described in their respective chapters.

Table 4. Research framework

	Research clarification	Descriptive studies 1 (Understanding design)	Prescriptive studies (Developing design support)	Descriptive studies 2 (Evaluating design support)
1 **RQs**	**RQ1** What support do garment designers currently have to design for sustainability? **RQ2** How have existing DfS strategies been applied in practice?	**RQ3** What are the most important design factors for garment sustainability? **RQ3a** How might these factors be related?	**RQ4** How might considerations of the primary design factors be structured to guide decision-making processes to enable efficient, systems aware Design for Sustainability?	
2 **Chapters & Studies**	Chapter 2 **Literature review** Chapter 4 **Practice review**	Chapter 5 **Exploring important DfS factors** Study 1 **Consumer interviews** Study 2 **Industry focus group** Chapter 6 **Building & Defining GLM** ingredients and recipes	Chapter 7 **Testing GLM as support for diagnosis** Study 3a **Design workshop** Study 4a **Design workshop**	Chapter 8 **Testing GLM as support for DfS (practice)** Study 3b **Design workshop** Study 4b **Design workshop**
3 **Outcomes**	**Gap** in knowledge **Key factors** for DfS GLM **framework**	GLM **tool** STAY or GO **method**	Garment concept ideas Garment Prototypes	New support for DfS
4 **Data collection**	**Grounded theory**	**Grounded theory** Workshop / focus group Interviews	**Action research** Research through Design Workshops, Interviews	
5 **Data analysis**	Thematic analysis Visual mapping	Thematic analysis Visual mapping	Thematic analysis Visual mapping	

3.2.1. Layer 1: Research questions

Shows the research questions as they were addressed in the different phases of this research. Here it is evident how the research grew to become increasingly focused towards developing support for DfS: First, in RQ1 focusing broadly on understanding existing support for DfS, discovering potential barriers for implementation of DfS strategies, and then in RQ2, on how these have been applied in practice. Based on this knowledge, RQ3 focused more specifically on identifying the most important factors for DfS in garment design and understanding how these correlate to affect garment's lifecycles. Finally, RQ4, focused on how these factors might best be structured to guide efficient DfS.

3.2.2. Layer 2: Chapters & Studies

Shows the chapters of this thesis in relation to the four conducted studies.

3.2.3. Layer 3: Outcomes

Shows research outputs in relation to the research phases and studies. As mentioned above, the practice-aspect of this research was crucial for the ability to develop and communicate the understanding of the various DfS factors. In the diagram (Table 4) these outcomes are shown as (pink) arrows to illustrate how these outputs fed into each other to shape the direction of the research, and ensure that the outcome, the DfS tool and method, was grounded in data generated from the research process.

3.2.4. Layer 4 & 5: Methods of data collection & analysis

This shows the methods employed for collection and analysis of data. For a full description of the methods used in each study, see the relevant Chapters 4-8.

Research Clarification

This first phase took a qualitative exploratory approach to understand current support for garment designers to design for sustainability, and how it has been applied in practice.

Chapter 2 consisted of a literature review which revealed the gap in knowledge that this research has addressed. This enabled a clarification of the research objectives and proposal of the research questions (visible in Table 4).

Chapter 4 focused on reviewing existing cases of companies which have applied DfS strategies in practice, to clarify what strategies have been applied and in what manner, and to determine their efficacy. A comparative case study method (Goodrick, 2014) was employed to identify patterns between these sustainable business cases. Additionally, this method proved useful for generating an understanding of how and why particular strategies work or fail to work. To extract themes from these cases, the data was analysed through Thematic Analysis following Braun and Clarke's (2006) guidelines (described in Section 3.1.1.). The Thematic Analysis was complemented by visual mapping and thinking methods, such as Mind Mapping (Hannington & Martin, 2012) as detailed in Section 3.1.1.

Findings from this first phase spilled over into the phase of 'Descriptive studies 1' as it contributes to building support for understanding design by proposing a particularly important set of *enabling* and *primary factors* for DfS.

Descriptive studies 1

In this phase, two qualitative studies, which is reported in Chapter 5, builds further understanding of the proposed set of key factors for sustainable garment design, and how these factors correlate to affect garment's lifecycles.

Chapter 2 (literature review) established that consumers are important actors that contribute to, or hinder, the environmental impact of garments, and therefore, perspectives of uses were studied to understand how the identified factors for DfS affect/are affected by their behaviour. Study 1 consists of 23 qualitative, semi-structured consumer interviews. This interview structure allowed for objective comparison between participants while at the same time opening up rich stories. Additionally, inspired by the method of 'Wardrobe studies' by Klepp & Bjerck (2014), these interviews were centred around a physical element; garments from participants' own wardrobes, to focus the conversation on participants' own experiences with garments. Once again, a combination of Thematic Analysis (Braun & Clarke, 2006) and visual mapping methods (Hannington & Martin, 2012) were employed to support synthesis of the data to extract important themes. See p.42 in the appendix for a step-by-step description of the Thematic Analysis.

To build further understanding of how the identified factors for DfS correlate, the accumulated data thus far (i.e., The secondary data from the literature review (Chapter 2), the review of business cases (Chapter 4), and the primary data from Study 1) was synthesised through an iterative RtD experiment (Frayling, 1993). This experiment resulted in the establishment of a framework, the 'Garment Life Matrix' (GLM), which articulates the relationship between the *primary factors* for DfS.

Study 2 was conducted to test and extend these findings by drawing in the perspective of garment industry professionals. This study employed a focus group method (Krueger & Casey, 2000) to enable focused insights into the identified *primary* and *enabling factors* and the GLM framework. This study also incorporated design workshop elements (Hannington & Martin, 2012) which is a form of participatory design, conducted with groups of participants, usually structured around co-design activities. This method was chosen because it encourages participant engagement and can support these exploratory discussions to become concrete and tangible. Once again, a combination of Thematic Analysis and visual mapping was employed to draw out salient points.

At the end of Chapter 5, the findings from Studies 1 and 2 were synthesised in the GLM framework through another set of visual mapping experiments, to develop further understanding of the relationship between the identified set of *primary* and *enabling factors*. The visual maps which emerged from these experiments articulate how the *enabling factors'* characteristics vary depending on the *primary factors*, and how these characteristics should be configured, for garments to be sustainable.

In Chapter 6, a complementary review of literature was conducted to build theoretical support for, and fully define each of the GLM-elements: the *axes, recipes,* and *ingredients*.

Prescriptive studies & Descriptive studies 2

To develop the GLM framework into support for designers, a new series of RtD experiments were conducted, as reported in Section 7.1.2. Here, the initial GLM *framework* was redesigned as an interactive, digital GLM *tool*. Furthermore, a new, supplementary method, the 'Stay or Go' method, was developed to ensure designers could use the GLM tool easily and systematically.

The GLM tool and the 'Stay or Go' method were tested with designers and garment industry experts in a series of studies: the two studies in Chapter 7 focused on testing the GLM as support for designers to diagnose the sustainability of their current practice and identify relevant opportunities for improving this, and the two studies in Chapter 8 focused on testing the GLM as support for DfS in practice. The approach of the studies in chapter 7 was more exploratory and open than those in Chapter 8, which were focused on concept generation as part of validating the proposed DfS support.

Study 3a and 4a, reported in Chapter 7, were structured almost identically but conducted with two different garment companies. They followed a mixed workshop/ focus group format (Krueger & Casey, 2000; Hannington & Martin, 2012) to engage participants in mapping their current range in the GLM framework, to gain an overview

of sustainability-related issues and relevant areas/products to improve. As well as to actively engage participants in exploring opportunities for improving sustainability, supported by the GLM tool. Thematic Analysis (Braun & Clarke, 2006) (detailed in 3.1.1.) was supported by visual analysis of the GLM-framework which, during study-sessions, was populated by participants. Furthermore, the GLM was used for visually mapping study-outcomes to analyse how the GLM tool had been used by participants.

Study 3b and 4b, reported in Chapter 8, took a practice based RtD approach to test the efficacy of the GLM tool and method as DfS support for garment designers in practice. These studies were conducted as a series of workshop-like engagements with garment designers. The designers were tasked with redesigning garments from their current range and developing these as prototypes, while using the DfS tool and method as support. The goal here was to validate the GLM as efficient support for sustainable garment design through instances of it being applied in practice. Once again, the collected data from these studies was analysed using a combination of Thematic Analysis and visual mapping.

Chapter 4

A review of sustainable business cases - investigating examples of successful application of DfS strategies in practice

According to literature, as shown in Chapter 2, several DfS strategies have been developed, but their tangible impact on practice has been limited. This chapter looks beyond literature to investigate real-world, state-of-the-art examples of businesses who have applied DfS strategies into their practice.

The aim here is to understand which strategies have been applied and how, to respond to **RQ2** (*How have existing DfS strategies been applied in practice?)*, and to investigate the characteristics of successful models, in order to build support for responding to **RQ3** *(What are the most important design factors for garment sustainability?)*

4.1. Methods of data collection and analysis

The comparative case study method (Goodrick, 2014), which involves analysis and synthesis of similarities and differences between cases, was used as the overarching approach for this review of DfS practice. This method was chosen as it enables identification of patterns between cases that share a common focus, as well as generating understanding of how and why particular strategies work or fail to work. Additionally, the 'DfS innovation framework' by Ceschin and Gaziulusoy (2020) (described in Section 2.5.1.), was employed to support the comparative analysis. Mapping the selected cases in this framework, supported the identification of which DfS strategies had been applied, and at which innovation level these cases had managed to develop solutions.

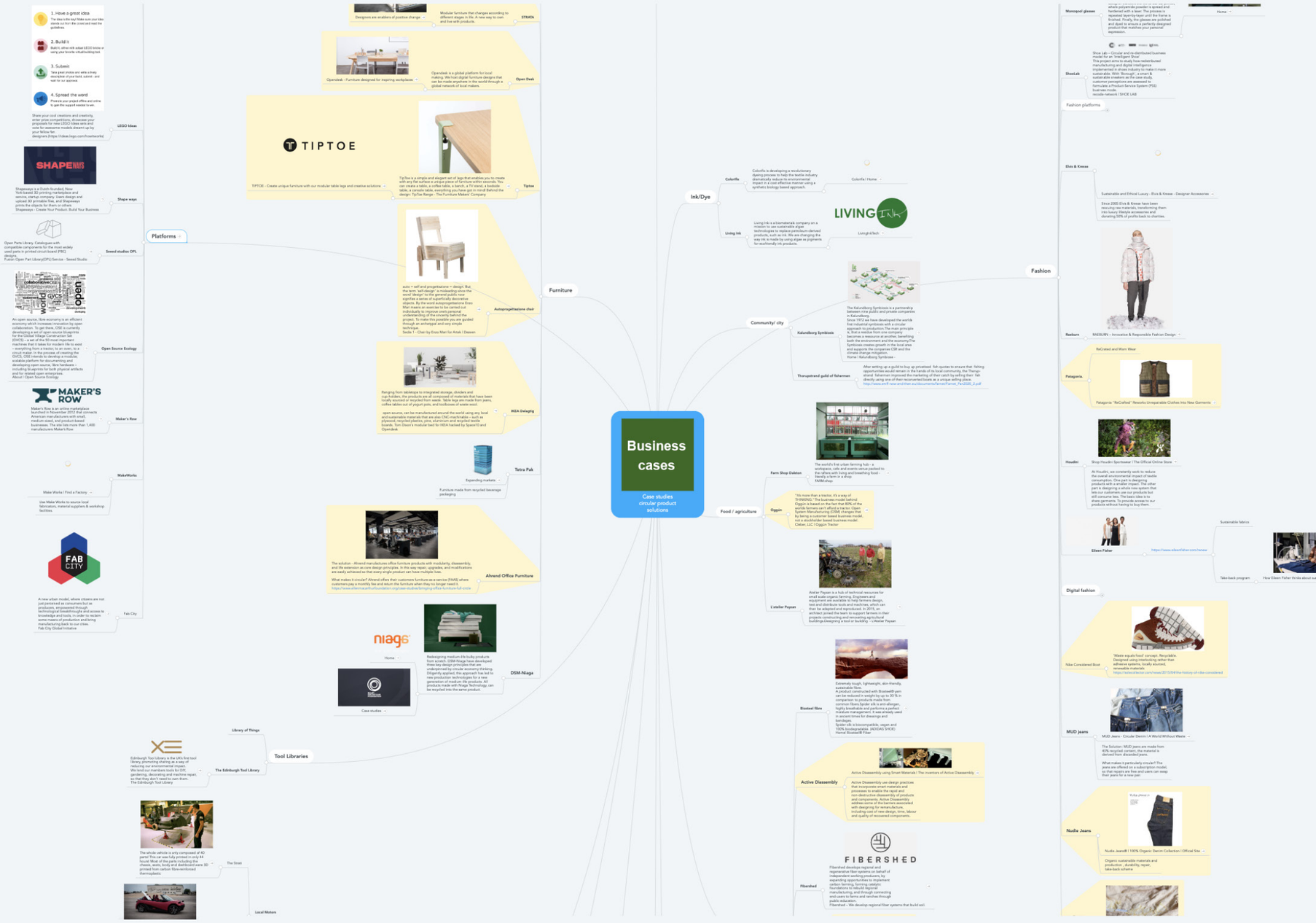
The findings from these case studies were subjected to further analysis to establish the most important factors which have enabled the sustainability of designed solutions in each of these cases. This was done through a combination of Thematic Analysis (Braun & Clarke, 2006) and a visual mapping exercise following the method of Affinity Diagramming (Hannington & Martin, 2012), which allowed for identifying patterns and recurring themes within the data.

Identifying and selecting exemplary cases

This practice-review started with a broad search for examples of businesses which had applied DfS strategies in practice. The cases in this study are not limited to garments as they were chosen during the early phases of this research, prior to the focus on the garment industry. Due to the industrial design background of the author (cf. p.22), this research started out with a broader focus on physical products more generally to find examples that, based on the knowledge generated in the literature review (Chapter 2), could be considered to have applied DfS strategies. This search revealed an initial pool of 88 cases. To retain an overview as these cases were discovered, they were visually mapped in 'Mindmeister', an online software programme, and organised using Affinity Diagramming (Hannington & Martin, 2012) where insights are clustered based on affinity. Initially, the cases were mapped according to industry-type. A screenshot from the process can be seen in Figure 4. The interactive version of the map can be viewed online by the pink button here:

Click to view map

Figure 4. Sustainable business cases mapped in 'Mindmeister'



4.2. Analysis of cases

To gain an understanding of the types of DfS strategies that had been employed by these businesses, ten cases from the initial pool were selected for further analyses according to Ceschin & Gaziuliusoy's (2020) DfS innovation levels. These cases were selected for being representative as archetypes of sustainable product design solutions in different design areas. The selected group of ten business cases were mapped into the DfS innovation framework as pictured in Figure 5.

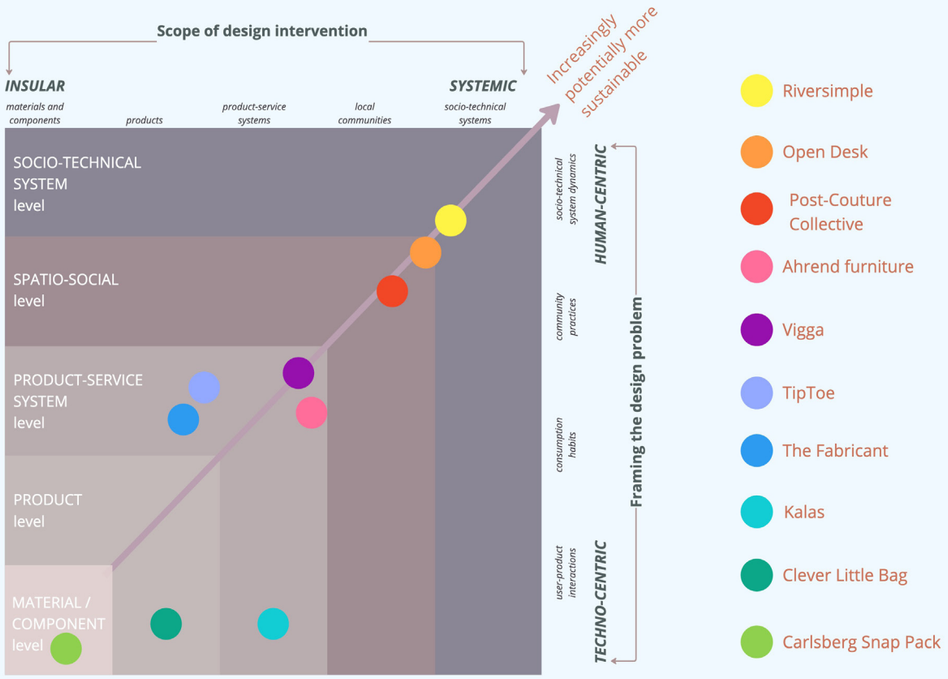


Figure 5. *Exemplary cases mapped in the DfS innovation framework. (Diagram by Katrine Hesseldahl, adapted from Ceschin & Gaziulusoy, 2020)*

As visible in Figure 5, these cases had employed a broad range of DfS strategies such as: 'Design for narrowing loops', 'Cradle to cradle design', 'Design for multiple loops', 'Design for sustainable behaviour', 'Product-service system design', and one example of 'Whole systems design'. As also visible in Figure 5, there were examples on all innovation levels, from the example of Carlsberg Snap Pack (light green) - a new material-based sustainable solution for beer bottles addressing the lowest 'material/ component level', to 'Riversimple' (yellow), which employs whole-systems design to provide a new emission-free, subscription-based transport solution, placed on the highest 'Socio-technical system level'.

To further explore how these cases have applied DfS strategies and identify characteristics of successful models, three cases - 'Vigga' (plum purple), 'Kalas' (turquoise) and 'Post-Couture Collective' (red) - were analysed in more depth. These cases were selected as they each represent different parts of the DfS innovation framework, and (as we shall see) employ vastly different means of reaching sustainable solutions, which allowed for investigating a broad spectrum of approaches. These cases were also chosen due to their placement on the higher innovation levels (product-service system level or higher) which are "increasingly potentially more sustainable" (Ceschin & Gaziulusoy, 2020). Furthermore, Vigga and Post-Couture Collective were naturally relevant for this thesis as they represent DfS solutions in the garment industry. The learnings generated from the initial set of ten cases, were used to inform and support insights where relevant.

In the following, I turn to describe and analyse the three selected cases, the DfS strategies they have employed and the most important characteristics of each model, which have enabled them to efficiently apply these strategies in practice.

Case 1: The Post-Couture Collective - DIY garments on-demand

The Post-Couture Collective offers an alternative to the overproducing fashion industry by selling garments that are produced locally and on-demand using digital manufacturing. This company invites consumers to customise, download, produce, and assemble their own garments. They offer customers the ability to purchase garments as digital files, and then guide them through the process of sourcing material, producing the garments at a local Makerspace (open creative workshop with digital manufacturing tools), and eventually assembling them. Using distributed manufacturing, sending files instead of physical material, can help reduce transport emissions, and importantly, it shifts the timeline of production to be opposite to that of conventional garments: To avoid the risk of overproduction, manufacturing will only happen *after* the point of sale. This company is deeply engaged with all actors that contribute in their system; on their webpage, they call themselves *"the world's first maker community for clothing"* (van Strien, 2017, n.d.), referring to the fact that their garments' designs are based on open-source principles and intended to be shared in a global network of designers and producers. The collections of garment designs are created by independent designers and hosted on an online platform.

The Post-Couture Collective employs a mix of DfS strategies aimed both at material- and product-longevity. The company employs strategies related to 'Design for narrowing loops', such as 'Design for resource conservation' (cf. Section 2.5.1.). They do this by designing ultra-simple garments, cut from a single material using a laser cutter, and made with modular seams that slot together so that no thread, adhesives, or tools are

needed for assembly. This simple design is also essential for enabling the distributed model of production, which is a central part of the company's business model. The garments' modularity and ability to be easily assembled/disassembled also relates to the DfS strategy of 'Design for multiple loops' as it enables easy repair, reuse and recycling of garments and components. Finally, the Post-Couture Collective employs the DfS strategy of 'Emotionally durable design', aimed at encouraging sustainable behaviours and potentially extending the life of garments by strengthening the emotional attachment between product and user (Chapman, 2005). Post-Couture Collective does this by inviting and enabling users to participate in customising and making their own clothes. However, as not all users are interested in such a high level of participation, the company offers different levels of participation: customers have the option to either download, customise, and produce their garments at a local Makerspace, or to buy a kit containing pre-cut parts that can be easily assembled. Furthermore, the aesthetic of these garments plays an important role; the simple style of the garments makes them resilient to shifting trends. It also makes them intuitively understandable for customers to engage in assembly, while at the same time being refined enough for users to find them attractive.

In regard to business model, The Post-Couture Collective profits from a product-service system model (Tukker, 2015), as their offer goes beyond individual physical and digital products towards integrated combinations of services and stakeholder networks. The service element lies in the online platform and the connection they provide between consumers, designers, local material suppliers, and makerspaces. Thus, the provided value, to a large degree, resides in the user-friendly website platform and manufacturing-guidance, and well-designed digital files, as much as in the end-product itself. The physical product is important, but the criteria for success are different compared to conventional garments; the design needs to function well for a varied group of actors involved in the producing the product, much beyond functioning as a stylish, comfortable garment for the end-user.

As seen in Figure 5, The Post-Couture Collective is placed at a high DfS innovation level, between the 'Product-service-system level' and the 'Spatio-social level' because it addresses a design problem through consumption habits and community practices, which potentially can inflict change on patterns of consumption and production in local communities.

* Since this research was initiated, Post-Couture Collective's website has been closed (http://www.postcouture.cc/diy), thus it is assumed that the business is terminated. This may illustrate another barrier for DfS - scaling and making it a viable business.

Case 2: Vigga - Baby clothes

Vigga tackles the problem of waste in the children's clothing industry by selling high-quality, sustainably sourced baby-clothes as a subscription service. For a monthly fee, customers receive new packages of clothes as their children grow and need bigger sizes. After use, it is sent back to Vigga and exchanged for a fresh packet with an updated fitting size. The clothes from the "old" packet are cleaned, assessed, repaired (if needed) and sent to a new family.

The pace of conventional baby-clothes consumption is fast; companies offer a new collection with every season. Vigga's collection is expected to last at least 82 weeks in active use, up to six months by each user (Ræbild & Bang, 2017). This means customers have to adapt to a slower exchange flow of garments. To accommodate this change and ensure an enjoyable consumer experience, it is a central design challenge for Vigga to create a slow but fluid system of collection updates. This means striking a balance between classic or 'basic' aesthetics to ensure longevity instead of short-lived fashion trends. Vigga employs the overarching DfS strategy of 'Design for product service systems', designing the garments to be flexible for growing and varying body shapes, and durable and repairable so they will last through multiple users. Furthermore, the garments are designed so that the different pieces within a package can be combined to form multiple combinations, to cover shifting needs and preferences over a longer period of time.

Vigga's product service system model relies heavily on the participation of their users. As the users of Vigga's garments only have them temporarily, it is important that they take good care of them during the usage-period, and that they send the garment-packages back after use. To make the model work, the company has found multiple ways of engaging users: firstly, they have ensured that the process of the exchange is convenient by designing a handy, recognisable bag for returns and delivery. Secondly, customers are engaged in an active community that exists through online forums and live events. Vigga can be described as a new product category, and therefore needs to take great care to engage with users to earn their trust and buy-in.

Vigga has seen and made use of an existing pattern of use and re-use specific to baby clothes: the practice of 'hand-me-downs' within communities. Sharing and reusing baby clothes is a well-known tradition that is familiar to most people. The business model is entirely different to that of conventional garments but in the end, the user experience is comparable to convenient garments. In this way, Vigga uses familiar patterns of user-product behaviours and existing cultural norms to ease the adoption of their products. This is also the reason for why Vigga, when the various business cases were mapped in the DfS innovation framework, as shown in Figure 5, also was placed at a high innovation level between the 'Product-service-system level' and the 'Spatio-social level' just below Post-Couture Collective, as its scope also lies in creating change at

consumption habits by involving entire systems of actors in co-consumption, but not through co-creation like Post-Couture Collective.

* Since this research was initiated, Vigga has been acquired by Circos.co, a larger clothing subscription service company (Ringtved Jensen, 2019).

Case 3: Kalas - Reduction Reel

The Reduction Reel is a redesign of the conventional shipping reel carried out by Bresslergroup for wire-manufacturer Kalas (Sustainable Minds, 2011). Kalas produces and ships millions of tons of wire every year to their customers across the US. One of their largest operating costs is the reels on which the wire is transported. The design of the traditional reel is heavy and inefficient, which makes them difficult and expensive to send back after the wire has been used. To reduce this cost, Kalas hired Bresslergroup to redesign the reels.

Kalas differs from the other selected cases in this study as it is the only non-garment solution and sits in an entirely different part of the DfS innovation framework. As mentioned, this allowed for this research to gain broad insight into how different types of DfS strategies have been applied in practice. Another important reason for its inclusion here, is the fact that this case is a particularly clear example of a company who has created a sustainable solution by competently selecting and combining DfS strategies across multiple innovation levels, which, as observed by Ceschin & Gaziulusoy (2020) is required for efficiently addressing sustainability challenges. To do this, Bresslergroup applies a mix of lower level DfS strategies such as ‘Design for physical durability’ and ‘Design for narrowing loops’, to improve the physical durability and environmental impact of the reel and its components, as part of an overall approach of ‘Systemic design’, which sits at the higher ‘product-service system’ and ‘spatio-social’ levels and looks at the efficiency of the entire system of the reel.

The core improvement of the Reduction Reel’s function lies in its ability to be collapsed and sent back once the wire-material has been delivered. In a collapsed state, twenty of the modular reels can fit in the space of a single assembled reel, which is a huge benefit for the wire company. It makes them easier to maintain, upgrade and recycle, and importantly, it creates a cost advantage for return and reuse. The reel is highly durable, and due to its life expectancy of 36 shipments, the company has seen an opportunity to start a take-back program. In this way, the reels stay in a closed loop system, as they eventually are returned to Kalas’ own on-site recycling facilities.

Importantly, the success of this model relies entirely on users, who, in this case, aren’t private consumers, but the workers involved in processes within Kalas’ supply chain. It is crucial that the workers are able to handle the assemblage and dis-assemblage of these reels efficiently, otherwise the system simply doesn’t work. The reel’s modular structure is an important aspect of this: made from only two materials - a plastic core and wooden sides(”flanges”) consisting of only four parts - the reels are extremely easy to assemble and dis-assembled. Kalas and Bresslergroup achieved this simple, user-friendly design by paying close attention to the workers through user testing, observations and carefully listening to feedback (Sustainable Minds, 2011).

As can be seen in Figure 5, this case was placed on the third ‘Product-service system’ level in the Innovation framework, as this solution, despite not directly affecting consumers, goes beyond the design of the individual product towards improving the surrounding infrastructure and business model.

4.2.1. Discovering the enabling factors for sustainability

These three cases have all applied a combination of different DfS strategies at different innovation levels from design of individual components to product service systems. The sustainability of each model can be attributed to many different factors that lie outside of the design of the physical product in itself, such as the choice of business model or production method. However, these system-wide factors still have decisive influence on whether the application of DfS strategies will be effective.

To gain a better understanding of these factors, and to investigate which of them have been particularly decisive for enabling sustainability in these cases, the collected data related to characteristics of each case was subjected to a combination of Thematic Analysis (Braun and Clarke, 2006) and Affinity Diagramming (Hannington & Martin, 2012) to systematically cluster the various characteristics into overarching themes.

As themes emerged from the data, they were clustered, re-evaluated and further synthesised into overarching themes. From this process a set of seven factor-categories emerged: **‘DfS strategy’, ‘Product life expectancy’, ‘User engagement’, ‘Business model’, ‘Production method’, ‘Materials’** and **‘Aesthetics’**.
These categories were established as the *enabling factors* for DfS.
The visual map of this process can be seen Figure 6:

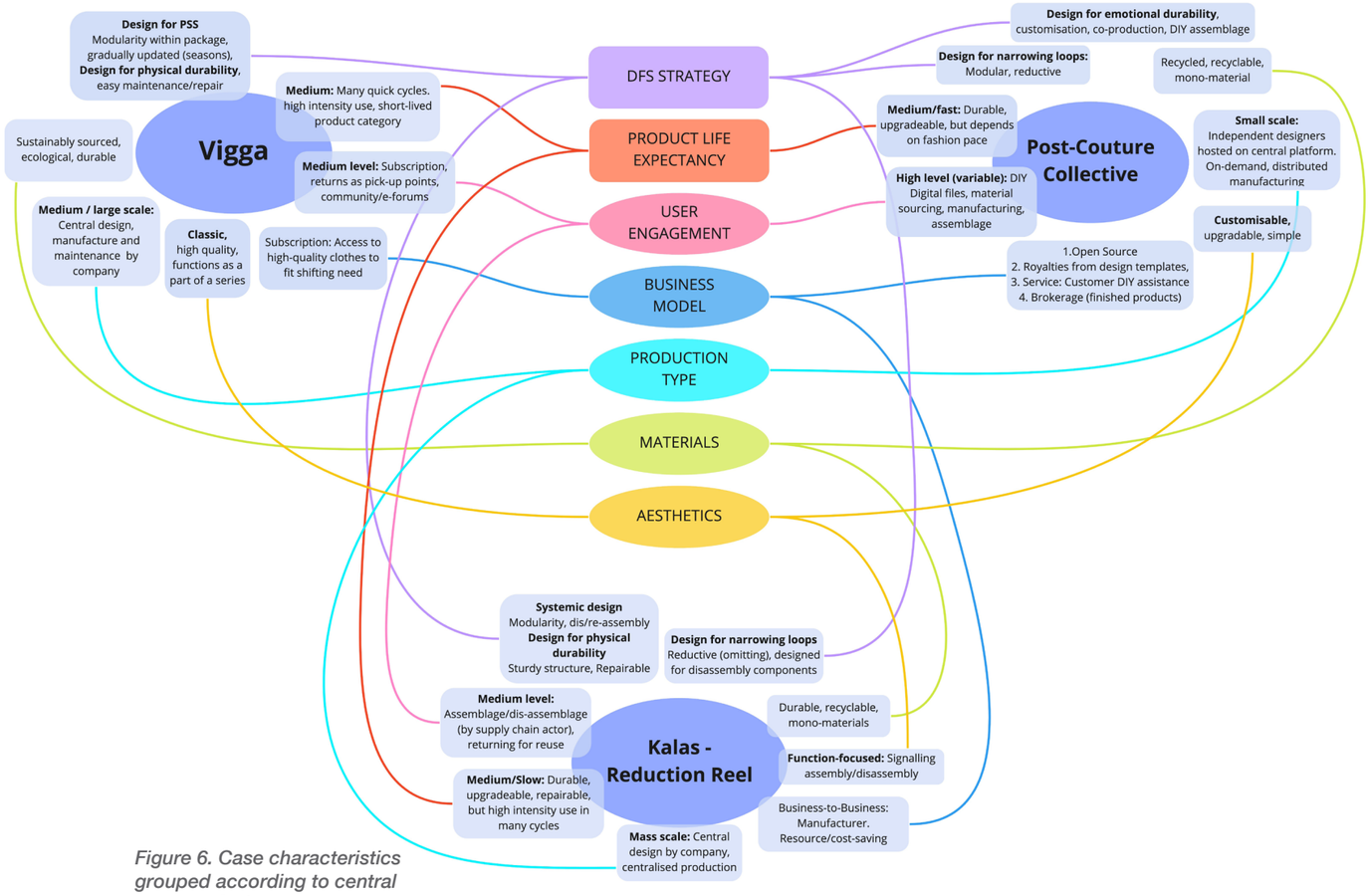


Figure 6. Case characteristics grouped according to central enabling factors

In this map (Figure 6), the characteristics deemed particularly important for enabling sustainability can be seen grouped around each of the three cases. The characteristics are connected with a colour-coded line to a central row of overarching categories, representing factors that have been central for enabling efficient DfS.

4.3. Discussion

The studied business cases vary greatly in terms of the type of value they offer and how they deliver it. However, as the visual mapping exercise revealed, these cases share a set of central factors which have enabled their sustainability as can be seen in Figure 6. **Therefore, this set of factors was named the *enabling factors.***

The following section describes how consideration of these *enabling factors* have in fact enabled successful implementation of DfS strategies in each business case.

DfS strategy

All of the studied cases aim to extend the use phase of their products, but through different DfS strategies: the Post-Couture Collective employs ‘Design for emotional durability’ to encourage the individual user to keep caring for and using garments, whereas both Vigga and Kalas rely more on ‘Design for physical durability’. In the cases of Vigga and Kalas, designing for physical durability is in fact part of an overarching approach to designing a product service system. The physical durability of these companies’ products enables them to withstand many subsequent use-cycles. In these two cases, enhancing the physical durability is more relevant than strengthening the bond between users and products, especially since both Vigga and Kalas rely on a business model where the company, not users, hold the ownership of products. Despite these differences, the three business cases share one approach; they all employ the DfS strategy of ‘Design for narrowing loops’; to reduce the number of components and use as little, impact-light material as possible, to minimise resource consumption.

Business model

All these cases can be said to provide value through a form of Product Service System (PSS) model as they base themselves on a combination of physical products and intangible services (Tukker, 2015). PSS can help enable more sustainable consumption, as it ensures that products are used by more people and for longer periods of time than conventional ownership models, essentially getting the most use out of as few resources as possible (Goedkoop et al., 1999; Tukker, 2015; Bocken et al., 2016).

Despite this common trait, the business models of the three cases are still entirely different: Vigga’s model can be categorised as “use-oriented” PSS, as customers pay a monthly subscription fee for using the garments for a certain period of time, and then receive a fresh garment-package when necessary (Tukker, 2015). The company retains ownership and responsibility for maintaining and cleaning the garments between users, to continuously rent them out and generate revenue. Post-Couture Collective’s model is “product-oriented” (Tukker, 2015), as they offer a product as well as services, connecting

users to makerspaces to enable DIY production. This model is very close to a traditional ownership model as the Post-Couture Collective would sell garments to customers who gain full ownership. Finally, in the case of Kalas, the Reduction Reel is not in itself the source of profit, as it merely functions as an element of a service, delivering their actual product (wire) to customers. Instead, the company profits from the significant cost reduction which the new type of reels brought. The reels' ability to be collapsed and returned using minimal time and resources, and capability to withstand repeated usage for more than 35 shipments enables significant savings.

Production method

The production method is relevant for sustainability in all the studied cases. Especially for Post-Couture Collective, the production method was a significant *enabling factor* for sustainability, as this concept's reduction of resource-use relied exactly on its distributed method of manufacturing. Vigga's garments were produced using centralised production, primarily in India and the Baltic, but their production was of a smaller scale focusing on the Danish market where all remanufacturing and repairs would take place. In the case of Kalas, there was no available data on how these reels are produced, but the simplicity of the design indicates simple, standard production processes, which make sense to carry out as mass-scale centralised manufacturing to benefit from economies of scale.

Aesthetics

Each of these cases also use careful consideration of the factor of aesthetics to support overall DfS strategies. In Vigga's' case, where the garments need to stay in use for longer than conventional baby-clothes, it is important to strike a balance between a classic, timeless aesthetic, while still attracting new customers. Furthermore, the collections need to function as part of a series, so that the pieces in each package function together. For Post-Couture Collective, it is important to offer a visually appealing garment which users want to keep and use for a long time, but also a garment whose design is simple enough that it might be "open" for customisation and easy assembly by consumers. In the case of Kalas' Reduction Reel, since this is not a consumer product, the aesthetic element was absent; however, it can be argued that its visual features play a role in communicating to users how the reel should be dis- and re-assembled.

Materials

All three cases focus on selecting of materials to be sustainable: Vigga only used high quality, certified organic cotton, and wool (Ræbild & Bang, 2017), Post-Couture Collective's garments are made from materials such as wool, felt, and Spacer Fabric – a 3D-knitted material made from recycled PET bottle which can also be recycled

after wearing (Tucker, 2015). However, when the garments are purchased as a digital file for DIY production, the material-choice is up to users, and therefore the company provides guidance for selection of suitable low-impact, recycled/-able materials. Kalas' Reduction Reels are made from only two materials; wood and recycled/recyclable plastic (Sustainable Minds, 2011). Importantly, these cases employ (or in Vigga's' case, plan to employ) 'Design for disassembly', which entails the use of mono-materials and designing products so that components can be easily separated for efficient reuse or recycling.

Product life expectancy

The exact life expectancy of these products can only be determined in Vigga's' case. However, it is estimated that the two garment products, Vigga and Post-Couture Collective, would have the shortest life expectancy because of the product type. It is a clear aim for Vigga's garments to be long-lasting, but as they are likely to get considerably more wear from being circulated through multiple (up to eight) different use phases, they are likely to have a shorter lifespan. To account for this, Vigga designs these garments to be very durable. Similarly, Kalas' Reduction Reel is designed for physical durability, and certainly has a significantly extended lifespan of 36 shipments compared to 2 shipments of conventional reels. Like Vigga's clothes, the reel's lifespan is also considerably affected by the many consecutive intense use phases. Also in this case, the clear aim for longevity, and awareness of how the product will be treated during its use phase, impacts other design decisions, such as choice of materials and structural properties (Sustainable Minds, 2011). In contrast, Post-Couture Collective's garments are made for and worn by a single user, who, because of emotional attachment, ideally keeps the garment for a long time. Thus, the consideration of life expectancy in all these cases seems to play a central part in enabling sustainability. In fact, consideration of this factor seems to have had a decisive impact on the decisions made around the remaining *enabling factors.*

User engagement

Finally, the three cases all rely heavily on consideration of users, regardless of if they are private customers or supply chain workers, the active engagement of users at certain points along these products' lifecycles is crucial for enabling sustainability. If Vigga's' customers are unable (or unwilling) to pack and send garments back after use, the company is unable to keep cycling them between users. If the workers in Kalas' supply chain can't handle the assemblage and dis-assemblage of the reels, the system of transporting the company's wire-product simply doesn't work. And, if Post-Couture Collective's customers aren't interested in DIY manufacturing, or if they discard the garments after only a few wears, this concept will lose its fundamental value.

Despite being important in all three cases, the type of user engagement varies between each: the only interaction required from Vigga's customers is to post the garments back to the company every four-six months, while Vigga handles maintenance. In contrast, Post-Couture Collective's customers are engaged at a much deeper level, at more points, and earlier in the garment lifecycle, downloading the design-file, customising it, sourcing fabric, digital production, and assemblage. Interestingly, this factor, like the factor of 'Product life expectancy', also seems to have an impact on the remaining *enabling factors;* the material choice, garment structure and choice of production method have all been specifically chosen to suit a high level of user engagement. This tendency of some *enabling factors* to impact others in a DfS process is investigated and described in more detail in the following section.

4.3.1. Identifying the primary factors for DfS: 'User engagement' & 'Product life expectancy'

The analysis of the exemplary cases in this review reveals a set of *enabling factors,* which are central for enabling efficacy of the DfS strategies applied in each of these cases. The analysis indicates that these *enabling factors* are correlated, and that these factors are adjusted to each other, so that their characteristics collaboratively contribute to form a sustainable solution.

From the Thematic Analysis and mapping exercise pictured in Figure 6, a pattern begins to emerge in how the *enabling factors* correlate, and a hierarchy of how these affect each other in a DfS process is gradually formed. Specifically, the two *enabling factors* of 'Product life expectancy' and 'User engagement' seem to have a decisive impact on the other identified *enabling factors* when the solutions in each of the exemplary cases have been designed. Therefore, the factors of **'Product life expectancy' and 'User engagement' are proposed as the most important, *primary factors* for DfS.**

The next section describes how consideration of the two *primary factors* seems to influence or guide the remaining *enabling factors* in the three cases studied.

Primary factors - Impact on the enabling factor 'DfS strategy'

When looking at the DfS design strategies which are employed in each business case, it seems consideration of the two *primary factors*, 'User engagement' and 'Product life expectancy' have guided these decisions. Further description of the DfS strategies mentioned in this section can be found in Table 2 in Section 2.5.1, as well as in the Appendix, Section A1.

In all three cases , the choice of DfS strategy is based on a wish to extend product longevity, which relates to the *primary factor of* 'Product life expectancy'. Vigga and Kalas both do this by employing the DfS strategy of 'Design for physical durability'. In Vigga's case, this means designing garments to be repairable with strong seams, few components, and durable materials; for Kalas, it means designing the reel to have a simple, sturdy structure that could resist frequent, heavy-duty use. Post-Couture Collective also aims at extending longevity, but instead aims to achieve this through the DfS strategy of 'Design for emotional durability'.

The other *primary factor*, 'User engagement', similarly has a decisive impact on the *enabling factor* of 'DfS strategy' in each of the three cases. Again, Vigga and Kalas' are comparable in the sense that their models don't rely on a strong bond between the individual user and product. In the case of Kalas, users only engage briefly with the reels when receiving wire-product from Kalas, or when quickly collapsing them for return-shipment. Similarly, Viggas' users don't have a strong bond with the individual garment; besides daily wear and washing, user engagement is limited to packing and returning them to Vigga. These minimal instances of emotional and physical user engagement in Kalas and Vigga's products lead to a choice of strategies related to 'Design for Product Service Systems' (PSS) which are useful for designing the few, but crucial moments of users' engagement in these products' lifecycles to be as quick and convenient as possible. Vigga has made great efforts to ensure the service-side of their concept (website, communication, transport) is user-friendly and engaging. For Kalas, the DfS strategy 'Design for dis-/re-assembly', is important for ensuring that the point at which the reels need to be collapsed by supply chain workers for return shipment is frictionless.

For Post-Couture Collective, consideration of the *primary factor* of 'User engagement' is also decisive for the choice of DfS strategies: This company's model relies on a much higher level of physical and emotional user engagement than the other cases, which likely influences the choice of the DfS strategy of 'Design for emotional durability'. To further strengthen the connection between users and products, Post-Couture Collective employs co-design and participatory approaches.

Primary factors - Impact on the enabling factor 'Business model'

Considerations of the *primary factor*s of 'life expectancy' and 'user engagement' also influence the choice of business model in each of the three exemplary cases.

Vigga's model was a clear example of this. Firstly, the *primary factor* of 'Product life expectancy' affects the company's choice to employ a rental-model. This decision builds on an observation of the discrepancy between the fast speed at which children grow out of garments, and the much longer lifespan of garments themselves; the garments'

materials far outlast the consumers' want/need for them. This understanding leads Vigga's founders to propose a new subscription-based model where the garments can be used to their full potential. Similarly, for Kalas, the company's ability to consider, enhance and take advantage of the long life expectancy of their shipping reels makes a take-back model optimal in terms of sustainability. Post-Couture Collective's business model is also affected by considerations of product life expectancy: it offers a garment which can easily be repaired, upgraded, and customise their garment, without necessarily having to discard the entire product.

The other *primary factor* of 'User engagement' also has an important impact on the business cases' choice of business model.

For Vigga, whose users' feel very little attachment to the individual garments, it makes sense to optimise sustainable consumption through a subscription model. Similarly, for Kalas, whose users certainly have no emotional connection to the reels, it makes sense to retain ownership of the reels and to circulate them between customers. However, in both Vigga and Kalas' case, it is important that engagement between brand and user, albeit minimal, is sufficiently frictionless and engaging for users to interact effectively, as these are crucial points for the model to function.

In contrast, for Post-Couture Collective, the deep and extensive engagement of users in their products means they can offer the garments through a new on-demand, tiered model: deeply engaged customers can buy garments cheaply as digital design files for DIY production, and less committed customers can spend slightly more money to buy them as DIY-kits.

Primary factors - Impact on the enabling factor 'Production method'

The two *primary factors* also seem to impact decisions regarding the *enabling factor* of 'Production method' in the three cases.

For The Post-Couture Collective, considerations of 'Product life expectancy' influences the choice of letting users take over (at least parts of) the production of garments: as this company aims for extending the lifespan of garments through strategies of emotional durability, the choice of such co-production methods is a logical choice.
However, the other *primary factor* of 'User engagement' seems to have been particularly influential for this company's choice of production method. As described, the value which Post-Couture Collective offers is reliant upon high levels of user engagement, and involving users in production processes is central to this.

Looking at Vigga and Kalas, the *primary factor* of 'Product life expectancy', which in

both cases is long, leads to a demand for high quality and durability of the products which can only be achieved through centralised, large scale production forms conducted by professionals. Finally, the *primary factor* of 'User engagement', impacts the choice of production method: As the level of user engagement is relatively low in both Vigga and Kalas, it is clearly unnecessary for them to make an effort to cater for individual preferences by offering customisation or involving users in co-production.

Primary factors - Impact on the enabling factor 'Aesthetic'

Considerations around the *enabling factor* of 'Aesthetics' also seem to be significantly influenced by the *primary factors* in each of these cases.

In Vigga's case, the *primary factor* of 'Product life expectancy' influenced the choice of a simple, classic aesthetic, to avoid dependency on shifting fashion trends, as well as matching garments in batches so they can be used in many combinations (Ræbild & Bang, 2017). The *primary factor* of 'User engagement' also plays an important role here: as the engagement from each user was relatively low, the aesthetics of Vigga's garments are "toned down" and neutral, to ensure a broad appeal for many consecutive users.

In the case of Kalas' reels, the long life expectancy and low levels of user engagement, with no actual "consumer", leads to a standard, anonymous aesthetic, purely focused on functionality.

For The Post-Couture Collective, the aim of extending longevity of the garments necessitates a classic, minimalist aesthetic, which is resilient to fast-changing trends. Consideration of other *primary factor* of 'User engagement', which as described is significant in this case, leads to an aesthetic of these garments which could be easily customised.

Primary factors - Impact on the enabling factor 'Materials'

Finally, regarding the decisions around the last *enabling factor* of 'Materials', the two *primary factors* once again have significant influence in each case.

In terms of the *primary factor* of 'Product life expectancy', all the studied cases aim at extending product longevity, and they therefore all choose durable materials.

For Vigga and Kalas, considerations of the other *primary factor* of 'User engagement' does not seem to weigh as heavily as the *primary factor* of 'Product life expectancy' since the level of user engagement in both cases is relatively minimal. However, in Vigga's case, the company still must consider the taste and preferences of users in their material choices; the parents paying for Vigga's offerings are often engaged in the

brand and its values rather than the individual garments, and thus sourcing materials and communicating the safety and sustainability (e.g.,100% organic certification) of these materials is important.

For Post-Couture Collective, the high levels of user engagement lead to offering customers the option of sourcing material themselves when producing their garment. In this case, the company has little to say in the choice of material; however, they do offer guidance for choosing recycled/recyclable materials.

Regardless of levels of user engagement and product life expectancy, all these companies choose low-impact, mono-materials which can be recycled, demonstrating the understanding that it always is beneficial for sustainability to design for as minimal impact as possible.

4.3.2. Use of the enabling and primary factors in DfS practice

To recap, the analysis of the exemplary cases led to the establishment of the set of enabling factors for DfS: ‘DfS strategy’, ‘Business model’, ‘Production method’, ‘Aesthetic’, ‘Materials’, ‘Product life expectancy’, and ‘User engagement’.

The characteristics of the three exemplary cases are very different, but the analysis indicates that in each case, considerations related to these *enabling factors* have been carefully adjusted according to each other to achieve efficient DfS.

Examining how these *enabling factors* for DfS are balanced in connection to each other leads to the insight that decisions related to specifically two of these factors, ‘User engagement’ and ‘Product life expectancy’, have influence, and guide decisions related to the remaining *enabling factors* in each exemplary case. Therefore, these two factors are described as the *primary factors* for DfS.

The cases analysed in this chapter illustrate how the ability to consider factors beyond the design of the physical product itself, and include factors related to the entire lifecycle and surrounding system, has enabled these companies to successfully apply DfS strategies and develop sustainable solutions.

Unfortunately, as established in Chapter 2, most designers aren’t equipped to take such a holistic approach, as it can be overwhelmingly complex. The numerous moving parts of a product’s system can be difficult to negotiate, especially as designers currently don’t have a system for considering these factors. The exemplary cases studied in this chapter have managed to focus their efforts around certain particularly important factors for DfS: ‘Product life expectancy’ and ‘User engagement’, established as the *primary factors*. Knowingly or intuitively, they have made remaining design decisions related to other (*enabling*) factors, according to these two (*primary*) factors.

Therefore, based on these exemplary cases, the following hypothesis was proposed: ***To design effictively for sustainability, designers should consider the two primary factors of ‘User engagement’ and ‘Product life expectancy’ at the beginning of the design process to guide further decision-making.***

4.4. Summary

This chapter has investigated a set of exemplary business cases which apply various DfS strategies in practice, to understand which strategies have been applied and how, and to identify characteristics of these successful models.

The findings showed that these cases all have applied a combination of different DfS strategies at different innovation levels, from design of individual components to product-service systems. The sustainability of each model can be attributed to a range of factors that lie outside of the design of the physical product itself.

Further analysis of the characteristics of these models and products revealed a pattern in the types of overarching factors which these characteristics relate to. The themes which resulted from this process were proposed as a set of the most important *enabling factors* for DfS, comprising: ‘DfS strategy’, ‘Business model’, ‘Production method’, ‘Points of user engagement’, ‘Materials’, and ‘Aesthetics’.

Furthermore, the findings indicated that these *enabling factors* for DfS are correlated, and that designers therefore should consider and adjust them carefully in relation to each other, so that their characteristics can contribute collaboratively to sustainable solutions.

Finally, further analysis enabled the identification of a hierarchy in how the identified *enabling factors* affect each other: two, namely ‘Product life expectancy’ and ‘User engagement’, are identified as supremely important *primary factors* for DfS, which have a decisive impact on the other *enabling factors*. This allowed the following hypothesis to be proposed: **Consideration of the two *primary factors* should guide designers’ decisions around all the other *enabling factors*, for them to design efficiently for sustainability.**

Chapter 5

Investigating the *primary* and *enabling factors* for sustainable garment design - characteristics and correlations

The review of sustainable business cases in Chapter 4 resulted in the proposal of a set of *enabling factors* for DfS. Furthermore, two specific factors, 'Product life expectancy' and 'User engagement' were identified as supremely influential *primary factors*, which have decisive impact on the other *enabling factors*. Thus, it was suggested as a working hypothesis that: *consideration of the two primary factors should guide designers' decisions around all the other enabling factors, in order for them to design efficiently for sustainability*.

The aim of this fifth chapter is to test the proposed hypothesis and build further understanding of the proposed *primary* and *enabling factors* for sustainable garment design, how they correlate and how they affect garments' sustainability.

This chapter responds to the third research question: RQ3: *What are the most important design factors for garment sustainability?* And RQ3a*: How might these be related?* Furthermore, it builds preliminary knowledge towards responding to RQ4.

The research questions are addressed through two qualitative studies: Study 1, a series of consumer interviews, and Study 2, a focus-group session with garment industry experts, conducted to investigate the *enabling* and *primary factors'* influence on garments' lifecycles, informed by these perspectives.

5.1. Study 1.
Investigating the *primary* and *enabling factors* from the perspective of consumers

The findings from Chapters 2 (literature review) and 4 (review of sustainable business cases) showed that consumers' behaviours are crucial for garment sustainability. They decide, knowingly or unknowingly, how a garment's lifecycle will unfold; if it will be long or short, whether it will be used and cared for, and ultimately, if it will be looped back into the wider system for its components to be used in new product-assemblages. Thus, it was crucial that the consumer perspective inform research into understanding of the *primary* and *enabling factors* for DfS. What ultimately becomes clear from such an investigation is the importance of considering the user for designers applying DfS strategies.

5.1.1. Study design

This study took a qualitative approach to investigating, from the perspective of consumers, the importance of the *primary* and *enabling factors*, and how these factors correlate to affect garments' lifecycles. The *primary factor* of 'Product life expectancy' provides the starting point around which consumer interviews were structured, as a means of examining the relationship between the two *primary factors* ('User engagement' and 'Product life expectancy').

The concept of pace is crucial to an understanding of 'Product life expectancy': garments can be understood as either having a 'fast' lifecycle, moving from production to use to disposal (or recycling into material loops) at a rapid pace; or a 'slow' lifecycle, where the process from production to disposal is much more gradual. These different paces are influenced by a range of factors (particularly the *enabling factors* that this thesis identifies). The pace of 'Product life expectancy' is primarily connected with 'User Engagement': a consumer's relationship with a product will dictate the length of the passage of time from use to disposal and will also impact the means of the product's disposal, and thus influence whether the 'pace' of the product is slow or fast, and how the product will be reintroduced to other material loops (or not). The pace of 'Product life expectancy', and how a consumer understands and impacts this, also allows for several observations to be drawn on *Enabling factors.* 'Product life expectancy' thus provides an excellent starting point to explore how consumers understand and impact the *primary* and *enabling factors* that this thesis has identified.

A semi-structured interview structure (Crouch & Pearce, 2012) was chosen to allow participants to partly control the conversation, while still allowing the researcher to steer

the overarching focus. The overarching qualitative approach was supplemented by quantitative questions to develop a more precise understanding of the studied garments and enable comparisons between garment types. A combined approach of Thematic Analysis (Braun and Clarke, 2006) and visual mapping exercises was taken to extract core themes. The researcher took the role of a 'receptive interviewer' (Crouch & Pearce, 2012), adding little more than questions and encouragement to the conversation to retain focus on the participant.

Prior to interviews, participants were sent an email detailing the task of selecting two garments from their wardrobe to bring to the study. The wording of this task was carefully chosen to ensure precise communication using common language and trying not to affect participants' garment-selection process, as seen here:

Garment 1) *A garment from your wardrobe which you think is very long-lasting. Something you expect to have or have had for a very long time.*

Garment 2) *A garment from your wardrobe which you think will not last long or you will not keep. Something you expect to have or have had for a very short period of time.*

The purpose of this task was to focus the conversation on something concrete which related to participants' own lives, rather than a general conversation. This approach was inspired by the 'Wardrobe Studies' by Klepp & Bjerck (2014). This method was developed to analyse *"the way in which clothes relate to each other on the whole or in parts of the wardrobe"* (p.373). Klepp & Bjerck describe how *"with their physical presence the garments remind the informant about specific considerations, experiences, emotions, etc*." (2014, p.377). Thus, this method enables rich descriptions which is useful for the focus of this study and assists the understanding of consumers' experiences and behaviours.

Participants

A total of 23 members of the consumer public participated in this study. The aim was to recruit a broad range of participants representing UK and EU fashion consumers. A broad spectrum of ages (21 - 60), ethnic and professional backgrounds were represented. There was a slight overrepresentation of 15 participants presenting as female, compared to 8 male. Participants were primarily recruited through ON ROAD, a strategic insight agency, The Nu Wardrobe, an online clothes-sharing platform, and the researcher's own network. Most (48%) of the participants belonged to the youngest group (aged 21-26), slightly fewer (30%) were between ages 26-32, and fewest (22%) from the group over 50 years old. The participants' names were anonymised for analysis and given ID codes as can be seen on p.33 in the appendix.

Data collection methods and setting

The interviews were conducted and recorded via an online platform. Video recording ensured anonymity and focused on the garments themselves; all participants were interviewed in their homes, with their wardrobes and garments close at hand, as seen in Figure 7, which allowed for an organic interview process within the context of the interviewee's private, usually domestic, space, which provided important insights into consumer behaviour.

Figure 7. *Screenshots from Study 1 Zoom interviews.*

Interview structure

In these semi-structured interviews, all participants were asked the same questions. To start, participants were asked to introduce the two selected garments and "tell the story" of how they acquired them. This was followed by a series of closed, quantitative questions regarding measurable facts. Further in-depth questions regarding the points of interaction between the participant and garment were asked. The interview was concluded with personal "feeling questions" (Crouch and Pearce, 2012), exploring the value which the garment represented to the participant. The interview protocol can be seen in Table 5.

Table 5. *Interview protocol Study 1*

Description of garments	1	*Please describe the two garments you have brought for this interview, and tell the story of how you acquired them*
	2	*If you look at the label, can you tell me what materials each garment is made from?*
	3	*How much did each garment approximately cost?*
	4	*How often do you wear each of these garments?*
	5	*How long do you expect each of these garments to last? (Before you / with you / future life / in total)*
Points of engagement during garment lifecycle	6	*Please walk me through your experience of acquiring each garment*
Acquiring	7	*Can you think of actions you do to maintain these garments? Which? How often?*
Repair / Maintenance	8	*Have either of these garments ever been repaired? Why/why not?- If so, how? By whom? Did you pay for it?*
	9	*If this garment failed, would you repair it yourself or be willing to pay someone to repair it? Why/why not?*
Provider engagement	10	*Please walk me through the points at which you have interacted with the brand or retailer after acquiring it*
Sharing	11	*Have you shared this garment with others?* Why/why not? - *And, If so, how?*
End of use	12	*What will you do with each of these garments if/when they are no longer useful to you?*
	13	*What do you think makes your long-lasting garment able to have such a long lifespan?*
	14	*What do you think makes the short-lasting garment's life so short?*
	15	*What would cause you to discard each of the garments? Is this related to particular parts of the garments? -Which?*
Psychological value	16	*What do you do with these garments? What do they enable you to do?*
	17	*What do you want these garments to say about you to others? Do you think it says that?*

Method of Analysis

The recorded data was transcribed and analysed using qualitative methods supported by quantitative data. A Thematic Analysis method (Braun & Clarke, 2006; cf. Chapter 3) was employed, as it enables systematic analysis and synthesis of rich data into comprehensible themes that represent the whole dataset, which was particularly useful to help focus the research at this early stage of the thesis. The Thematic Analysis was enriched by the visual mapping method of Mind Mapping (Hannington & Martin, 2012) (cf. Chapter 3) and Thematic Networks (Attride-Stirling, 2021). First, Mind Mapping was employed to help extract the most important themes from the data. The step-by-step process, which is described in detail in the appendix on pp.42-47, resulted in the identification of three themes: 'User engagement', 'Value' (for the user), and 'Design characteristics'. Each theme gathered sub-themes underneath them, depending on whether they related to garments with a long or short life expectancy. Observing these themes, a clear affinity with the primary and enabling factors identified in previous chapters becomes visible. To further organise the generated themes and begin to explore how they might relate, the method of Thematic Networks was employed. This method organises themes into three classes:

1. **'Basic themes',** which are the first initial codes that emerge directly from the data.

2. **'Organising themes'**, which organise basic themes into groups of similar topics. As organising themes are generated from the basic themes, they are connected to other organising themes to start forming an overall position or assertion about a given situation or reality. The macro theme that emerges is the global theme.

3. **'Global themes'**, represent an overarching point of the text into a single statement (or here, a word), and are the most abstracted representations of the textual data.

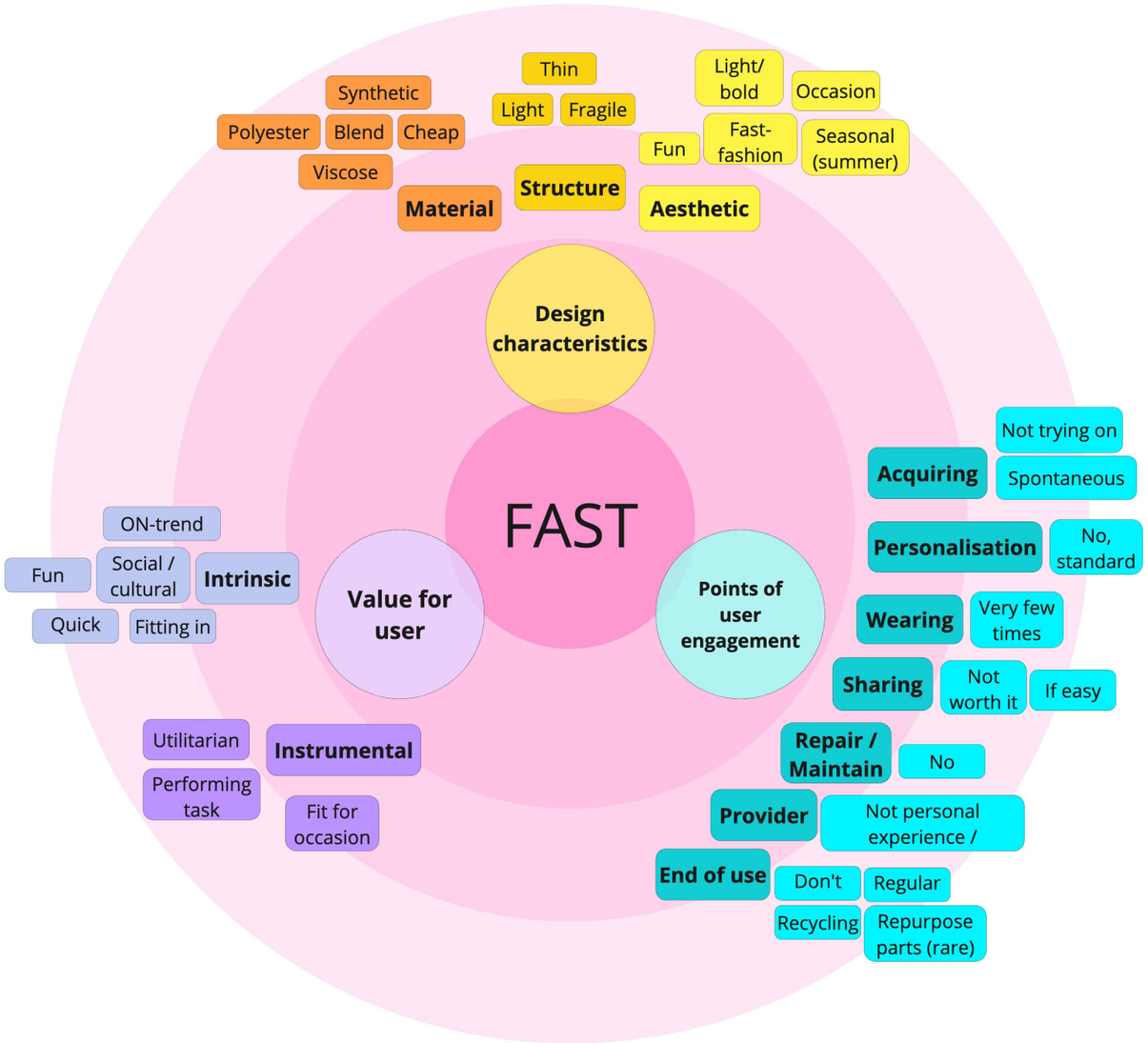
Whereas Thematic Analysis and Thematic Networks generate themes directly from the data (Braun & Clarke, 2006; Attride-Stirling, 2021), a different approach was employed here, effectively reversing the methodological process, to concentrate analysis on exploring the relationship between the themes identified through thematic analysis. Here, the primary factor 'Product life expectancy' provided the central point of analysis of data, represented as the two global themes, 'fast' and 'slow' in Figure 8, referring to the lifecycle pace of the two types of garments that consumers had chosen for this interview.

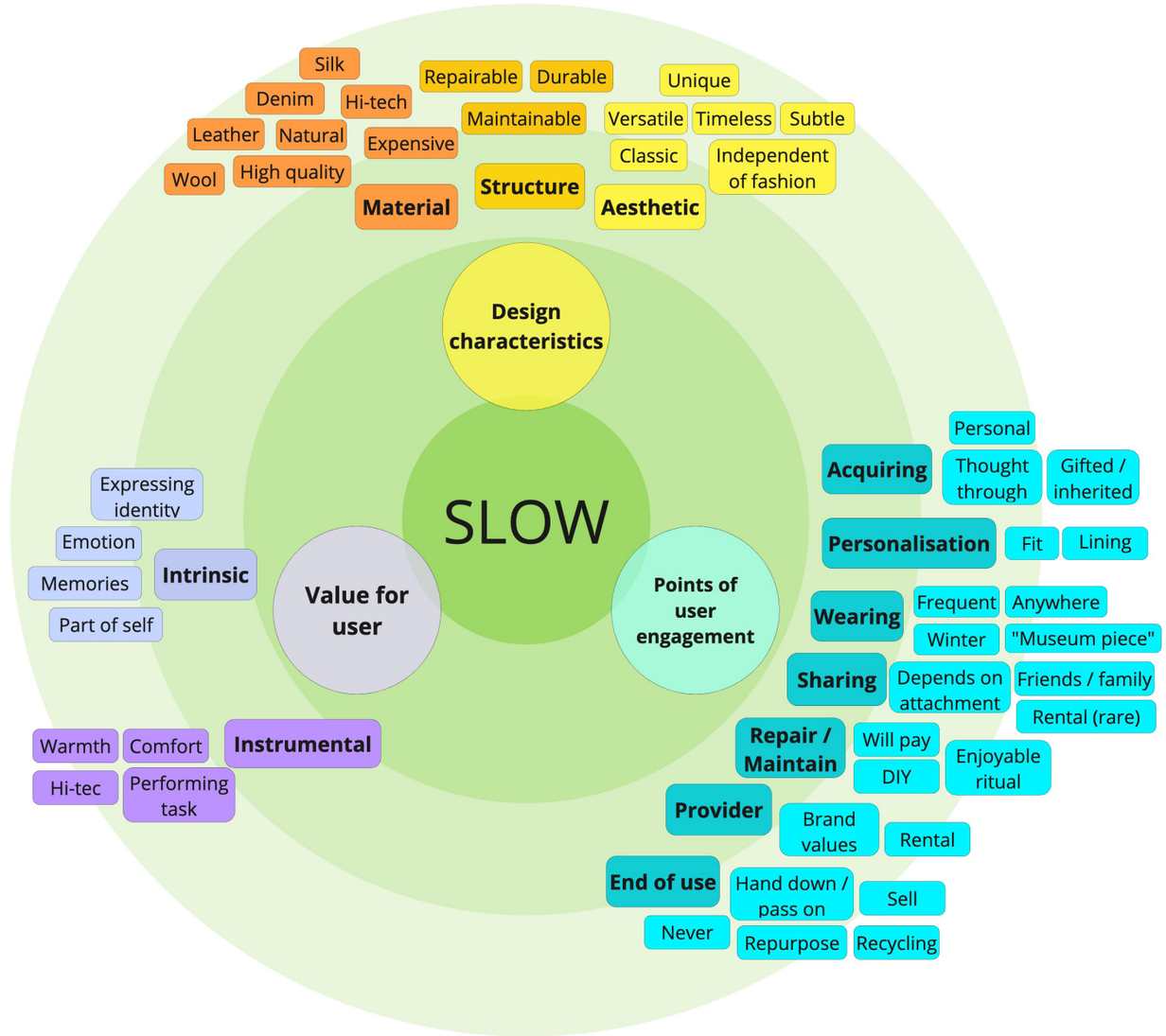
These global themes were used to explore various aspects of the relationship between the consumer ('User engagement') and 'Product life expectancy', and provides three organising themes, which are centred around aspects of the second primary factor, 'User engagement: (1) 'value for user' (referring to the forms of value participants derive from 'fast' and 'slow' garments); (2) 'Points of user engagement' (the different points along the garment's use phase where users would/wouldn't engage); (3) 'Design characteristics' (related to the material, structural and aesthetic characteristics of the two garment types that impacts both a user's engagement with the garment and the lifecycle pace of the garment, including 'production method, 'aesthetics' and 'material', but also considerations of 'DfS strategy' and 'business model', such as rental or sharing models).

A clear relationship is thus established between the global themes (the 'slow' and 'fast' pace of 'Product life expectancy') and the organising themes, which represent aspects of the second primary factor ('User engagement'). This established the basic framework for mapping out the data generated in the interviews; Recurring words, topics and connections in interview transcriptions were used to generate and organise the 'basic themes' that are represented in the outer spheres of the diagram (and thus aligning with the methodological practice stipulated by Attride-Stirling, 2021, in which themes are directly generated from the data). This qualitative data produced by the interviews is supported by additional quantitative data which can be viewed in the appendix (Section D2). What becomes clear, as will be discussed below, is that many of these 'basic themes' correspond strongly with the enabling factors identified in Chapter 4.

Figure 8 (next page) shows the interrelationship between the themes described above; there is a clear correlation between the two primary factors, and this is also evidenced by the grouping of qualitative data produced by interviews with consumers as themes which are intrinsically related to these primary factors. Further discussion below will show how the data from these interviews provides strong support for the importance of the enabling factors identified in Chapter 4, and, ultimately, the consumer's central role in considerations for DfS.

Figure 8. Study 1 themes organised using Thematic Networks method





5.1.2. Findings Study 1

The following sections describe how the three organising themes of ‘Design characteristics’, ‘Lifecycle points of user engagement’ and ‘Value for user’ relate to the global themes of ‘fast’ and ‘slow’.

Design characteristics of ‘slow’ and ‘fast’ garments

The quantitative data from interview questions related to life expectancy allowed for setting a baseline understanding of what characterises ‘slow’ and ‘fast’: The estimated total life expectancy of participants’ ‘slow’ garments was 46 years. In comparison, ‘fast’ garments had an average life expectancy of 4,2 years.

As Figure 8 shows, there are certain material, aesthetic, and structural characteristics which are connected to either ‘slow’ or ‘fast’ garments, and these characteristics seem to be almost opposite between these two garment-types:

In relation to aesthetics, ‘fast’ garments would often be connected with characteristics such as bright colours, bold cuts and patterns; features that make garments suitable for quickly matching a fast fashion trend or specific occasion, like a holiday or party. In opposition to this, ‘slow’ garments were described as “classic”, “subtle” and “elegant”. A high proportion of the ‘fast’ garments were only deemed suitable for the summer season, whereas ‘slow’ garments were outdoor/winter garments or worn year-round. The aesthetic features of ‘slow’ garments did not depend on fast-moving fashion trends or seasons; instead, they were seen as timeless, versatile wardrobe staples. Central to both garment types was the wish for the garment’s aesthetic to suit and/or express the identity of the wearer. However, the “message” communicated through these garments differed significantly depending on garment type, which is detailed on p.113 in connection to the theme of ‘Value for user’.

When looking at the design characteristics related to the basic themes of ‘Material’ and ‘Structure’, there was a tendency for ‘fast’ garments to be thin and light in their construction. Participants would often perceive these garments as fragile and reported therefore using them less. As one participant said: *“I can’t carry it anywhere unless I fold it. I just don’t trust that one as much”* (P9). In contrast, participants often described the structure of ‘slow’ garments as “sturdy” and “well-constructed”. They described “trusting” and using this garment-type more, which in many cases meant that participants would engage more with these garments, both physically (i.e., maintenance/ repairs) and emotionally (i.e. memories, or symbolism).

One design characteristic which this study collected quantitative data for was material composition (shown in Figure 9). This data demonstrated a clear difference between

the two garment types: ‘Slow’ garments generally comprised mono-materials and natural materials such as leather, silk, cotton, and wool. Polyester blends and synthetic materials, such as nylon, were also frequently seen. In ‘slow’ garments, synthetic materials were mainly used in performance-based pieces, such as rain jackets. In contrast, the ‘fast’ garments were generally made from cheap materials such as cotton, polyester, and viscose, and these were often textile blends. The most common materials used were petrochemical textiles such as polyester, viscose, and acrylic. From this data, one clear discrepancy stood out: The ‘fastest’ garments were often made from materials which are amongst the longest lasting, most resource intensive, and environmentally damaging textile materials available. This confirmed the need for a new design approach and understanding of how to design for a better balance of the different design decisions made in relation to garments’ lifecycle pace.

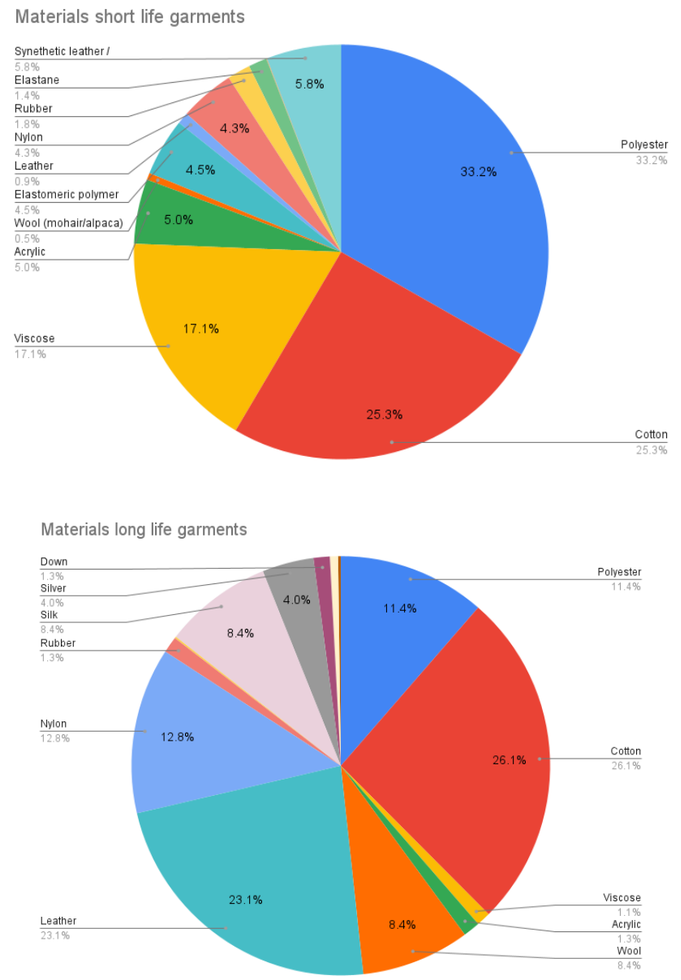


Figure 9. Material composition of ‘slow’ and ‘fast’ garments from Study 1

Lifecycle points of user engagement

This research theme relates to the *primary factor* of 'User engagement'. It covers identified points along the lifecycle of the two garment types where participants described engaging with the garment. Each of these points can contribute to strengthening the bond between user and garment, and, as proposed by Chapman (2005) the strength of this relationship can be decisive for whether users will engage in sustainable behaviours (e.g., to keep and maintain the garment).

1. Acquiring

The acquisition is important for how the lifecycle of a garment, whether 'slow' or 'fast', will unfold; it is the moment the user takes a garment into possession and thus the responsibility for its further journey.

For 'fast' garments, this point was commonly described as "spontaneous" or "rushed", as one participant said: *"It's rare that I impulse-buy, but this had to happen in a hurry, which is probably why it went wrong"* (P20). Others described being triggered by price-offers and convenience to buy 'fast' garments: *"I let myself be seduced by a low price and the fact that I'm in the shop anyway…"* (P19). Often, these 'fast' garments had been acquired with little to no interaction with the provider, and often through online shopping. Many described not even trying garments on before buying them. Furthermore, 'fast' garments were often bought for an occasion, like a party or holiday, with that single usage in mind.

In sharp contrast, the process of acquiring 'slow' garments was described as "personal", "meaningful" and "thought through". Participants were often familiar with the garment and/or brand beforehand, from online research or carefully trying it on. Acquiring 'slow' garments was often described as an engaging experience with personal encounters such as friend-like interactions with staff, family members or friends passing on/gifting the garment.

The point of acquiring seemed to impact participants' overall relationship to their garments: insignificant or negative experiences seemed to spill over into less user engagement in a garment's lifecycle, whereas deeply meaningful experiences might cause the user to take better care of the garment.

2. Personalisation / customisation

Acts of personalisation and customisation were infrequent for both 'slow' and 'fast' garments in this study. However, in the few cases where it had taken place, the scale and type of customisation, and who performed it, generally varied depending on garment type: customisation of 'fast' garments was done by the users themselves, as a form of "hacking" or experimentation, not worrying about the quality of the result. One participant described a 'fast' pair of shorts as her "creative playground" and explained: *"I would definitely just whip out a sewing kit and start thinking like I'm a pattern cutter"* (P15).

Customisation of 'slow' garments was described as a more significant undertaking which needed to be performed by a professional. For example, one participant had a tweed jacket whose lining he was considering upgrading. This jacket was very special to him, as it had been handed down through generations, and therefore he insisted that any changes had to be done by a skilled professional. Finally, 'slow' garments were perceived to be personalised through wear and tear; for example, a pair of jeans or shoes that had been shaped to the wearers' body over time. Customisation of 'slow' and 'fast' garments was different, but generally seemed to have extended their overall life expectancy.

3. Wearing

This theme focused on the frequency of wear: how much the user would "get out" of each of the two garment-types.

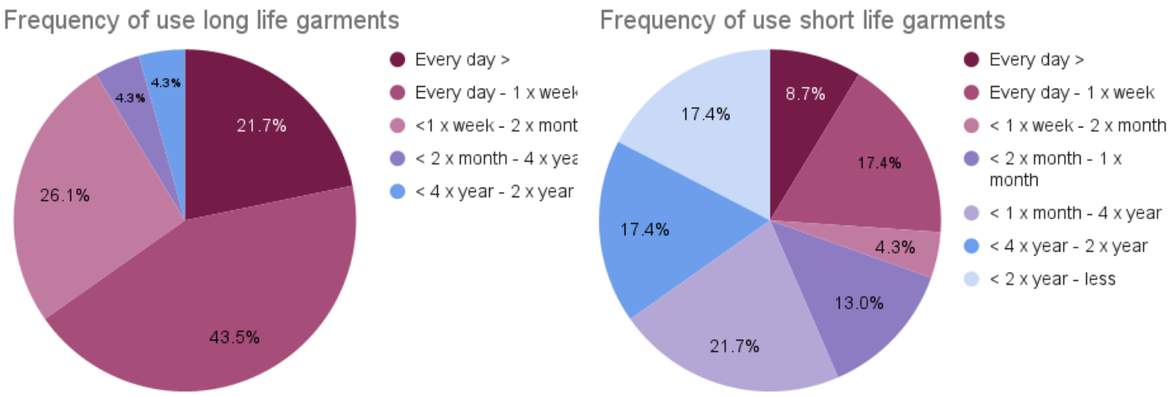


Figure 10. Frequency of use for the two garment types

One might expect that 'slow' garments are able to live for longer due to being worn less frequently than 'fast' ones. However, as demonstrated in Figure 10, that was not the case in this study: apart from a few cases, 'slow' garments were worn much more frequently than 'fast' ones: 65% of participants reported wearing their 'slow' garments more than once a week, and almost a quarter would wear them every day. In fact, only one of the 'slow' garments in this study was used less than twice a year, and this was due to its value being more like that of a personal "museum object" - this was a dress which the participant never wore but loved dearly and kept in her closet as a reminder of a special time in her life.

Some ‘fast’ garments were also worn very frequently, around a quarter of them more than once a week. Unfortunately, the structure and materials of these ‘fast’ garments were not strong enough for this, which caused them to wear out quickly. But in general, ‘fast’ garments were worn less frequently than ‘slow’ ones. Almost a third of participants reported wearing their ‘fast’ garments less than four times per year, with some hardly remembering wearing them at all. Participants’ reasoning for this related to functional characteristics: not being fit for purpose, or fitting participants’ bodies, as well as psychological, as well as emotional factors connected to aesthetics, such as garments not “fitting” people’s identity anymore.

4. Sharing

In recent years, the idea of the ‘sharing economy’ where individuals rent or borrow goods rather than buying and owning them, as an alternative, sustainable form of consumption has gained much traction (Belk, 2014; Hossain, 2020). However, participants in this study were generally not interested in sharing their clothes beyond close family and friends. Only one participant was a member of a garment rental platform. Several were users of the ‘Nu Wardrobe’, an online clothes-swapping marketplace, but this involves the transfer of ownership, not sharing. However, participants described being slightly more willing to share ‘fast’ than ‘slow’ garments. The main barrier for the participants to share garments, whether ‘fast’ or ‘slow’, was the fear of damages or losing a garment they were deeply invested in, especially if it was irreplaceable. Many described having some garments which were deeply connected to their identity, which they therefore feared sharing: “*I don’t share my most valuable clothes because it’s part of my identity. It’s not something I want other people to associate with or get the compliments for”* (P14). In summary, the willingness to share was not so much related to the pace of a garment’s use phase, but rather how deeply consumers were emotionally engaged in it.

5. Maintenance and Repair

Many participants were aware of environmental impacts of laundering and tumble-drying garments and described trying to do it less. Participants described washing ‘slow’ garments much less than ‘fast’ ones. Here, participants explained that ‘slow’ garments often were used further away from the body than ‘fast’ ones, and that ‘slow’ garments were made from materials which needed less laundering.

In regard to other forms of maintenance, there was a clear difference between participant’s willingness to engage in the two garment-types: They were much more involved in maintenance of ‘slow’ garments than ‘fast’ ones. Maintenance of ‘fast’ garments was seen as “not worth it” due to their perceived low monetary and personal value, and distrust in repairs having a lasting effect.

This was completely different for ‘slow’ garments where participants would describe maintenance as enjoyable, almost ritualistic practices. One participant described his monthly routine of maintaining his leather shoes: *“I polish and brush them and make sure they are in good condition because I am fond of them”* (P22).

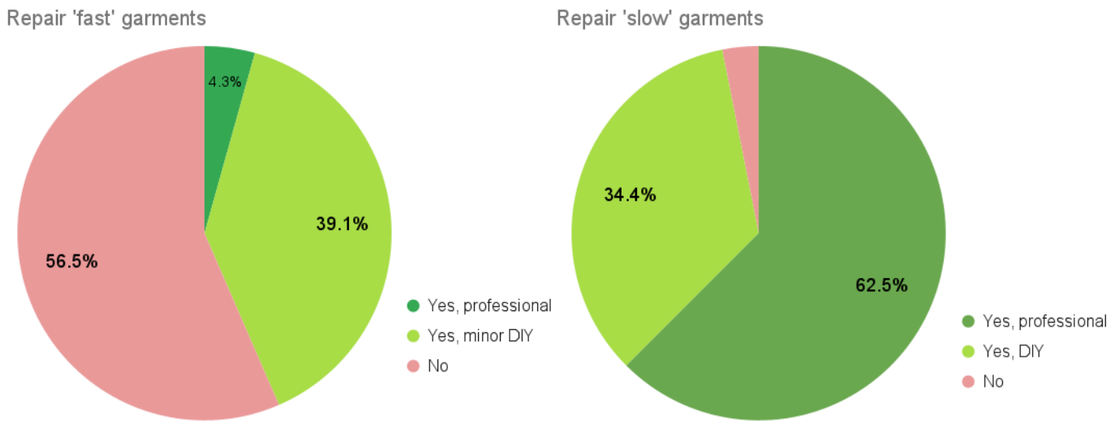


Figure 11. Participants’ willingness to repair ‘fast’ & ‘slow’ garments

As Figure 11 shows, a similar pattern emerged for acts of repair: participants were less likely to engage in repair of ‘fast’ garments than ‘slow’ ones. As one participant said about her ‘fast’ garment: *“I just don’t care enough to repair it* [...] *even if I did repair it, it would break again somewhere else”* (P7). 80% of participants were willing to pay for a professional to perform repairs on ‘slow’ garments, while no one was interested in paying for repair of ‘fast’ garments. However, interestingly, 40% of participants were in fact willing to engage in (usually minor) DIY-repair of ‘fast’ garments. This was less prominent (34%) for ‘slow’ garments, due to people not trusting themselves to do a good job -a risk they were not willing to take for ‘slow’ garments.

6. End of use

Even the final part of the relationship between the garment and consumer, varied significantly for two garment types, especially in terms of the reasons for and methods of discarding. Obviously, at the time of this study, none of the garments had been discarded yet, and thus the data for this lifecycle point is based on participants’ expectations.

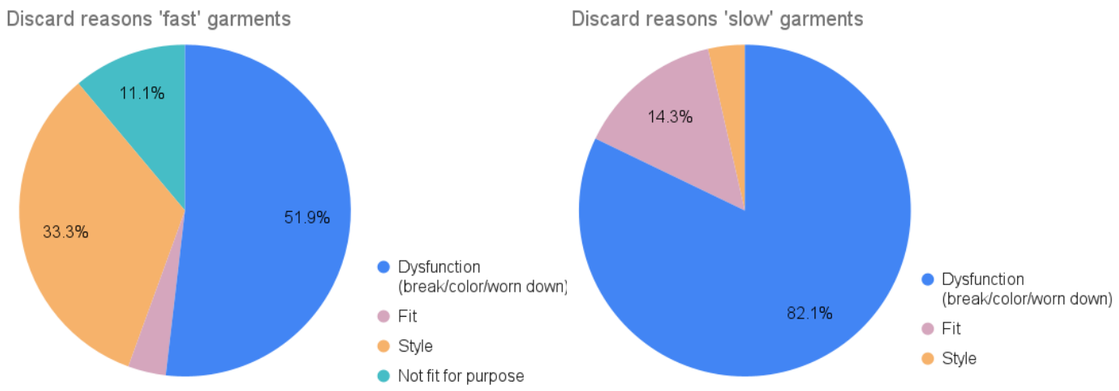


Figure 12. Participants' reasons for discarding 'fast' & 'slow' garments

As pictured in Figure 12, the reasons for discarding 'fast' garments were an almost even mix of psychological and physical factors. Common physical factors included not being fit for purpose and functional failures such as seams bursting, fasteners breaking, colours fading, and especially (up to 40% of physical factors) the material itself tearing, piling, or causing the garment to become ill-fitting.

Common psychological factors for 'fast' garments related to style or aesthetics, and participants no longer perceiving them as trendy and/or fitting their identity, and these accounted for almost 60% of the total reasons given. In comparison to this, discard-reasons related to style and psychological factors were much less prevalent for 'slow' garments, only accounting for 12%.

For 'slow' garments, functional defects that arose from simply being worn out through many years were the main expected reason for discard accounted for 60%. Apart from the material itself, almost a third of these functional defects were specifically related to mechanisms such as zippers and fasteners, as well as high-tension/abrasion areas like linings, pockets, knees, and sleeves.

A common denominator for 'slow' garments was that almost a third of participants refused to even describe ever parting with their 'slow' garment. Instead, many intended to keep at least the remaining parts for repurposing or embedding them in a new garment. As one participant said: *"I would want to repurpose it into something else[...] because it has more meaning to me"* (P4).

Statements like these indicated a deep level of emotional attachment where the emotional value of the garment far surpassed its functional value. People wanted to keep garments (or what was left of them) almost as a token or talisman, enabling them to savour a memory of a time or person in their lives.

Finally, in terms of discard methods, the difference between 'fast' and 'slow' was again significant: People did not care much about where their 'fast' garment would go, as long as it was convenient. Many were aware of environmental impacts and wanted to "do the right thing" to recycle it but admitted being too lazy or unsure how. Participants would not generally resell or donate a 'fast' garment, as they believed it wouldn't be in a condition to be of value to others.

The discard methods of 'slow' garments were much more thought-through. People cared about their garments' further life and often, if not keeping them, wanted to pass them on to close friends or family. Some even expected their 'slow' garment to outlive them and be passed on to their children. Another common option for 'slow' garments, was to sell them as they often were of decent monetary value (60% more than £50, and some over £300). Essentially the difference between 'fast' and 'slow' was that once the end of use was reached, 'fast' garments were seen as waste that people wanted to free themselves of, whereas 'slow' garments were seen as an asset that might have value for others or as part of a new garment.

Value for the user of 'slow' and 'fast' garments

The types of value participants experienced from 'slow' and 'fast' garments varied greatly, but was always a mix of different symbolic, emotional, and functional forms of value.

To understand this, I draw on sociologist Max Weber's (1978) definition of two overarching types, or patterns, of value creation: 'instrumental' and 'intrinsic'. 'Instrumental' value is measured according to an object's utilitarian ability; how it performs the task it was designed for. This type of value is measurable and objective. In contrast, 'intrinsic' value is subjective and depends on cultural and emotional factors. 'Intrinsic' refers to the object being good *in and of itself*, besides its utilitarian function. A garment's intrinsic value depends on its ability to generate or signify meanings within social or cultural contexts, i.e., Belonging to a specific social group one wants to be part of (Chapman, 2021).

The themes generated from the analysis of Study 1's data show, (depicted in Figure 8, p.104), that these two types of value (intrinsic and instrumental) occurred in connection to both 'fast' and 'slow' garments, but seemed to be experienced in larger or smaller quantities/intensities in each type, as visualised in Figure 13, on a sliding scale:

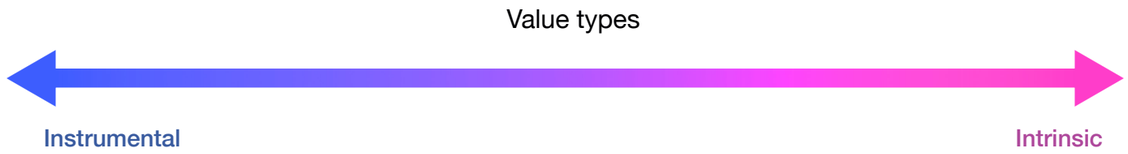


Figure 13. Instrumental and intrinsic value types - a sliding scale

The study showed ‘slow’ garments at both ends of the scale: An example of a garment with high instrumental value was a standard black rain jacket, mainly appreciated for its functional abilities, such as being lightweight and waterproof. In contrast to this, we find the previously mentioned ‘slow’ silk dress, bought to mark the participants’ transition to a new life-phase: This piece holds little instrumental value as the participant barely wears it. Instead, its main value is intrinsic; it evokes deep emotions and reminds her of her ability to overcome challenges. Even though both types of value were experienced in ‘slow’ garments, the intrinsic type seemed to be dominant. Interestingly, the study data also showed a dominance of experienced intrinsic value of ‘fast’ garments.

This indicated that garments as a general product-type carry more intrinsic than instrumental value. Thus, the difference between ‘fast’ and ‘slow’ lies not in whether the value is less or more intrinsic or instrumental, but rather, as the data indicated, there is a difference in the “depth” at which value was experienced.

For example, one interviewee had a ‘fast’ shirt, bought for a Christmas party: the value of this blouse was mainly intrinsic, allowing the user to fit into a specific, temporary social context, but the user’s relationship to this garment was relatively shallow as the extent of this value was limited to that single office party. In comparison, one participant had a deep connection to a ‘slow’ shirtdress, which she had inherited from her mother, loved dearly, and found pleasure in taking care of. In both these cases, the value is mainly intrinsic, but the value is experienced at completely different levels, or “depths” of emotional engagement.

Another set of concepts which informed this thesis’ understanding of “depth”, is psychologist Daniel Kahneman’s idea of ‘Hedonic’ and ‘Eudaimonic’ well-being, which distinguishes between these two perspectives on, or ways of achieving, happiness, and well-being: ‘Hedonic’ well-being relates to experiences of pleasure and enjoyment, whereas ‘Eudaimonic’ well-being is achieved through “deeper” experiences of self-realisation, purpose and meaning (Kahneman et al., 1999).

When looking at the garments in this study, the value that ‘fast’ garments would provide was often more hedonic; almost a “quick fix” to bring enjoyment for the user; enabling them to swiftly, and for a short period of time, dress up for a specific social context. On the other hand, ‘slow’ garments would elicit more eudaimonic forms of value; anchoring participants’ sense of belonging in a social group and/or enabling deeply personal experiences of purpose and meaning. For example, the previously mentioned tweed-jacket, which had been handed down through generations, is an example of these ‘slow’ and ‘deep’ garments which elicited a deep sense of meaning, comfort and belonging for the user.

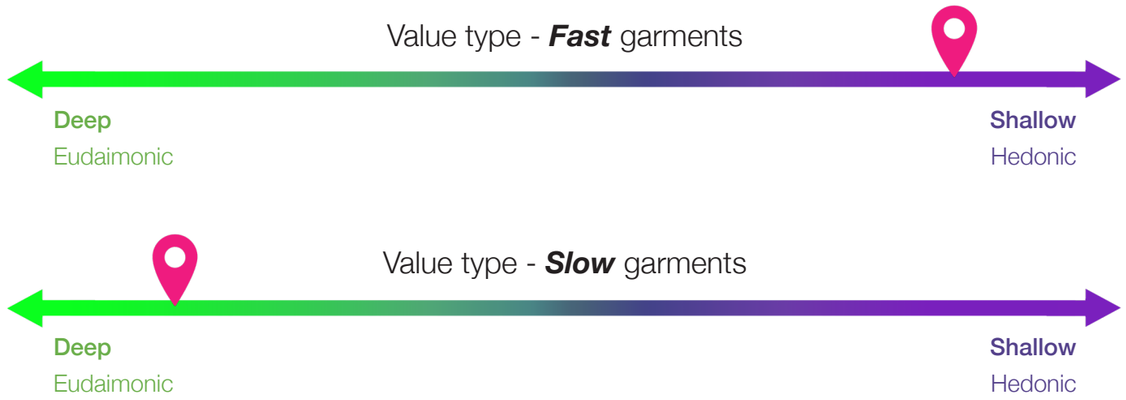


Figure 14. ‘Fast’ & ‘slow’ garments’ most commonly form of experienced value mapped on a scale from ‘deep’ to ‘shallow’

Broadly generalising, the data from this study showed that the experienced value of ‘slow’ garments usually was deeper than the value of ‘fast’ garments, as illustrated in Figure 14. This indicates a close correlation between the two *primary factors*: The deeper the value a garment holds to a user, the more likely it is to have a long life - and vice versa. This also leads to the observation of a strong correlation between the depth of a user’s experienced value of a garment, and the level to which they will engage with it at different points during the garment’s lifecycle, which form two of the organising themes in Figure 8. As visible in Figure 8, the ‘slow’ garments, which generally hold deep forms of value, clearly also have more user engagement, and at more points during their use phase. In contrast, ‘fast’ garments, which would hold more shallow value for consumers, would have much less engagement.

This ultimately allows a refining of how the *primary factor* ‘User engagement’ can be understood and analysed, by focusing on the proportionate relationship between depth of value and the level of physical user engagement. Just as ‘Product life expectancy’ could be analysed on a spectrum between ‘fast’ and ‘slow’, similarly, attention to the ‘depth’ and ‘shallowness’ of ‘User engagement’ provides a clearer understanding of how this *primary factor* influences a garment’s lifecycle. More importantly, a consideration of how the spectrums of these two *primary factors* intersect and correlate can provide a sophisticated framework for analysing garments, and ultimately the appropriate DfS strategies for designers to consider, which will inform the creation of the Garment Life Matrix and Tool (Chapters 6-7).

5.1.3. Study 1 summary

This study has built further understanding of the identified *primary* and *enabling factors* for sustainable garment design, and how these correlate. The Thematic Analysis of data from interviews with consumers regarding their experiences with 'fast' and 'slow' garments revealed a set of key themes describing factors which, from the perspective of consumers, have particular impact on garments' lifecycles. These themes, structured under the organising themes of 'Design characteristics', 'Lifecycle points of user engagement' and 'Value for user', all relate directly to, and thus confirms the *primary* and *enabling factors* established in Chapter 4.

Furthermore, this study has revealed a tendency for design characteristics of aesthetics, structure, and materials (which relate directly to the *enabling factors*) to vary depending on the speed of a garment's lifecycles (which relates directly to the *primary factor* of 'Product life expectancy').

In regard to the *enabling factors* of 'Points of user engagement' and 'Business model', this study has built an understanding of the kinds of activities consumers willingly engage in throughout the lifecycle of 'slow' and 'fast' garments; demonstrating what types of offers and engagements might be relevant depending on the *primary factor* of 'Product life expectancy'. This revealed an overall tendency for consumers to engage in more activities and invest time, effort, and money into garments the longer their life expectancy, which indicates a correlation between the two *primary factors:* 'User engagement' and 'Product life expectancy': The more engaged (both emotionally and physically) the user is in a garment, the longer its life expectancy - and vice versa.

Furthermore, the findings from this study allowed for a refined understanding of the *primary factor* of 'User engagement': firstly, it provided the insight that there is a difference in the depth of value that the 'slow' and 'fast' garments hold for consumers. 'Slow' garments generally provide deeper forms of eudaimonic value, with a higher degree of psychological resonance, than 'fast' garments. In contrast, 'fast' garments tend to provide more shallow, hedonic forms of value.

The following section describes a series of visual mapping experiments conducted to extend and articulate the understanding of the presumed correlation between the two *primary factors.*

5.1.4. Preliminary framework - The Garment Life Matrix

At this stage of the research, the data collected thus far on the *primary* and *enabling factors* and their correlation was combined and used as input for a series of iterative Research through Design (RtD) (Frayling, 1993) experiments, to make further sense of and refine the understanding of the following findings:

1. The identification of the set of *enabling factors* and *primary factors* (Chapter 4).

2. A refined understanding of these factors and their correlation from the perspective of consumers, specifically the relationship between the two *primary factors.*

3. Through analysis of users' experience of garments, a refined understanding of *primary factor* 'User engagement' as occupying a spectrum from 'deep' to shallow' (Study 1, Section 5.1).

These findings were mapped out on a coordinate plane entitled the *Garment Life Matrix* (GLM), using the two *primary factors* as the two axes. The horizontal axis represents 'Depth of user engagement', reaching from 'shallow' to 'deep'. The vertical axis represents 'Product life-expectancy', reaching from 'slow' to 'fast'.

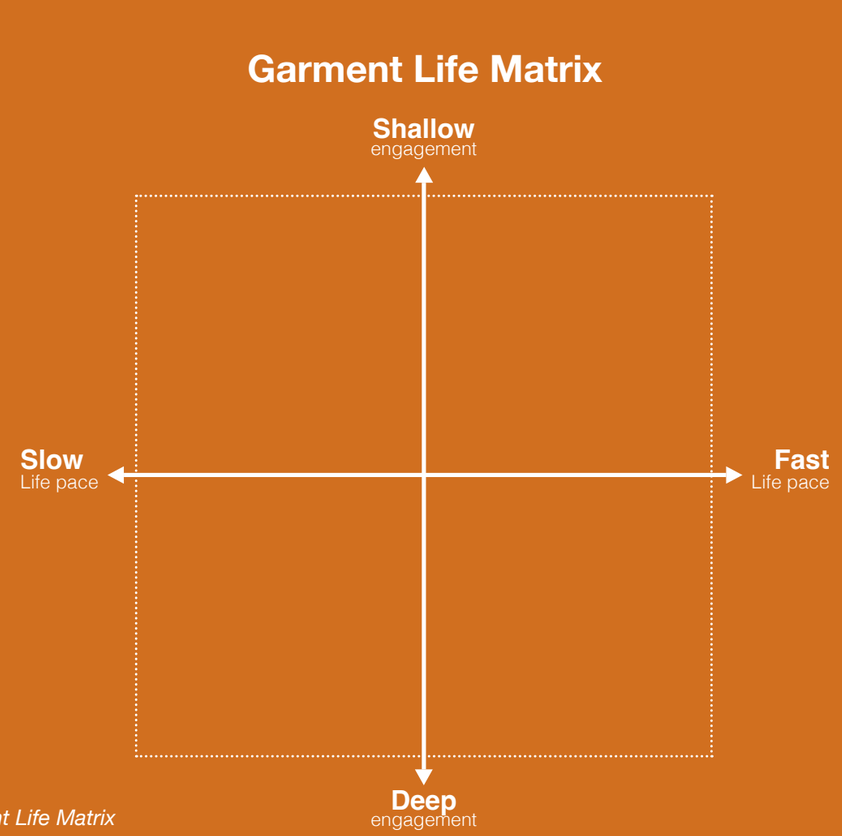


Figure 15.
The Garment Life Matrix

The GLM framework was tested by mapping the two garment-types (‘fast’ and ‘slow’) chosen by participants into it. Each garment was represented through a photo, either shared by participants, or sourced online based on information from participants, as seen in Figure 16. Using these photos allowed for the garments’ visual characteristics to support their placement in the matrix.

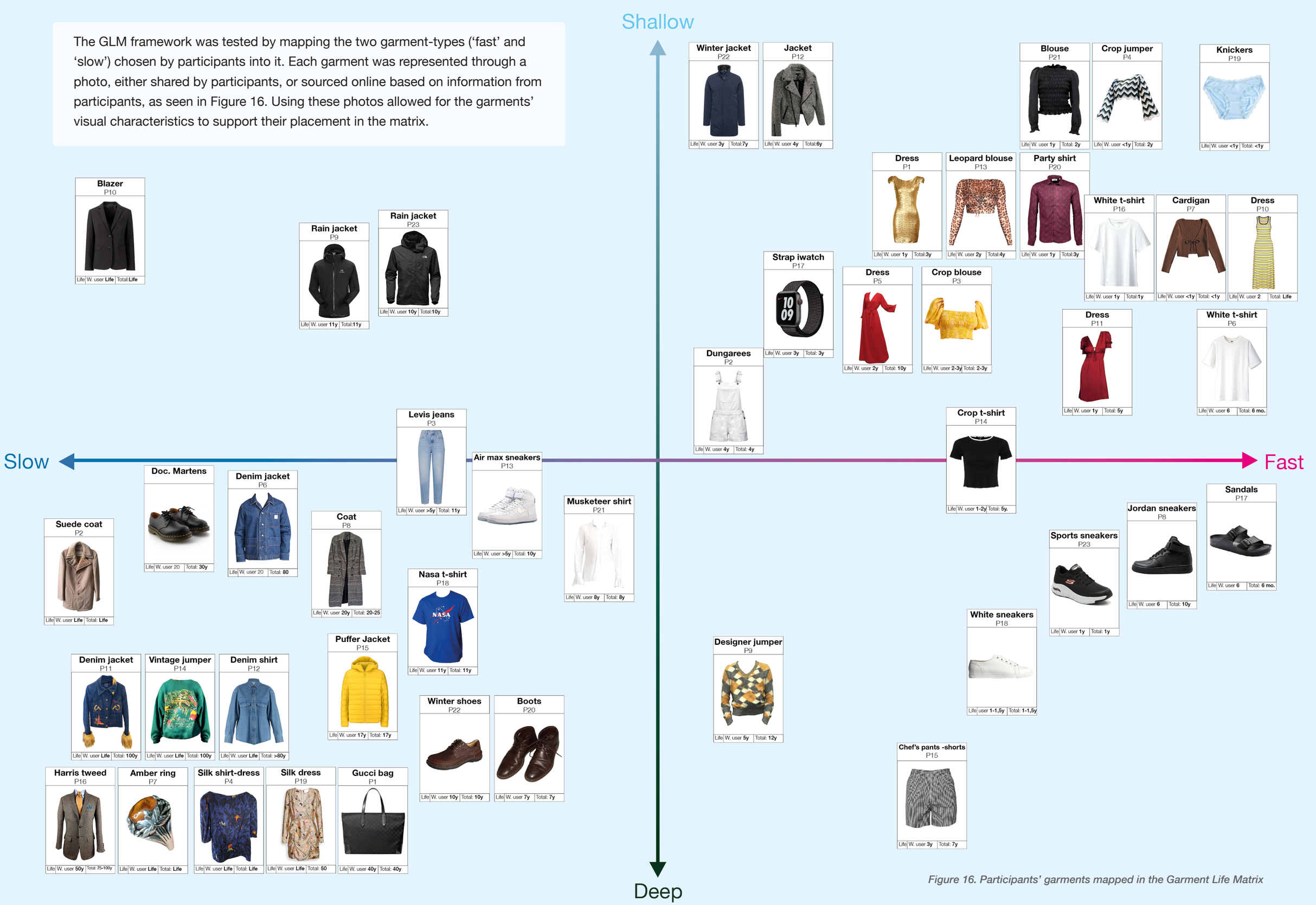


Figure 16. Participants’ garments mapped in the Garment Life Matrix

Along with visual characteristics, this process was supported by interview data; each garment-placement was annotated with interview-quotes, documenting the reasoning for their individual placement in relation to the two axes, as seen in Figure 17.
As participants' garments were distributed within the matrix, a clear pattern from the bottom-left to the top-right corner emerged (visible in Figure 16). This supported the assumption of a correlation between the two *primary factors*: The longer the life expectancy, the deeper the engagement, and similarly; the shorter the life expectancy, the shallower the level of engagement.

However, when looking at the 'fast/deep' and 'slow/shallow' quadrants of the matrix (Figure 16), it also emerged that not all garments follow this logic. For these 'fast/deep' garments, it was a combination of constant use and fragile materials and colour that would lead to the fast use phase. The few garments which were placed in the 'slow/shallow' quadrant (top left, Figure 16), were highly functional, durable garments with an almost anonymous aesthetic in dark, muted colours.

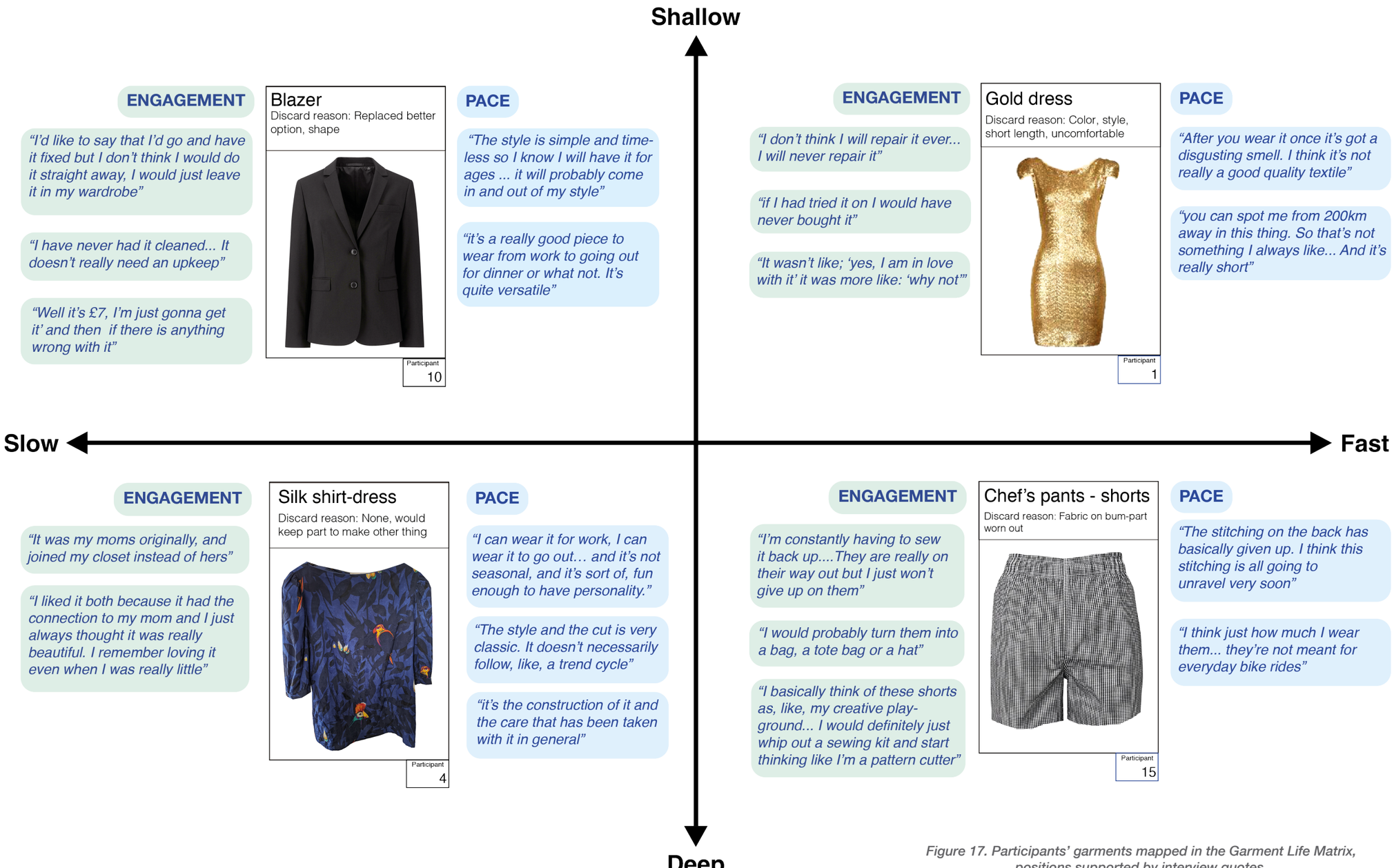


Figure 17. Participants' garments mapped in the Garment Life Matrix, positions supported by interview quotes.

The rather elaborate Figure 16 was synthesised into a simpler diagram, Figure 18 (below), where only the most prominent garment characteristics of each matrix quadrant were inserted. Through this process it emerged that many characteristics are relevant across an entire axis, so that a set of more general characteristics could be established in relation to the *primary factors* at the end of each axis. For example: 'Slow' garments generally have a sturdy, easily maintainable structure, and tend to have neutral, muted colours, regardless of if they belong in the 'deep' or 'shallow' half of the GLM.

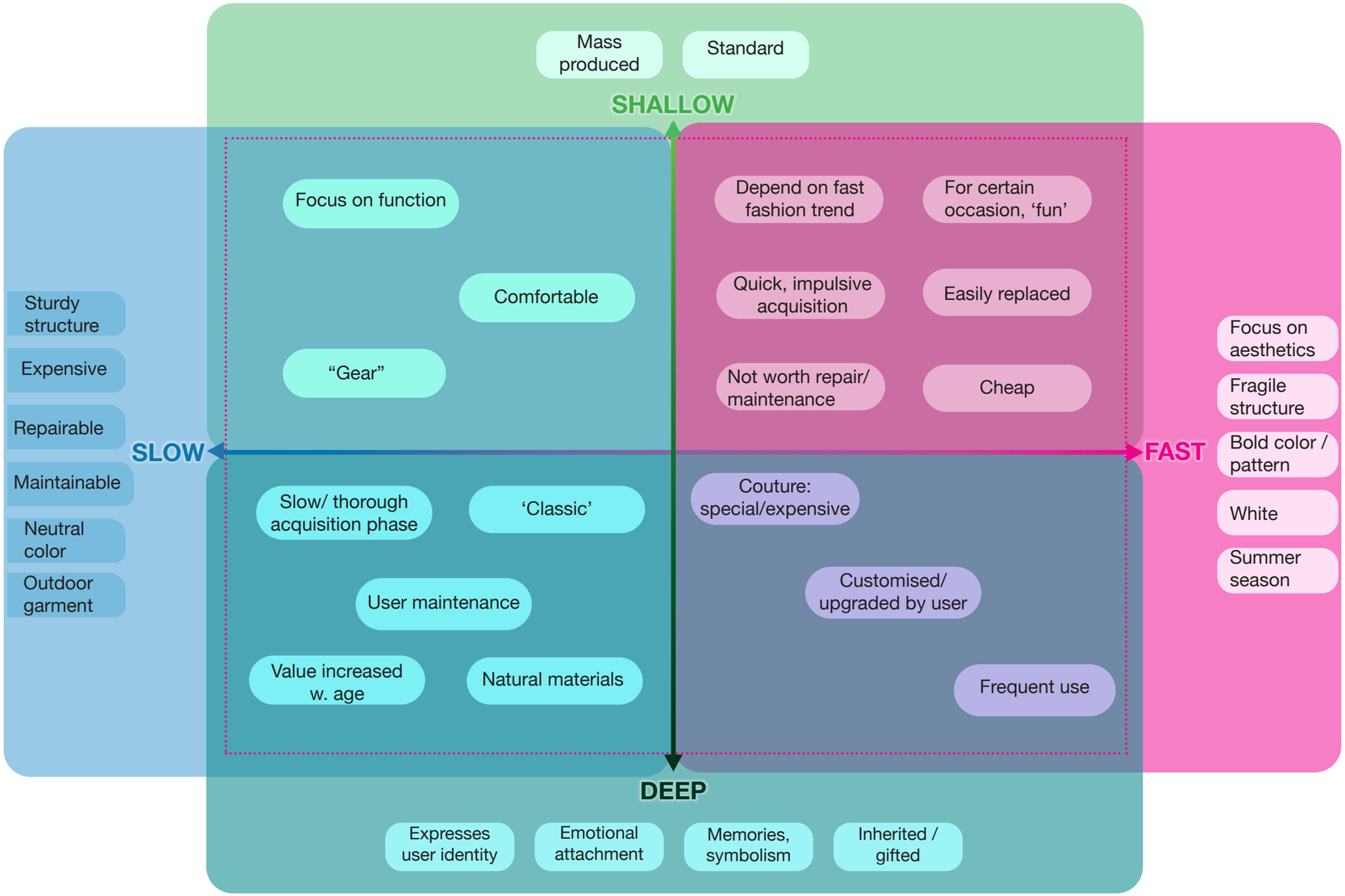


Figure 18. Garment Life Matrix with synthesised characteristics of Study 1 garments

Relationship between the two primary factors

These mapping exercises (Figure 16, 17, 18) added to the findings from the Thematic Analysis of Study 1 data (Section 5.1.2.) to further define the relationship between the two *primary factors*: the deeper the level of user engagement, the slower the garment pace of the use phase, and vice versa; the slower the lifecycle pace, the deeper the level of user engagement. And similarly, the shallower the level of user engagement, the faster the garment lifecycle pace, and vice versa. This works as a general rule, but this is not true in all cases.

The following section turns to investigate these *primary* and *enabling factors* influence on garments' lifecycles, but this time, from the perspective of garment industry professionals.

5.2. Study 2.
Investigating the *primary* and *enabling factors* with garment industry experts

This second study draws on the perspective of garment industry professionals to test and extend findings from Study 1, to further respond to RQ3 and RQ3a: *What are the most important design factors for garment sustainability? And how might these be related?*

In this study, the relationship between the two *primary factors* is tested through a focus group session with garment industry professionals, in which the GLM framework (which articulates this relationship), is used to facilitate discussions.

Furthermore, the GLM framework is used as a vehicle for discussing the relationship between the *primary* and *enabling factors,* to investigate if and how, from the perspective of industry professionals, the *enabling factors* vary depending on the *primary factors*.

Finally, by engaging industry professionals in visual experiments focused around the *primary* and *enabling factors*, and their relationship, this study also builds knowledge towards developing support for DfS in the garment industry, which is the goal of this thesis.

5.2.1. Study design

This study was run as a focus group session (Krueger & Casey, 2000) with a selected group of participants consisting of garment designers and other industry professionals. The study did not follow an interview protocol, but instead incorporated design workshop elements (Hannington & Martin, 2012, p.62) so that the focus group-session was structured around a small set of group activities.

Participants

The eight participants in this focus group were garment industry professionals recruited from the Innovation Team of a major UK-based clothing, footwear, and sporting goods conglomerate. The participants represented different disciplines and organisation levels including material specialists, garment designers, managers, and experts in supply chain, business models and consumer experience. All participations signed consent-forms prior to the study as described in the Ethics Statement (p.3). Participants were anonymised for analysis and given ID codes as can be seen in Table 6.

Table 6. Study 2 Participant ID

ID	Field of experience
Materials 1	Materials Specialist in Innovation Team- Soft Goods
Materials 2	Materials Specialist in Innovation Team - Hard Goods
Apparel 1	Apparel Designer in Innovation team
Apparel 2	Apparel Designer
Compliance 1	Product Compliance Manager in Supply Chain Team
Creative 1	Creative Talent and Networks Director
Product 1	Product Development Manager
R&D 1	Head of Research and Development

Data collection - methods and setting

Due to the ongoing COVID-19 pandemic which caused a UK-wide lockdown, this focus group took place in an online virtual environment: A Miro board containing interactive activities, designed by the researcher using the software program ‘Miro’. The session was facilitated through the video meeting software ‘Zoom’, and audio and video recorded. The Miro board, which resulted from these activities, served as an important way to document participants’ contributions. The Miro board can be seen by clicking the button below, or in the appendix Section E1. This will open a copy of the original Miro board, you are invited to move things around and explore the different elements.

CLICK HERE
to open the
Miro board

Method of Analysis

Once again, Thematic Analysis (Braun & Clarke, 2006) (cf. Section 3.1.1.) was used to identify important research themes. First, the process of transcribing the video recordings was used for ‘familiarising’ with the data. The next steps in the analysis of identifying important themes in the data were supported by the Miro board which had been filled in by participants during the study.

Study activities

Participants were invited to test and respond to the Garment Life Matrix (GLM) framework through two activities: the first activity was centred around the ‘pace’ axis, and the second activity introduced the ‘depth’ axis, encouraging the participants to consider the two axes together. These activities were ‘flexible modelling’ activities (Hannington & Martin, 2012), where participants were engaged in configuring elements within the Miro board, whose features had been predetermined by the researcher. This method encouraged participants to interact directly with the GLM’s elements, which was particularly helpful for gaining knowledge and feedback around the framework’s structure.

Activity 1

First, the participants were invited to categorise garments according to lifecycle pace by dragging images symbolising different garment types from a virtual “wardrobe” (Figure 19) and placing them along a double-sided arrow whose polar ends represented ‘fast’ and ‘slow’ lifecycle pace. There was one “rule” in this activity, which also applied to the remaining session: participants were tasked with reasoning and discussing each placement of a garment with the group. This led to discussions and iterative movements of the garments along the axis as the group reached consensus - which they did surprisingly quickly.

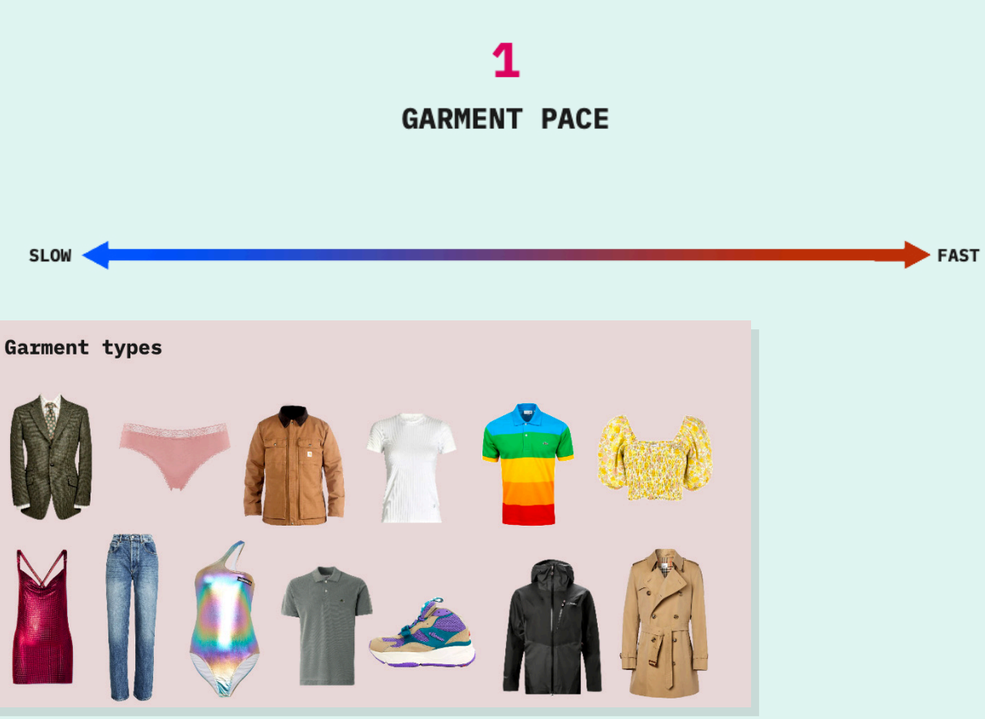


Figure 19. ‘Pace’ axis activity in Miro virtual collaborative environment

Next, this exercise was expanded to include discussion of the lifecycle pace of garments’ individual parts, considering them as ‘assemblages’ whose components age at different paces. As shown in Figure 20, participants picked components from the virtual “wardrobe” and inserted them along the ‘pace’ axis.

Figure 20. Garment components placed on the ‘pace’ axis

Activity 2

This activity introduced the GLM axis related to ‘Depth of user engagement’, focusing group discussions on consumer behaviours and emotions, and how these affect garment life expectancy (or the other way around). As in the previous activity, participants placed images of garments while explaining their decision, but this time the discussion had the added dimension of ‘depth’ as seen in Figure 21 (below). Here, participants built onto their reasoning from Activity 1 to negotiate garment placements.

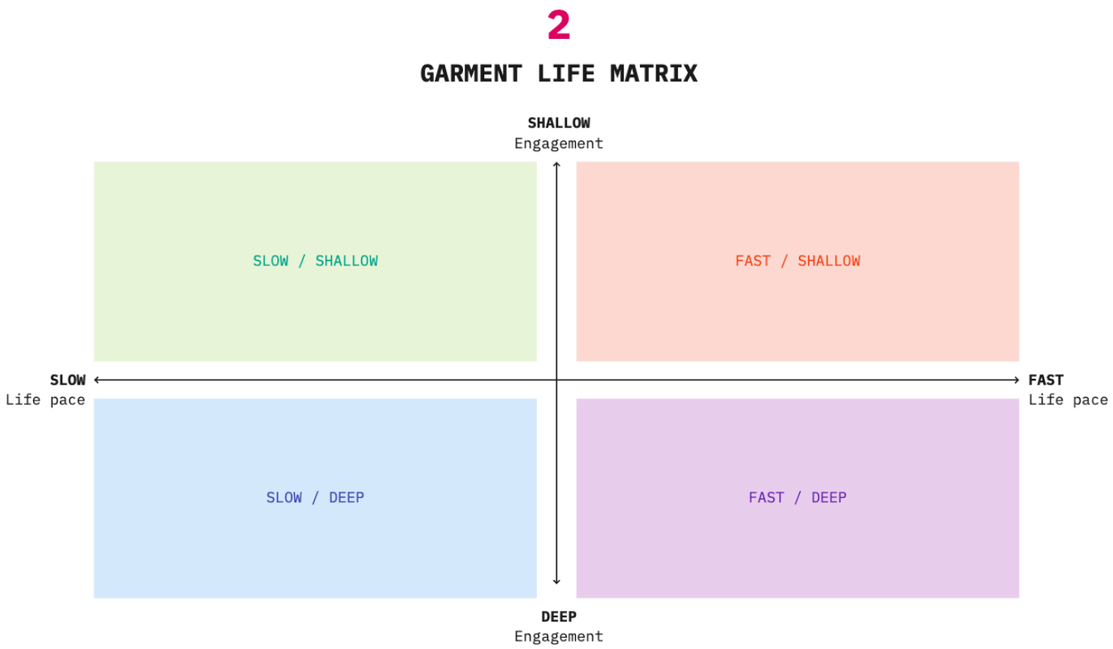


Figure 21. Garment Life Matrix (GLM) to be filled in by participants in Activity 2

Next, participants were invited to place characteristics related to the enabling factors, shown on virtual post-it notes (Figure 22), into the matrix framework (Figure 21). The task here was to determine and explain which characteristics they, as industry experts, thought would be most suitable for designing sustainable garments, in each of the four quadrants of the GLM.

The participants were also encouraged to add their own ideas for design characteristics by grabbing an empty post-it note, writing their idea on it and placing it in the GLM.

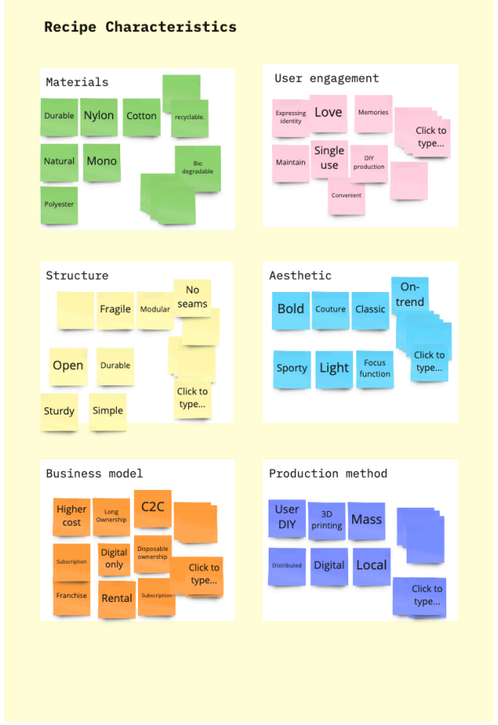


Figure 22. Characteristics related to the enabling factors to be placed in the GLM by participants

5.2.2. Findings Study 2

The collected data and the Miro-board generated during Activity 1 (Figure 23), in which participants placed garment-types along a ‘pace’ axis, showed a clear tendency: the most common reasons given for placing garments on the ‘fast’ end had to do with style and aesthetics, not functionality. The bold, brightly coloured, and structurally light garments were placed on the ‘fast’ end of the axis, whereas thicker, dark, and more subtle garments, described as “classic” or “iconic” were placed on the ‘slow’ end. Despite no previous experience with thinking of garments in terms of pace, participants placed garments on the axis with very little hesitation.

Figure 23. Participants’ placements of garment types along the ‘Pace’ axis

The next step of Activity 1, which “zoomed in” to focus on garments’ components to place these along the pace axis (visible in Figure 24), started discussions in the group around how different components of garments age. E.g., How parts affect each other, and how this might affect the overall life expectancy of the whole garment.

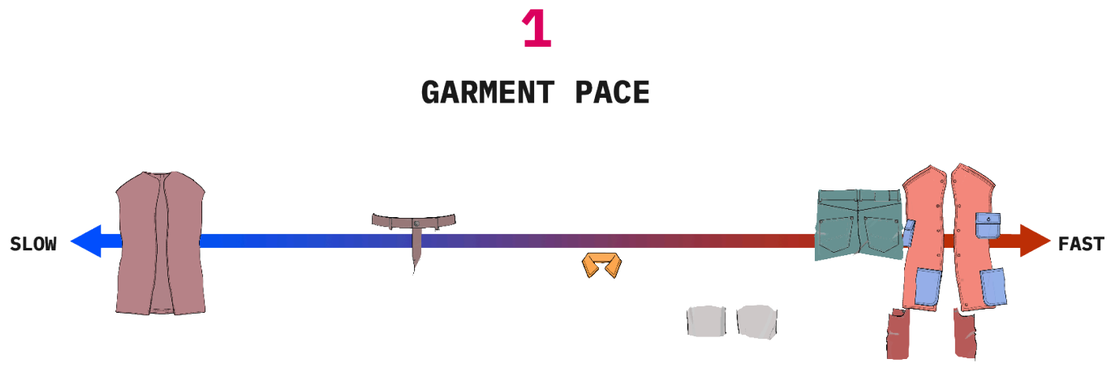


Figure 24. Participants’ placements of garment components along the ‘Pace’ axis

Generally, structural parts, such as the belt of a pair of jeans, or main body of a jacket, were placed in the ‘slow’ end, whereas closing mechanisms, zippers, pockets, and the inner lining were seen as ‘fast’. Participants described these ‘fast’ components as “high risk” or “high abrasion”-areas.

This exercise led participants to reflect on their own current practice, and sparked new ideas for how they might improve sustainability. e.g.*: “A lot of these pockets and linings and things, are usually made from cheaper fabrics only because they’re not seen by customers, but actually they are high use, high abrasion areas”* (Apparel 1). Another participant responded: *“Maybe if you were able to replace the cheap inner lining of a jacket compared with the more expensive outer. That would be interesting”* (Materials 1).

Activity 2, which introduced the second ‘depth’ axis, was more demanding for the participants: they took longer to place each garment than in Activity 1, and each placement was debated more. The populated GLM which emerged from Activity 2 (Figure 25), showed a clear diagonal pattern from the bottom-left to the top-right in how the garments had been placed: Most garments were placed in the ‘slow/deep’ and ‘fast/shallow’ quadrants. This indicates a correlation between the two *primary factors*, represented on the GLM axes: generally, a deeper level of user engagement means the garment will have a slower lifecycle pace, and vice versa.

Figure 25. Participants’ placement of garment types in the GLM

Like Activity 1, the most common reasons for participants perceiving garments as ‘fast’, had to do with style and aesthetic, not functionality. ‘Fast’ garments were often described as “fashionable”, their value depending on the speed of fashion trends, eliciting shallow forms of happiness, but also quickly becoming irrelevant. The participants connected acquiring ‘fast’ garments with impulse-buying or for a specific occasion. As an example, one participant said about a pink, skimpy dress she placed in the ‘fast/shallow’ quadrant: *“It's about creating a look, very quickly*” (Creative 1). Garments in this ‘fast/shallow’ quadrant were described with characteristics such as “disposable” and “commodity”.

Although most ‘fast’ garments were placed in the ‘shallow’ GLM half, a few were also placed in the ‘deep’ half. These ‘fast/deep’ garments were described as personal, special, and expensive, and likely to be worn for a memorable occasion. Here, one participant mentioned a wedding dress being the ultimate ‘fast/deep’ garment. Finally, ‘fast’ garments were connected to a lack of versatility or ability to match with other garments.

A recurring characteristic for ‘slow’ garments was the capacity for ageing well and retaining its value for the owner, as one participant described: *“The Burberry coat, I think it's a classic that lots of people keep. It’s an icon that just keeps on giving [...] And even if you don't keep it, you can sell it”* (Creative 1). This “slowness” was described as related to aesthetics and cultural value assigned to the garment with time. Furthermore, characteristics of durability, high-quality of materials, and capacity for repairs was emphasised in relation to ‘slow’. As one participant explained: “*I think it looks better the older it gets, it's designed with durable materials that are going to age in an interesting way*” (Materials 2).

In relation to “ageing well”, participants mentioned the users’ “history” or “emotional connection” to the garment, as one participant explained: “*The history with the product is going to build up over time and make it even more than it was to start”* (Materials 2). These features were specific to ‘slow’ garments placed in the ‘deep’ GLM quadrant.

Even though ‘slow’ garments were usually placed in the ‘deep’ half of the matrix, a few were also placed in the ‘slow/shallow’ quadrant. These garments were appreciated for their instrumental qualities and “doing the job”; keeping the user warm and comfortable season after season, rather than their aesthetic features, which were described as “standard” or “anonymous”. Nonetheless, the general assumption was that a stronger, deeper, bond between consumer and garment would mean they would take better care of it, and that this would lead to a longer garment life. On the other hand, a weaker bond, with shallow levels of engagement, was associated with a fast lifecycle pace. Lastly, participants agreed that, despite strong overall patterns, consumers are all different people who form different levels of attachment to garments.

The last part of Activity 2 drew specifically on participants' expertise; getting them to place design characteristics related to the *enabling factors*, based on their suitability to support development of sustainable garments in each GLM quadrant (Figure 26).

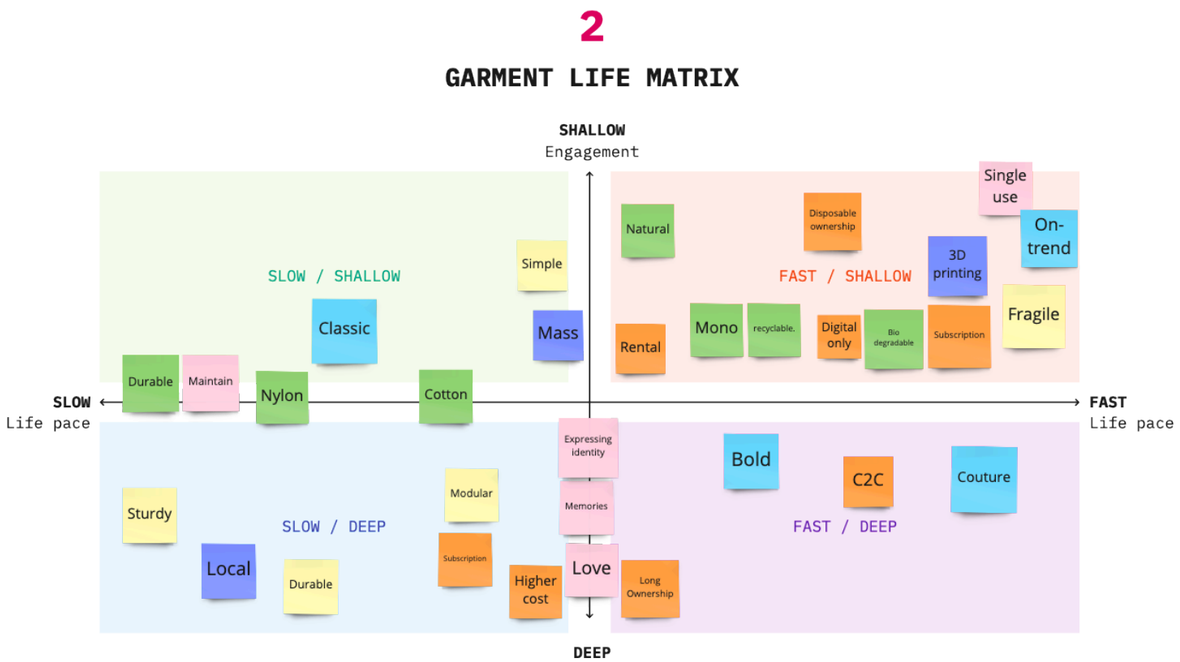


Figure 26. Design characteristics (post-it notes) placed in the GLM

The placement of characteristics from the categories of 'Materials', 'Structure', 'Aesthetic' and 'User engagement' in the GLM followed the same pattern as the previous study activities and are thus not reported in detail here.

In terms of characteristics related to 'Production method', there was a tendency for the scale to increase, the 'shallower' the garment type: mass manufacturing was assigned to the 'shallow' GLM half. Conversely, local and specialty craft methods, such as the 'Harris Tweed' were assigned to the 'slow/deep' quadrant, as these were perceived to *"have a lot more emotional connection to it, than if it was a denim that you've picked up at your local supermarket"* (Apparel 1)**,** and thus strengthening an emotional connection to the manufacturer; a deeper level of user engagement, and a longer life expectancy of the garment. Furthermore, On-demand, digital manufacturing, which can allow for mass-customisation and limit overproduction, was placed in the 'fast' GLM half.

In terms of the *enabling factor* of 'Business model', the participants agreed that subscription models are suitable for both the 'fast' and 'slow' quadrants, but not for the 'deep' matrix half, as it was assumed that a deep level of user engagement would cause users to want full ownership. However, the nature of subscriptions models

would vary significantly depending on lifecycle speed: Participants imagined that 'slow' garments would be offered as a form of rental model where they would be sent back to the company for cleaning and reuse. For 'fast/shallow' garments, reuse would not be an option due to fragility, and thus sustainability would rely on the garment's design and surrounding infrastructure to allow for efficient composting/recycling of materials. Conventional models of ownership were assigned to the entire 'deep' half of the matrix, but also deemed suitable for the 'fast/shallow' quadrant.

Finally, as a general observation, participants stated very strict conditions for the 'fast' garments to be sustainable. e.g., they proposed clear requirements for garments' materials to be biodegradable and/or their structure to be either mono-material or easy to disassemble.

5.3. Discussion Studies 1 & 2

These studies have further responded to RQ3 *(What are the most important factors for garment sustainability?)* and RQ3a *(How might these be related?)* by further refining the understanding of the *enabling* and *primary factors* for DfS (identified in Chapter 4), and how these correlate. This understanding was based on the perspective of consumers (Study 1), and garment industry professionals (Study 2).

In relation to RQ3, the findings from these studies **confirmed the *primary* and *enabling factors,* identified in Chapter 4, as particularly important for garment sustainability.** In Study 1, the Thematic Analysis of consumer interviews confirmed that these factors have a particularly decisive impact on garments' lifecycles: e.g., how long they will stay in use, how much they will be worn, if they will be cared for and if/how they will be looped back into material cycles after use. Study 2, where garment industry professionals mapped garments in the GLM, further confirmed this: the industry professionals used characteristics which relate directly to the *enabling factors* to explain why each garment was expected to have a particular lifespan or user engagement. e.g., a long lifespan was connected to features such as durable materials, a 'classic' aesthetic and the capacity for maintenance and repair.

Furthermore, these studies generated new insights in response to RQ3a, regarding how the *primary* and *enabling* factors correlate:

Firstly, the findings from Studies 1 and 2 both revealed a similar pattern in **how the *enabling factors* vary depending on the *primary factors***. Study 1 showed how certain characteristics related to the *enabling factors*, such as aesthetic, garment structure, or production method were connected to garments having a short or long lifespan (related to the *primary factor* of 'Product life expectancy'). Similarly regarding the other *primary factor* of 'User engagement', certain characteristics related to *enabling factors,*

were also linked to certain levels of user engagement. These correlations were further confirmed and explored in Study 2: By placing different garment types in the GLM, the garment industry professionals confidently made similar connections between specific design characteristics related to the *enabling factors* and the two *primary factors*, as the consumer participants in Study 1 had done. E.g., features such as a trend-based aesthetic or a fragile garment structure were connected to a short garment life expectancy, and features such as a personalised/special aesthetic, durable materials that age well, and the capacity for maintenance, were connected to long life expectancy and 'deep' levels of user engagement.

Secondly, these studies both revealed a **clear correlation between the two *primary factors*** ('User engagement' and 'Product life expectancy'). Study 1 revealed an overall tendency for consumers to engage in more activities and invest time/effort into long-life garments, which indicated a clear correlation between the two *primary factors*: the more engaged (both emotionally and physically) the user is in a garment, the longer its life expectancy - and vice versa. The visual experiments which followed, led to the proposal of the Garment Life Matrix (GLM) framework, to articulate this correlation between the *primary factors*. The mapping experiments conducted to test it (by placing consumers' garments in the GLM, Section 5.1.4.) showed a clear pattern from the bottom-left to the top-right corner which confirmed the understanding of the correlation between the two *primary factors*. This correlation was confirmed in Study 2 where the mapping experiments by industry experts (Figure 26, Study 2) revealed a strikingly similar pattern (bottom-left to top-right) of garment placements in the GLM.

Finally, Study 2 indicated a potential for the GLM to guide DfS in garment design practice. The ease with which garment professionals assigned design characteristics related to the *enabling factors* to specific quadrants of the GLM, and drew connections between them, indicated potential for this framework to support designers to negotiate these factors in a DfS process. Thus, this study has also built support for responding to RQ4 related to the development of DfS support.

5.4 Employing findings to further develop the Garment Life Matrix

This section describes a series of iterative Research through Design (RtD) (Frayling, 1993) experiments, conducted to gain a deeper understanding of the findings from Studies 1 and 2. Specifically, these experiments investigate how the primary and enabling factors correlate, with particular attention to how the enabling factors vary depending on the primary factors. Additionally, these experiments further explore the potential, which emerged as a finding from Study 2, for the GLM to be developed into DfS support for designers.

GLM mapping experiment 1 - Synthesising characteristics from findings

This mapping experiment built upon the latest version of the GLM framework (Figure 18, Study 1), in which characteristics of consumers' garments had been synthesised and mapped. This experiment followed a similar approach, but this time the findings from both Studies 1 and 2 were combined and mapped into the GLM framework, as can be seen in Figure 27.

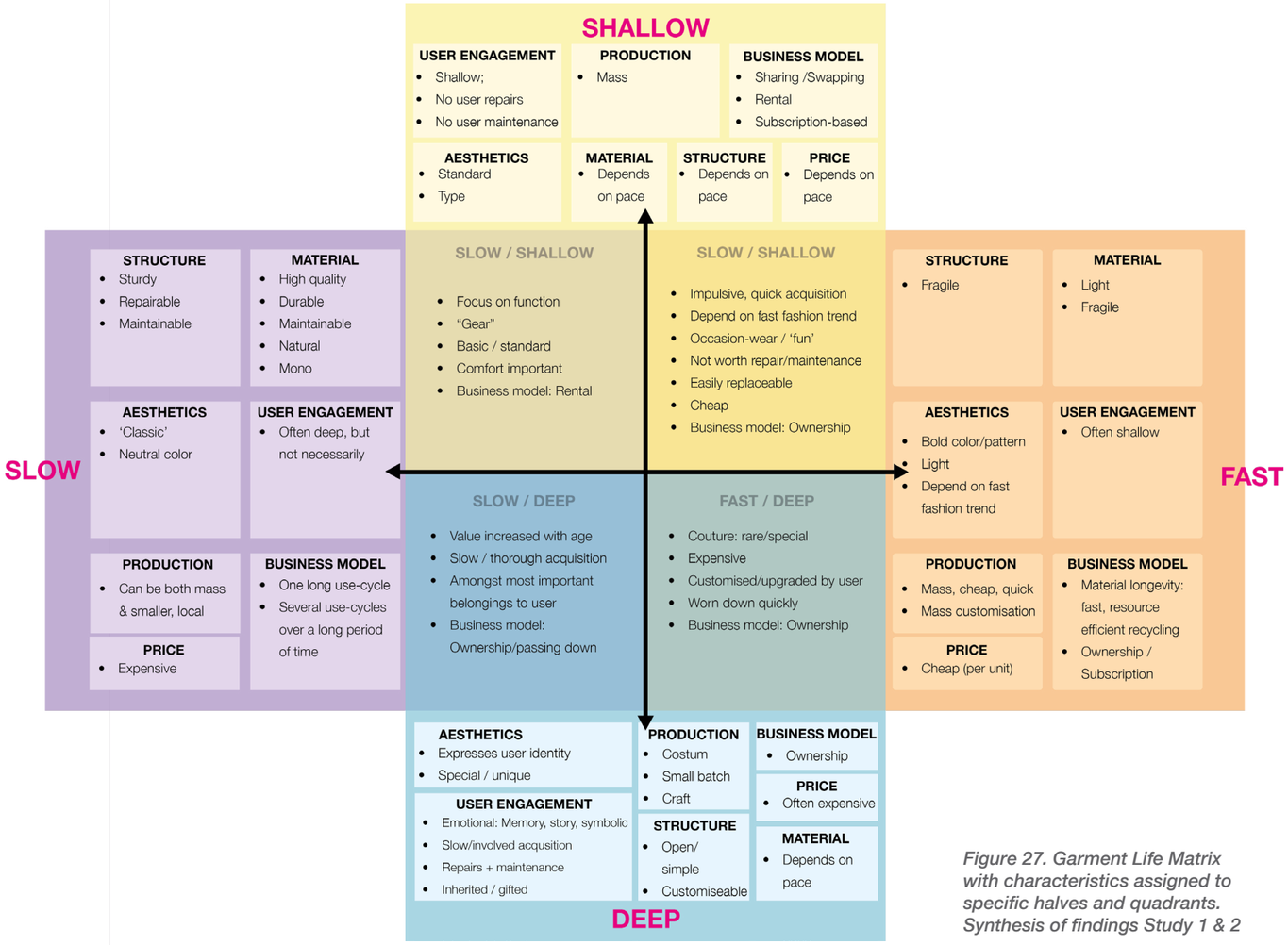


Figure 27. Garment Life Matrix with characteristics assigned to specific halves and quadrants. Synthesis of findings Study 1 & 2

GLM mapping experiment 2: Establishing characteristics of sustainable garments in each part of the framework

Now that the characteristics of existing garments had been established within each part of the GLM in Experiment 1, the next step was to consider how these characteristics would need to change for garments to be fit, not just for their current role in a *linear* economy, but instead, for sustainable consumption in a *circular* economy.
This mapping process was also supported by primary data from Studies 1 and 2, as well as insights from secondary data from Chapters 2 (literature review) and 4 (practice review). The resulting GLM with characteristics for DfS, can be seen here in Figure 28.

From this process, it became clear that what it takes for a 'slow' garment to be designed to be sustainable is very different from what it takes for a 'fast' garment, and similarly, there is a great difference in how to design 'shallow' and 'deep' garments to be sustainable. The design approach that is relevant for creating sustainable garment is entirely different depending on what part of the GLM one is designing for. For example, in regards choosing a suitable business model; a sharing- or rental-model might work perfectly well for a 'shallow', standard garment, but not at all for a 'deep' one, which is likely to be perceived as a too personal for people to want to share or access it, rather than own it.

This new version of the Garment Life Matrix (Figure 28) established sets of characteristics that garments should strive to have to be sustainable and function in a circular economy, depending on the two *primary factors* of 'Product life expectancy' and 'Depth of user engagement'. Essentially, the GLM's structure, in which the *primary factors* are pictured on two axes in a coordinate plane, defines a possibility space within each of the GLM's quadrants where the conditions for designing garments to be sustainable are different.

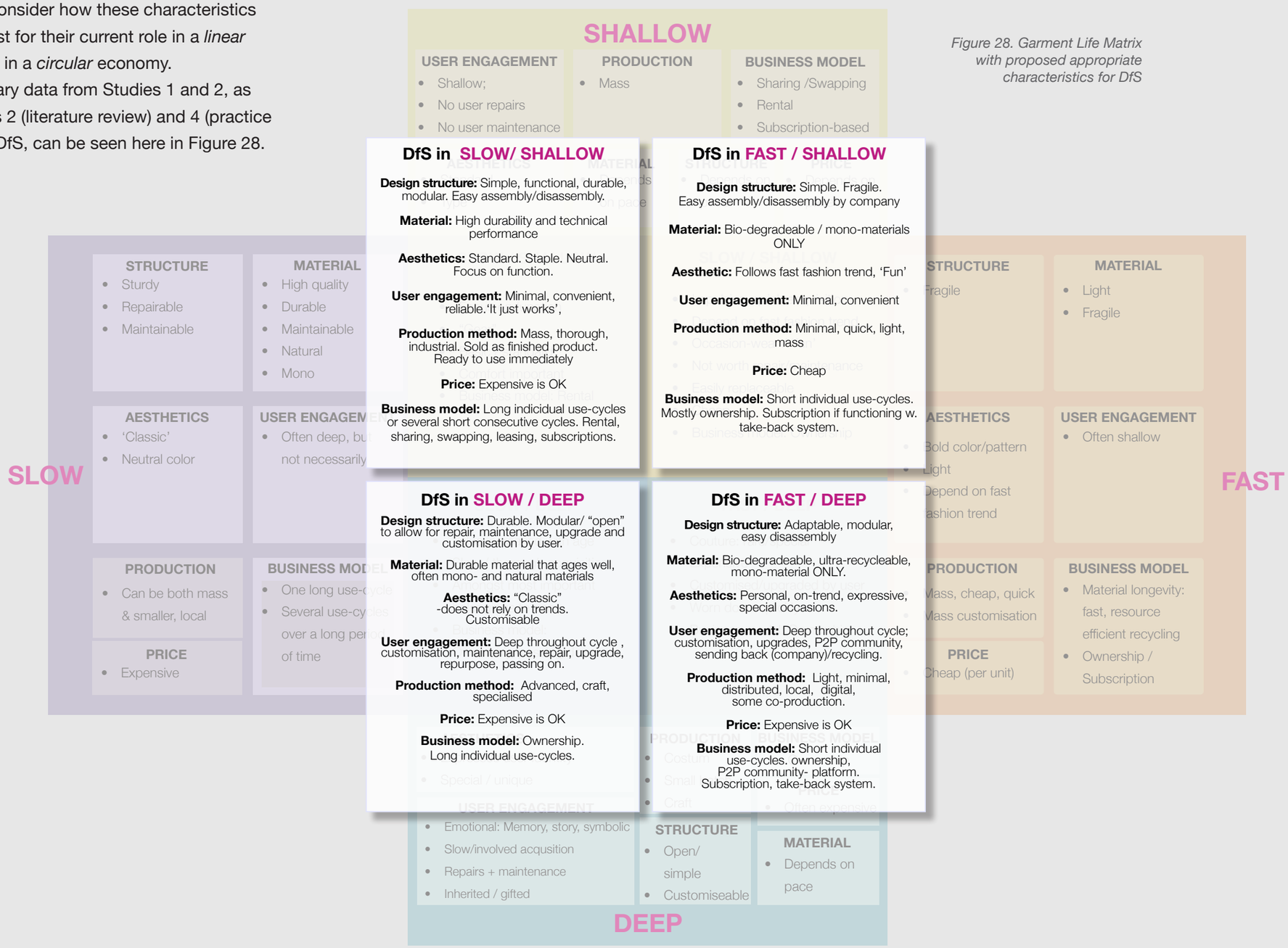


Figure 28. Garment Life Matrix with proposed appropriate characteristics for DfS

Building recipes

The RtD experiments with developing new iterations of the GLM showed that certain characteristics, from the different enabling factor categories, “stick” together in sets that logically come together in specific quadrants of the GLM to enable DfS. These sets of characteristics were further synthesised into more definitive sets named ***recipes*** and ***ingredients***.

These cooking metaphors were chosen as they are in line with the intention of the GLM; to provide a comprehensible overview of the many factors which must be considered to conduct efficient DfS and how they correlate. Cooking recipes usually provide the necessary information to enable any person, often not a professional chef, to arrive at an edible, hopefully even delicious result. To make this task manageable, recipes provide clear, systematic guidance. In the same way, the GLM *recipes* are intended to provide comprehensible guidance for designers to select and combine the many existing factors, or *ingredients*, to “cook well” and achieve efficient DfS. The *recipes* can be seen as a form of design briefs for designers to use as a starting point for designing sustainable garments.

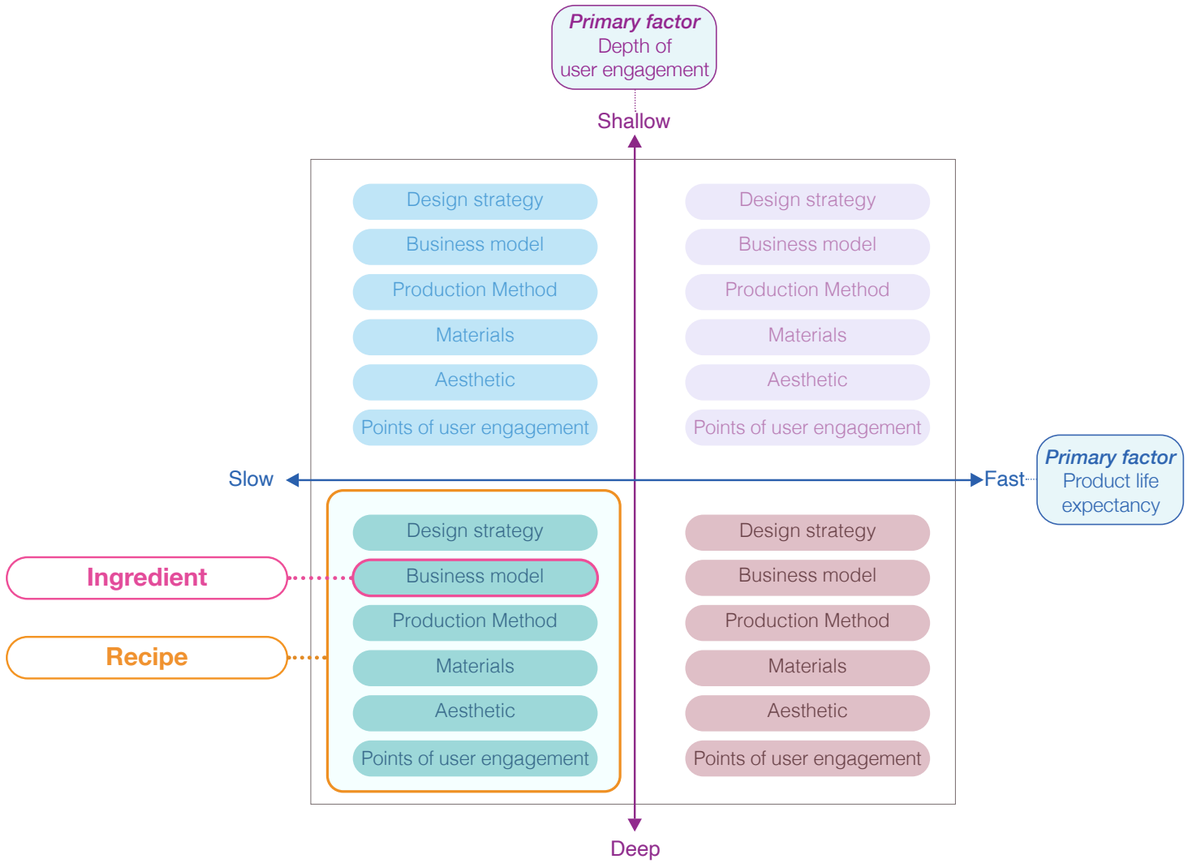
Many conventional cooking recipes are relatively strict and specify the exact amount of each ingredient and how they should be combined. But some, such as cooking advice shared between friends and family, are less strict. Instead, they are often more flexible, focused on using what is available at hand, and learning how to feel and taste when it is “just right”. The GLM’s *recipes* were developed towards this type of “family” recipe for two reasons: firstly because, as established in the literature review (Chapter 2), such an iterative approach is particularly suitable for the way garment designers work. Secondly, because, as also established in the literature review, aiming to create garments that are 100% circular or sustainable is not easy, nor realistic. As Alice Payne states: *“Let’s not pretend we can somehow have ‘a fashion system’ singular that’s in tune with nature [...] – it’s lovely, it’s utopian and it’s a complete denial of reality”* (2021, p.179). Therefore, the GLM *recipes* are not aiming for absolute sustainability, but instead to enable designers to have the most effective impact possible.

The GLM recipes took particular inspiration from one cookbook: ‘Salt, Fat, Acid, Heat’ by chef Sameen Nosrat (2017), which was developed with the focus of enabling readers to “master the elements of good cooking”, rather than providing them with exact ingredients and technical instructions. Nosrat provides a solid foundation from which people can begin to select and combine ingredients and be creative with their cooking. This thesis investigates if/how it is possible to use a similar approach to guide designers to design for sustainability. In line with Nosrat’s (2017) approach, the GLM recipes were designed to convey a fundamental understanding of how the various factors, or “elements” at play in DfS affect each other, to enable designers to master and negotiate these factors efficiently and iteratively in a design process.

Rather than a detailed protocol, the GLM *recipes*, aim to enable designers to quickly identify the most important leverage points (“*places in the system where a small change could lead to a large shift in behaviours”* (Meadows 2008, p.145), that they can change to have the most efficient impact.

Based on the observations in this section, and the mapping exercises in Section 5.4 which synthesised findings related to the *primary* and *enabling factors* and their correlation from Chapter 4 and Studies 1 and 2, the GLM *recipes* were structured as follows: Each quadrant of the GLM represents a different part of the garment market, in which the conditions for designing for sustainability are different. These conditions are laid out in each quadrant as *ingredients*; the characteristics, which garments should strive to have to be sustainable in each quadrant of the GLM. The *ingredient* categories were established as: ‘Design strategy’, ‘Business model’, ‘Production method’, ‘Material’, ‘Aesthetic’, and ‘Points of user engagement’. This structure can be viewed in Figure 29.

Figure 29. Ingredients and recipes in the Garment Life Matrix



5.5. Summary

This chapter has presented two qualitative exploratory studies: Study 1 with consumers, and Study 2 with garment industry experts, focused on developing further understanding of the *enabling* and *primary factors'* influence on garments' lifecycles informed by the perspective of each of these groups.

The findings from these studies have built upon previous findings by confirming that the *primary factors,* proposed in Chapter 4, have decisive influence on the other *enabling factors*, and supported the proposed hypothesis that: *consideration of the two primary factors should guide designers' decisions around the other enabling factors, for them to design efficiently for sustainability*.

These findings were further explored in a series of RtD experiments, which resulted in the proposal of a framework which articulates the relationship between the two *primary factors* as two axes in a coordinate plane: The Garment Life Matrix.

Further mapping experiments revealed that the conditions for designing a garment to be sustainable in each of the four quadrants of the GLM, which represent different segments of the garment market, vary considerably. The final iteration of the GLM framework (Figure 29), enabled the proposal of the GLM *recipes,* which specify *how* garments' characteristics should vary depending on these changing conditions. Each *recipe* provides a particular set of characteristics *(ingredients)* that designers should strive to follow, to design for sustainability in each of the GLM's quadrants.

By developing the GLM framework and its *recipes*, this chapter has proposed a preliminary response to RQ4 (*How might considerations of the most important design factors be structured to guide decision-making processes to enable efficient, systems-aware Design for Sustainability?)*

The next chapter turns to literature to build further understanding of the *primary* and *enabling* factors and how they correlate.

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Chapter 6

Refining the Garment Life Matrix elements – Additional literature on DfS factors

Chapter 4 proposed a set of important *primary* and *enabling factors* for DfS and described how these interrelate to affect garment lifecycles. This led to the development of the Garment Life Matrix, and the location of specific *recipes* (collections of DfS strategies) within the quadrants of the matrix, in Chapter 5.

This chapter situates the previous empirical findings within a review of DfS literature, in order to further refine an understanding of how the *ingredients* (*enabling factors)* in each *recipe* should be configured to ensure their guidance will lead to a sustainable outcome.

6.1. The Garment Life Matrix axes

The placement of the *primary factors* on two axes in a coordinate plane in the GLM articulates their close correlation, and together, the axes define a possibility space within each of the GLM's quadrants where the conditions for designing garments to be sustainable vary significantly. By describing how a garment solution's characteristics (related to the *enabling factors*) should vary in each quadrant, in the *recipes*, the GLM is able to offer support for designers to select appropriate DfS strategies in each garment's case.

The format of the GLM draws on a rich tradition of using matrix frameworks to provide an overview of business and design strategies simply and elegantly, e.g., the 'Product matrix' (Jobs, 1997), Boston Consulting Group's 'Growth Share Matrix' (Henderson, 1970), the SWOT analysis matrix (Gürel, 2017), and the Business Model Canvas (Osterwalder & Pigneur, 2010).

The following sections provide an examination of literature related to the GLM axes.

6.1.1. Slow / fast axis

Slow / fast axis definition: Garment use phase pace

This horizontal axis of the GLM describes the pace at which a garment is consumed by a user from the moment of acquisition until end of use.

The lifecycle of a garment can be understood as a series of interlocking phases ('materials', 'production', 'use' and 'recovery'), and it is important for efficient DfS to consider and balance the varying paces of these individual phases (Goldsworthy et al., 2019). The pace axis focuses on the use phase, due to the fact the length and happenings within this phase, as established in Chapters 4 & 5, should guide decisions made regarding the other lifecycle phases in a DfS process. To specify this focus, **this axis was renamed from 'Product life expectancy' to 'Garment use phase pace'**. Whilst the focus here lies on the use phase of a product's lifecycle, there are other elements in the GLM, for example the *ingredients* of 'Production method' or 'Business model' (described below), which ensure that designers include consideration of the other lifecycle phases.

This factor is well-described in literature; as reported in Chapter 2, consumption speed is a central concern in the field of DfS (p.44 ; Appendix A1). Below I shall summarise particularly relevant sources which inform the 'Use phase pace' axis.

Chapman proposes the notion of "longevity in use" (2021, p.98), and in line with his observations, the pace axis is concerned with how long a product is *actively* used for, rather than how long it has the *potential* to last for. This is important, as there is a large discrepancy between the enormous resource-intensity and longevity of materials currently used in mainstream garments, and the astoundingly short length of the actual use phase of these garments (Goldsworthy et al., 2019). This axis is intended to provide designers with an understanding of the pace of the use phase, to help them balance their designs to be "appropriately durable" (Fletcher & Grose, 2012, p.87), which, as established in Chapter 2, is one of the most promising approaches to achieve efficient DfS.

The notion of 'pace' was inspired and informed by scholars who have investigated and used the term in similar ways. Fletcher & Tham (2004) describe a garment's "metabolism", referring to the rate at which fashion pieces are consumed. Armstrong et al. (2016**)** also refer to the concept of the "metabolism" of fashion consumption, comparing consumption of fast fashion to *"an excess dose of carbohydrates, yielding a short-term high followed by an energy deficit that can only be satisfied by consuming again"* (2016, p.159). Building on Fletcher and Tham's work, Goldsworthy et al. (2019) take a practice-based approach to develop "ultra-fast" and "super-slow" DfS prototypes.

At a more detailed level, and particularly relevant in regard to this thesis' understanding of products as *assemblages* (cf. p.31), the various components within garments can also be seen as ageing at different paces. An important theoretical notion that lies behind this understanding of different paces within products is 'Pace Layer Theory' (Brand, 1994). Originally used in architecture to understand how to design buildings to age well (Duffy, 1989), 'Pace Layer Theory' considers buildings as composed of layers that age at different speeds, to construct them to have maximum resilience and adaptability. Pace Layer Theory presents a useful model for understanding and mapping multiple levels and qualities of change and life-expectancy in a product, environment, or system.

Much in line with Brand's Pace Layer thinking, Payne (2021) describes layers of pace in her analysis of the fashion system (cf. p.34): she describes the different speeds at which certain fashion products will change and become irrelevant/relevant in response to the broader societal time-paces that drive trends, social norms, and user behaviour. At a macro-level, she describes the slower long-term trends in thought and social norms. At a micro-level she describes the faddish changes in the style and appearance of individuals (Payne, 2021). Certain fashion products will change at a far greater pace in response to the rapid shifts in trends, others will remain an unchanging wardrobe-staple. Paying attention to how different garments respond to the various paces of change within the fashion system allows the designer to modify her design strategy accordingly.

In most cases, the ‘pace’ axis will likely be used by designers to understand the longevity of a whole product rather than the longevity of the numerous components and materials within it. However, this depends on how granular the designer is able and willing to be; for example, if looking at a jacket, it could be beneficial for DfS to split the product into ‘slow’ and ‘fast’ components: allowing ‘slow’ parts (e.g. main body) to stay relevant and in use for as long as possible, by employing ‘fast’ components (e.g. trims or aesthetic details) to enable the garment to adapt to changes in trends and user needs. In such a “layered” approach the components would follow different GLM *recipes* (cf. Section. 5.4), depending on what quadrant they belong in.

6.1.2. Deep / shallow axis

Deep/shallow axis definition: The depth of physical and/or emotional user engagement

This GLM-axis articulates the second *primary factor,* ‘Depth of user engagement’, established in this thesis. Chapter 2 showed that users’ behaviours are crucial for enabling a circular economy, but that consideration of users’ engagement in garment lifecycles generally is under-acknowledged in DfS support. The importance of this factor was confirmed in Chapter 4, where the analysis of sustainable business -cases revealed a clear pattern in how all aspects of these cases’ models and products seemingly had been adjusted to, and often relied on, a particular level of user engagement. This led to the proposal of ‘user engagement’, as one of the two *primary factors* for DfS. The importance of this factor was confirmed in Chapter 5, where the two studies (1 & 2), also showed this factor’s significant influence on garments’ lifecycles. Furthermore, the insights from Study 1, into the types of value different garments hold to users, i.e., that ‘slow’ garments usually are valued for eliciting deeper ‘eudaimonic’ experiences, and ‘fast’ garments tend to provide shallower, ‘hedonic’ experiences, led to the initial proposal of the concept of ‘depth’ of user engagement.

This thesis’ definition of ‘engagement’ is based on Vivek, Beatty & Morgan’s definition of customer engagement: *“the intensity of an individual’s participation in and connection with an organization’s offerings and/or organizational activities”* (2012, p.128). Vivek et al. argue that customer engagement is composed of cognitive, emotional, behavioural, and social elements. Similarly, but defined more simply, this thesis considers engagement as consisting of emotional and physical engagement. Here, emotional engagement refers to the experience, identity, and feelings of consumers. Physical engagement refers to actions of participation throughout the use phase (e.g., customisation or repairs).

Users’ experience of a garment product is complex: it is fluid, and unfolds over time (Chapman, 2021, p.71), and as Hekkert observes, it encompasses *“the entire set of affects that is elicited by the interaction between a user and a product”* (2006, p.160).

As first mentioned on p.114, this thesis draws on Kahneman’s concept of ‘Hedonic’ and ‘Eudaimonic’ well-being to help define and categorise the product experience into different “depths”. ‘Hedonic’ well being, which this thesis links to ‘shallow’ levels of user engagement, denotes the user’s experiences of fun, pleasure, and enjoyment. In contrast, ‘Eudaimonic’ well being is achieved through ‘deeper’ experiences of self-realisation, autonomy, purpose and meaning (Kahneman et al., 1999; Ryan & Deci, 2001; Bauer & McAdams, 2010).

Aditya Gupta draws a similar distinction between different forms of user engagement, noting the difference between *“consumption which is oriented more toward the experience of fun, positive affect, and/or pleasure, and that which is oriented more toward the experience of, for instance, autonomy, mastery, purpose, and/or self acceptance”* (2019, p.14).

Analysing a user’s engagement with a product on these terms enables a clearer understanding of the emotional intention, or purpose, that a product serves the user, and the relationship that is established between the two, within the framework of GLM.

Another instructive way of discussing user’s engagement in a product is proposed by Chapman (2021), who advocates for *“a scalar means of thinking about experience based primarily on its degree of psychological resonance”* (2021, p.78), and observes that an understanding of the depth of a user’s engagement or product experience is linked to the use phase pace.

A final reference point for this axis’ notion of the depth of a user’s engagement is Charlie Humble-Tomas (2021), who, in his Master’s DfS design project, presents a matrix structure which bears similarities to the GLM, albeit much simpler, considering just two factors: ‘Longer/Shorter physical longevity’ and ‘Weak/ Strong user bond’. Humble-Tomas employs this matrix to analyse existing products, and to identify objects to focus his project on. He then uses this analysis to inform the design of three umbrella-types, using three very different DfS approaches.

6.2. The Garment Life Matrix recipes

It is important for designers to be aware of the specific context they are designing for when selecting and employing DfS strategies, and as Earley and Goldsworthy state: "*We need to be very clear which segment of the fashion industry we are designing for and also which specific garment archetype"* (2015, p.6).

Therefore, the GLM framework is constructed to propose *suitable* strategies, in the form of the GLM *recipes*, for the specific garment-context and industry segment.

Building on findings from Chapter 5, **the GLM *recipes* are defined as: Collections of strategies, constituted of the *ingredients* which describe the *enabling factors* of 'Design strategy', 'Business model', 'Production method', 'Materials', 'Aesthetic', and 'Points of user engagement'.**

Each of the quadrants in the GLM framework represents a different part of the garment market, in which the conditions for designing for sustainability are different, and thus the *recipes* within each quadrant vary depending on these conditions.

As described in Chapter 2, efficient DfS requires designers to consider the many factors that affect the sustainability of a garment. Like a chef balancing flavours in a dish, or a music producer mixing audio on a console with hundreds of buttons (Figure 30), the many factors of DfS affect each other: when you change one, it immediately causes a need for adjusting others to ensure the outcome is sustainable. The GLM *recipes* aim to provide a systematic way to approach these complex decision-making processes.

Figure 30. Buttons on a music-mixing console, image by Katrine Hesseldahl

6.3. The Garment Life Matrix ingredients

As described above (p.139), the GLM *recipes* consist of collections of *ingredients* which provide guidance related to each of the *enabling factors*. The characteristics or nature of the guidance proposed in each *ingredient* will change depending on what GLM quadrant one is trying to design for.

6.3.1. DfS strategy

This section revisits the many existing DfS strategies which were reviewed in the literature review in Chapter 2 and described in detail in the appendix (Section A1) , in order to examine them in relation to the two *primary factors*, and, ultimately, to determine how the various DfS strategies best can be employed in the various quadrants of the GLM to ensure they will have efficient impact.

DfS strategies for a fast garment use phase pace

The overarching approach to designing in the 'fast' half of the GLM is to focus on designing for conservation of materials rather than product longevity; designing products that go through fast but (ideally) leak-free material cycles of use. The most appropriate DfS strategies for achieving this goal are those related to 'Design for closing loops' (Braungart & McDonough, 2002; Bocken et al., 2016), which aim for full biodegradability, and 'Design for narrowing loops' (Allwood et al., 2012; Bocken et al., 2016), which focuses on reducing overall resource consumption, i.e., less production steps, components, materials, waste, chemicals, and packaging. This can be enabled by strategies such as 'Zero-waste pattern-cutting' (Rissanen & McQuillan, 2016). or 'Design for on-demand production' (Bhamra & Lofthouse, 2007). Furthermore, strategies related to 'Design for multiple loops' (Bocken et al., 2016), aimed at designing for resource recovery, through strategies such as 'Design for disassembly' and 'Design for up-/re-cycling', can also be relevant in the 'fast' GLM half as these strategies also contribute to conservation of materials.

Strategies related to 'Design for slowing loops' (Bocken et al., 2016), are clearly not relevant in the entire 'fast' GLM half, as these aim to extend product longevity - which obviously contradicts designing for a fast use phase pace.

DfS strategies for a slow garment use phase pace

In the ‘slow’ half of the GLM, the most relevant DfS strategies are those which focus on designing for slowing material loops and extending product longevity such as ‘Design for emotional durability’ (Chapman, 2005) and ‘Design for maintenance, repair and upgrade’ (Van Nes & Cramer, 2006; Bakker et al., 2014), as well as strategies related to ‘Design for multiple loops’ (Bocken et al., 2016), such as ‘Design for dis- and re-assembly’ (Bogue, 2007; Johansson, 2008). Regardless of this focus, most DfS strategies described in Chapter 2 are in fact relevant in the ‘slow' GLM half, as they all contribute to sustainability, if a garment’s use phase is slow.

However, as the goal of the GLM is to help designers interfere at the highest possible level of innovation (Ceschin & Gaziulusoy, 2020), some strategies will be more effective than others. Strategies which integrate lower-level strategies to span multiple innovation levels, such as ‘Design for PSS’ (Clark et al, 2019; Bakker et al., 2014), which slows material loops through dematerialisation, will often elicit change at a high systems-level. In comparison, strategies of ‘Narrowing’ or ‘Closing loops’ (Bocken et al., 2016), intervene at lower innovation levels, only changing individual products or components.

DfS strategies for different levels of user engagement

There is also a clear difference between what strategies will be suitable for ‘deep’ or ‘shallow’ levels of user engagement.

There is a clear general rule which applies to the entire ‘shallow’ half of the GLM:
All strategies that rely on users engaging in activities even slightly more demanding than mainstream, minimal, cleaning and disposal behaviours, will be irrelevant.

In contrast, such strategies which aim at enhancing user engagement are *essential* in the ‘deep’ GLM half. This includes approaches such as co-design and participatory approaches, as well as strategies such as ‘Design for emotional durability’ (Chapman, 2005), which aims for product longevity through strengthening the consumer-product connection.

Strategies of ‘Design for maintenance, repair and upgrade’ (Van Nes & Cramer, 2006; Bakker et al., 2014) are relevant to the entire ‘slow’ GLM half, but here, there is a clear difference in the actor who will be undertaking these engagements depending on the depth of user engagement: In the ‘slow/shallow’ quadrant, maintenance should be the provider’s responsibility, but in the ‘slow/deep’ quadrant, it will likely a professional craftsperson paid by the user or the user herself.

Some strategies are particularly suitable for a single GLM *recipe*:
Strategies aimed at dematerialising products, such as ‘Design for PSS’ (Clark et al,

2019; Bakker et al., 2014) are usually only relevant in the ‘slow/shallow’ quadrant. It is rarely suitable in the ‘fast’ GLM half, as ‘fast’ garments simply won’t last to function for more than one user. Furthermore, this strategy is ill-suited for the entire ‘deep’ half of the GLM as garments with deep levels of emotional engagement, as seen in Studies 1 and 2, generally are considered too personal to swap, share, or access rather than own. This is further described in the next section related to the ‘Business model’ *ingredient*.

6.3.2. Business model

This *ingredient* describes which business model types will be suitable for companies to use in each GLM quadrant. This *ingredient* also varies considerably depending on the *primary factors*.

This research draws on scholars such as Stahel (1994; 2010), Braungart & McDonough (2002), Tukker (2004), Ellen MacArthur Foundation (2012), Bocken et al. (2016), and Bakker et al. (2019), who collectively have provided extensive reviews and taxonomies of sustainable business models. Based on an extensive literature review, Moreno et al. (2016) devise a ‘Circular design framework’ which maps out circular design strategies against circular business model archetypes on a spectrum from ‘Slowing resource loops’ to ‘Narrowing resource flows’. As this framework can be directly related to the ‘pace’ axis in the GLM, it was chosen as the primary source of information for this GLM *ingredient.* The business model archetypes in this framework are:

1. **Circular supplies**: The basic principle of this model is to generate value from using waste or residual outputs from one process in a company’s system as feedstock for other processes. Also referred to as ‘Industrial symbiosis’ (Bocken et al., 2016), this model usually takes place away from consumers, at the level of manufacturing, and mainly generates profit from reduction in costs, and potentially, from creating new products which utilise these waste streams.

2. **Resource value:** This model is also based on closing material loops, recovering resource value of materials, and using them to create new value. However, this model often happens at a product level, which means it often will require some involvement of consumers to return products for recycling.

3. **Product life extension:** This model is focused on extending the functional lifetime of a product. It follows a regular model of ownership and focuses on offering high-quality, long-lasting products, and repairable products, often at a high price point.

4. **Extending product value:** This model focuses on capturing any residual of value of products, for example by remanufacturing or repairing used products and selling them to consumers at an affordable price. Companies can do this with their own

products, or they operate as “gap exploiters” (Bocken et al., 2016) which capture value by repairing/reselling products from other companies. Some companies choose to retain ownership of their products to continue making revenue from renting them out to users during the product’s operational life. In this case, the model is related to what Tukker (2015) calls ‘Use-oriented services’, where value for users will lie both in the product and the service which is offered. Regardless of type, models which aim to extend product value will often include a form take-back system to ensure products are consistently returned (Bocken et al., 2016).

5. **Sharing platforms:** This category represents business models that “*enable increased utilisation rates of products by making possible shared use/access/ownership”* (Moreno et al., 2016, p.10). Profit is generated from selling access to products for a specific amount of time or number of uses. Companies will retain ownership of the products and their materials. This category relates to what Tukker (2015) calls ‘Result-oriented services’, where the value for users, which is paid for “per output”, lies more in service content, than the product.

Slow vs. fast business models

Based on the ‘Circular design framework’ by Moreno et al. (2016), the overall strategy for business models in the ‘fast’ GLM half should be to profit from recovering and reusing garments’ materials or components to create new value. This includes the models of ‘Circular supplies’ and ‘Extending resource value’.

In contrast, the overall strategy in the ‘slow’ half should be to strive for product longevity. This includes models that generate profit from extending garments’ life expectancy such as ‘Product life extension’ or increasing the number of wears through shared access or ownership through models related to ‘Extending product value’ or ‘Sharing platforms’. The business models of ‘Circular supplies’ and ‘Extending resource value’ are also relevant in the ‘slow’ GLM half, but as explained in relation to material hierarchies in a circular economy (p. 38), it is often preferable to keep products in use for as long as possible to save resources on remanufacturing or recycling.

Deep vs. shallow business models

Determining which business models will be appropriate in each GLM *recipe*, requires specific attention to questions of ownership and the role of the consumer; therefore, consideration of the *primary factor* of ‘Depth of user engagement’ is particularly important in regard to this business model-*ingredient*.

Two main differences separate business models suited for the ‘deep’ from those suitable for the ‘shallow’ GLM half.

Firstly, there is a clear difference between the types of physical user engagements which a business model will rely on to function: models that depend on users spending none or small amounts of time and effort can function both in the ‘deep’ and ‘shallow’ GLM half. Conventional ownership models, or models where the users discard products in a recycling bin are the most obvious here. However, most of the above-described business models can function in the ‘shallow’ GLM half, as long as points of user engagement are designed to require minimal user-effort. More “demanding” models, such as swapping or sharing models, where users will have to engage with each other or the provider, are more suited for the ‘deep’ GLM half. This also includes models that aim to engage users at earlier points of the garment lifecycle, such as Post Couture Collective’s (cf. Section 4.2.) model, which relies on users producing and assembling their own garments, are not suitable for the *shallow* GLM half.

The second, and perhaps more important, differentiating factor between ‘deep’ or ‘shallow’ business models relates to users’ associated sense of ownership. Findings from consumer interviews in Study 1 (Chapter 5) showed that participants were resistant to share garments which they had a strong personal connection to, especially outside of family or friends. This is confirmed in literature by Baxter et al. (2015) who state that objects which people feel attached to aren’t suited for any other sustainable business models than long-life ownership of products.

The mechanism and reasoning for this tendency is described in literature through theories of “psychological ownership”, which Pierce et al. define as “*the state where an individual feels as though the target of ownership is truly ‘theirs’”* (2002, p.5). An important part of the experience of ownership is that people feel a strong connection between their sense of identity and the object (Litwinski, 1942; Furby, 1978; Wilpert, 1991), to the extent that the object even becomes part of what Belk describes as the “extended self” (Belk, 1988). In a later article (2014), reflecting on his theory of ownership and the extended self (1988) in relation to business models in a sharing economy, Belk observes that people are more open to alternative models of ownership for objects that are not an important part of the extended self.

Based on these findings and literature, it becomes clear that models which depend on access-based or shared forms of ownership will be more suited for the ‘shallow’ GLM half, whereas this type of model is unlikely to function in the ‘deep’ half.

6.3.3. Points of user engagement

Chapter 2 (literature review) revealed the importance of consumer's physical and emotional engagement in products' lifecycles for enabling a circular economy, especially at certain points in the lifecycle where the product needs "help" to extend its use phase or to enable its components to form new assemblages.

Study 1 (Chapter 5) investigated six points of user engagement during a garment's use phase where users' involvement is particularly relevant for sustainability and circularity: 'Acquiring', 'Personalisation', 'Wearing', 'Sharing', 'Maintenance & Repair', 'End of use'.

Consideration of these points in relation to the GLM axes is useful for determining when/if/how users' engagement in a garment's lifecycle can enable or enhance sustainability. Furthermore, such an analysis informs how these points can be designed to offer the right conditions for enabling and motivating users to participate.

To give an overview of how this *ingredient* 'Points of user engagement' varies in each GLM quadrant, the points of engagement are described in relation to the GLM axes in Table 7 below. These characteristics are informed by findings from Studies 1& 2, and secondary literature described in the following.

Table 7. Variation in user's engagements during a garment's lifecycle depending on the two primary factors

Lifecycle engagement point	Slow	Fast	Deep	Shallow
Acquiring	Well-considered	Spontaneous	Careful, personal	Quick, uncaring
Personalisation	Structural, by provider or expert craftsperson	Quick, Surface changes	Important, both initially and over time as garment ages	No, at the most mass-customisation
Wearing	Frequent wear over many years	Frequent wear over short period (worn out), or seldomly worn and discarded	Careful if fragile. Often special, memorable occasions.	Careless. Often functional purpose.
Sharing	Yes, if shallow	Unlikely	Unlikely	Ideal
Maintenance & Repair	Yes	Unlikely unless minor	User DIY or pay professional	Provider responsibility
End of use	Likely involved in repurpose or take-back scheme	Minimal, convenience is key	Users take part in facilitating next lifecycle (repurpose part or passing on)	Minimal, convenience is key

Designing shallow vs. deep points of user engagement

The *primary factor* of 'Depth of user engagement' is the main factor which determines the types and number of points at which a DfS solution should aim to engage users during a garment's lifecycle.

As clearly observed in Studies 1 & 2, users are much more likely to engage at different points in a garment's lifecycle if they have a 'deep' emotional connection to it. Like the above *ingredient* of 'business model', this can also be explained through theories of 'psychological ownership' (the degree to which consumers feel a product belongs to them and is connected to their identity). Pierce et al. argue that a strong sense of psychological ownership is *"likely to lead to assumption of responsibility, caring, protection, nurturance, stewardship, and a willingness to make personal sacrifices and assume risk on behalf of the target"* (2002, p.33).

In a sense, physical user engagements can be seen as a self-reinforcing mechanism: Activities such as customisation and maintenance strengthen the bond between user and garment, which often will lead to a slower use phase (Fletcher & Grose, 2012; Chapman, 2021). This was also evident in findings from Chapter 5, which showed a correlation between garments having 'deep' levels of engagement and a 'slow' use phase. The more the user cares about the garment, the longer they will keep it, the longer they feel the garment has the potential to last, the more likely they are to maintain it. And the more they maintain it, the longer it is likely to last. This is supported by several scholars such as Chapman (2005), Laitala et al. (2015), Mugge et al. (2015) and Wastling et al. (2018).

Finally, the motivation for users to engage at these points will often be motivated by a sense of competence. Pierce et al. describe how "*the motivation for, and the meaning of, ownership is embedded in an effectance or competence motive*" (2002, p.10). When a user successfully repairs or maintains, e.g., a pair of leather boots makes them feel competent and in control, which in turn enhances their sense of ownership of the boots. Thus, it is relevant for designers aiming to enhance user engagement, to consider the design of these points to ensure that users will succeed in their efforts to customise, maintain, repair, etc. If users experience feeling incompetent, it can have the opposite effect and cause the sense of psychological ownership to crumble, perhaps even leading to the product being emotionally "dispossessed" and discarded (Chapman, 2021, p.42-46).

Designing fast vs. slow points of user engagement

As Table 7 illustrates, the type and number of engagements users will take part in also vary depending on the *primary factor* of 'Use phase pace'. Findings from Study 1 (Chapter 5) showed that users generally engage more, and at more points, in lifecycles of 'slow' garments than 'fast' ones. In the beginning of the lifecycle, people will take the time to properly try a garment on or select it. Users are also more willing to engage in maintenance and repairs of 'slow' garments. In line with the 'competence motive' described by Pierce et al. (2002), Study 1 participants explained that spending time, money and effort on maintenance or repairs of 'slow' garments, is "worth it", as these efforts likely will have successful, lasting impact, which is unlikely for 'fast' garments. At the end of the lifecycle, users will also be more likely to engage with 'slow' garments by passing them on for reuse or recycling. In the rare case of a 'fast' garment which the user feels 'deeply' emotionally engaged in (e.g., a tailor-made dress for a special occasion), the user might be willing to put in a lot of effort into activities such as customisation.

6.3.4. Material

The selection of materials is decisive for garments' environmental impact. Selection of materials for DfS is complex due to the many factors related to assessing their impact. Impacts are generated both during production, the use phase, and after use, where considerations of biodegradability and material renewability also come in (Fletcher, 2014, p.11). This complexity causes confusion for designers who struggle to negotiate trade-offs between different materials (Fletcher, 2014; Goldsworthy et al., 2019; Payne, 2021).

Fletcher proposes that designers should base their material choices on *"appropriateness to product and user"* (2014, p.43). In line with this, Goldsworthy et al. state that *"appropriate materials need to be developed and selected by designers to be used in fashion products where the duration of use by the owner/s has been noted and understood."* (2019, p.10).

Materials for a fast use phase pace

To enable garments in the 'fast' GLM half to be sustainable, the selection of materials must focus on materials which are sourced/produced/used with minimal environmental impact, and which are either biodegradable or can be recycled/upcycled using minimal amounts of resources and harmful chemicals after the end of use.

Regarding minimising environmental impact during the production phase, Goldsworthy et al. (2019) propose using non-woven textile materials, as this can reduce impacts through a simpler production phase with significantly less consumption of water and energy compared to weaving.

In regard to the materials' impact after the end of use, making garments from materials that can biodegrade after use is one of the most efficient ways to remove issues of pollution from clothes being sent to incineration or landfill. Instead, biodegradable materials serve as nutrients in the biological system. For a material to be considered biodegradable, it will typically decompose within three years (Kyrikou & Briassoulis, 2007). Examples of biodegradable fibre-types include cotton, lyocell, and new forms of plant-based biodegradable synthetics such as soybean fibre, pineapple shells and corn starch (Fletcher, 2007).

If not biodegradable, using recyclable materials can also be a means of improving sustainability after the end of use as it keeps resources in active use and prevents them from going to incineration or landfill (Goswami & O'Haire, 2016). An increasing number of companies include recycled content, such as polyester (rPET) in their products. However, this is still not really sustainable as the material often is inextricably mixed with other materials, releases plastic microfibers, and isn't biodegradable (van Elven, 2018).

Instead, one of the most efficient ways to ensure end-of-life recyclability and/or biodegradability of a garment is to use mono-materials, made from a single fibre-type (Goldsworthy et al., 2019). This is challenging because it requires all components to either be made from the same/similar material, or for the garment to be modular for its components to be recycled separately.

Most materials currently used in garment manufacturing are not suitable for 'fast' garments as the majority are hugely resource-intensive and heavily polluting to produce. Almost 70% of global fibre production is synthetics, based on fossil, a non-renewable resource (Changing Markets Foundation, 2021). Natural fibres are usually seen as more sustainable because they are made from a renewable source. However, natural fibres such as cotton, use huge amounts of water and pesticides in their production (Fletcher, 2014; Ellen MacArthur Foundation, 2017). Essentially, as Alice Payne states *"there is no perfect sustainable fibre"* (Payne, 2021, p.144). On a more positive note, numerous companies are currently experimenting to develop new sustainable textiles, namely: Allbirds, Vitrolabs, Infinted Fibre, Freitag, Adidas, Evrnu, Pangaia, Lenzing, Spiber Inc., Nature Coatings, etc. This is promising, but unfortunately it is likely to take a long time before these materials gain market traction (Payne, 2021; Textile Exchange, 2021).

This observation contains an important truth: designing 'fast' garments to be sustainable is very difficult, and if designers can't find a suitable material to follow the speed of a 'fast' garment's use phase, they need to consider slowing it down by using other approaches to slow down the use phase. For this reason, the GLM *recipes* for 'fast' garments have been constructed to be rather strict and narrow.

Materials for a slow use phase pace

The materials assigned to the ‘slow’ GLM half follow the logic of designing for product longevity to “lock” materials into their specific product assemblage for as long as possible. Thus, material selection for ‘slow’ garments is focused on materials that will retain their quality through long periods of wear and tear. It is relevant to note here that despite the primary focus on longevity in this ‘slow’ GLM half, the principles from the ‘fast’ half are still relevant, i.e., choosing materials with minimal environmental impact. All garment production adds to global emissions, and even long-life garments will eventually become potential sources of pollution.

‘Durable’ materials are materials that will be resistant to abrasion, tearing, spilling of liquids, and piling that often appear because of heavy wear. Another important factor for long-life is the garment’s ability to retain colour, elasticity, and shape (Laitala et al., 2015). Different fibres have different properties; some, such as wool, are durable because of biological properties which reduces the need for laundering. Others, like some synthetic fibres, will be particularly resistant to stretch and strain. Establishing which materials are most durable and appropriate for a ‘slow’ garment is difficult, as it depends entirely on the context and frequency of wear, laundering, and users’ interest/ability to maintain the garment (Laitala et al., 2018). This thesis proposes that considering garment material-choices in relation to the other *primary factor* of ‘Depth of User engagement’ can help designers ascertain which materials might be most qualified for supporting the durability of a specific garment.

Materials for deep or shallow user engagement

Besides physical and functional properties, the aesthetic and tactile qualities of materials play an important role in users’ experience of a garment. As Laitala et al., state: *“Textile materials are also a part of cultural or social practices, traditions, and value systems”* (2018, p.6), and this necessarily plays into how users will engage with garments. Some materials, such as leather or wool support a ‘slow/deep’ approach: They age gracefully and shape themselves to the wearer’s body, reminding the user of their story of wear over time. Furthermore, there is a rich tradition and well-known method for maintaining these materials, which contributes to a deeper level of engagement and slow use phase pace. On the other hand, the choice of material can also encourage a ‘fast/shallow’ form of consumption: e.g., cheap material-blends from polyester, acrylic and nylon, used in the majority of fast fashion garment production today (Textile Exchange, 2021), are often made as thin, obviously fragile textiles. There is no tradition for keeping or maintaining such materials, and this might cause users to perceive them as disposable. In this case, as mentioned regarding materials for a ‘fast’ approach (p. 156-157), low impact, recyclability and biodegradability take precedence to ensure sustainability.

It is impossible to guarantee that a garment will be kept in use as intended by the designer, due to user-related factors such as psychological obsolescence (Fletcher, 2017; Chapman, 2010). Therefore, designing with long-lasting materials could potentially lead to unintended consequences of long-lasting garments becoming a long-lasting source of pollution in landfill (Chapman, 2010; Evans & Cooper, 2010; Goldsworthy et al., 2019). Although there are no clear fixes for this issue, this thesis proposes that consideration of the ‘depth’ of user engagement -paying attention to the socio-cultural practices, traditions, and value systems which each material is part of -can help designers to make more suitable material choices for the context and length of a garment’s use phase.

6.3.5. Production method

With more than 70% of the emissions coming from upstream activities before garments reach the consumer, the choice of production method has a big impact on overall environmental impacts of garments (McKinsey & Company, 2020). Current methods of mainstream mass manufacturing garments are patently unsustainable; they are extremely resource intensive, especially in regard to water and energy usage, they rely mainly on non-renewable energy, use large amounts of toxic chemicals (Ellen MacArthur Foundation, 2017) and consistently lead to overproduction of garments that never reach the consumer (Andriiuk, 2020).

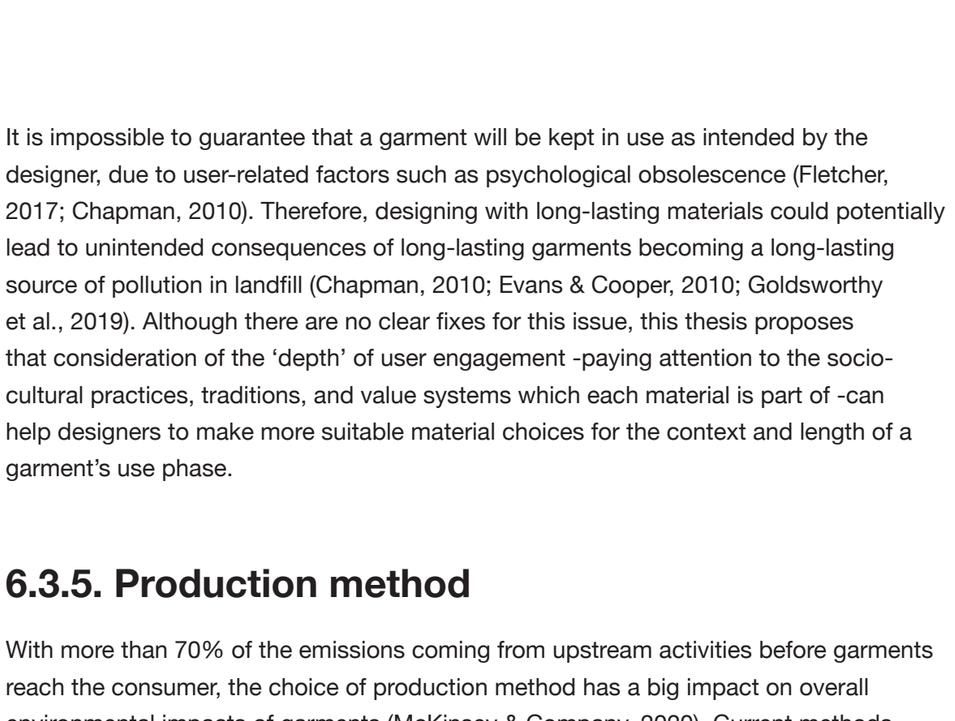


Figure 31. Production methods mapped in the GLM according to suitability for each quadrant

As a general rule, producers should always strive for resource efficiency, reuse, and recycling of deadstock materials, using renewable energy-sources, and excluding hazardous chemicals. More specifically, this research proposes that unsustainable production methods can be mitigated by designers through an understanding of the other contributing *ingredients* (viz. 'business model'), and specifically through an understanding of both *primary factors* for DfS:

- Analysing use phase pace will indicate the balance between the environmental impact of production methods and the product's overall use.

- Analysing a product's method of production in relationships to 'user engagement' will indicate both the need for production to be tailored to suit the specific requirements of the individual consumer, and the potential role of the user in the production of the product itself.

Production methods for fast vs. slow use phase pace

The main difference between fast and slow methods of production is the amount of resources and time spent on producing each garment. The faster the garment's use phase, the less resources and emissions should be spent on production. In their review of design approaches in relation to "design speeds", Goldsworthy et al. describe the importance of balancing the impact of production with how many times a garment will be worn: *"If production methods are out of balance with the expected lifetime of a product (high impact production in a short-life non-renewable material) then we have a mismatch."* (2019, p.13). Here, Goldsworthy et al. use the concept of "impacts per wear" (2019, p.8) to discover the most beneficial approaches. A relevant insight from this research is that "*some garments may come to the end of their useful life sooner than others, but if reduced impacts in the production or recovery stages (as compared to virgin production) can show an overall reduction in cost per wear, then this may be equally beneficial in the long-term"* (2019, p.17).

Thus, in the 'fast' GLM half, where the majority of the fashion industry is situated, the general rule of limiting emissions from production is particularly important. Ways of doing this include simplifying production processes (combined with designing simpler products with fewer components), switching to renewable energy sources, and entirely cutting out toxic chemicals.

On the other end of the spectrum, the *slower* the garment, the more advanced and uncompromising the production must be, to ensure the garment's quality and durability. Here, a slightly increased amount of resources spent on production of a *slow* garment can be justified if it enables a significantly longer garment-life expectancy, bringing down the garment's cost per wear the more it is used.

Production methods for shallow vs. deep user engagement

When analysing the relationship between production methods and 'Depth of user engagement' a primary consideration is the degree to which a method can be considered "mass" or "niche" production.

The shallower the level of user engagement, the less specialised production needs to be. For 'shallow' garments, a user will likely look for a standard, cheap garment, which is best achieved through mass-production methods where economies of scale can be reached. This is in line with an analysis of products with different levels of user engagement by Jonathan Chapman (2021), who connects methods of mass manufacturing to shallow levels of psychological resonance.

As described above, current forms of garment mass production are highly unsustainable, and one of the key issues is overproduction. If industry found ways to conquer overproduction, it could lead to a reduction of emissions of around 158 million tonnes in 2030 (McKinsey & Company, 2020, p.12). One way of doing this could be using new digital manufacturing technologies to allow for more on-demand production and customisation at a mass scale, only producing garments when and where they are needed (Ellen MacArthur Foundation, 2017).

As we move towards the 'deep' GLM half, the types of production become increasingly niche and tailored to the specific user, to the level of including them in production. Here, Anderson's concept of 'The Long Tail' (2006), which describes an extension of the value chain where very small providers, even users themselves, become part of the economy, is particularly relevant. In the context of the GLM, the 'deeper' the level of engagement, the further out in the long tail the garment is likely to be.

These increased levels of personalisation can be enabled by digital manufacturing methods such as automated embroidery, CNC-cutting, 3D-knitting and printing (Petreca et al., 2022). Such a movement towards distributed forms of production, placed closer to users, can lead to environmental benefits from reduced emissions from transportation, and support a circular economy: instead of mining, manufacturing, and throwing away, parts can be made, re-made, and repurposed locally (Stokes et al, 2016; Pendeville et al., 2016). Furthermore, as described regarding DfS strategies for 'deep' user engagement (p.150), engaging users in co-design and production can enhance the bond between user and garment (Mugge, 2007; Hirscher et al., 2018), which can lead to a longer use phase (Niinimäki, 2011; Niinimäki & Armstrong, 2013).

Traditional craft-based forms of manufacturing can also be particularly appropriate for the 'slow/deep' GLM quadrant: methods such as traditional tailoring or specialist producers bring a unique quality and story to the garment, which can support a long lasting and 'deep' connection between the garment and the user (Fletcher, 2014).

As described by Payne (2021), designers who work in large-scale fashion production will rarely have control over the company's chosen production methods. However, having an idea of where the various types of production sit in the GLM, in relation to the other *ingredients*, can provide an overview of how design decisions can be made to suit the available types of manufacturing in each company, or how other *ingredients* in the garment's design can be adjusted to account for potentially non-negotiable forms of production.

6.3.6. Aesthetics

Aesthetics describes the non-instrumental, expressive, formal, and symbolic qualities of a garment (DeLong et al., 1994; Fiore & Kimle, 1997; O'Neal, 1998; de Klerk & Lubbe, 2004). The aesthetic experience is much more than just seeing a garment - it is multidimensional, and encompasses the thoughts, memories, and emotions the garment evokes and involves emotional, sensory, and cognitive dimensions (DeLong et al., 1994; de Klerk & Lubbe, 2004). The aesthetic experience of a garment is a big part of how consumers judge the overall quality of a garment, which, as Aakko and Niinimäki (2022) observe, is important for garments' lifespan. In fact, the aesthetic characteristic of a garment is often a determining factor for their life expectancy (Bianchi & Birtwistle, 2012; Collett et al., 2013; Laitala, 2014; Laitala et al., 2018). When acquiring new garments, people tend to focus more on how they will help them express identity and feel part of social groups than functionality (Fletcher, 2012; Jørgensen in Hesseldahl, 2021).

What is considered desirable aesthetic characteristics, or "in" (fashion) constantly changes as a result of the user's continuous development of identity and shifting trends in society. When a garment's aesthetic characteristics cause it to be disposed of before it's physically worn out, the garment becomes "style obsolete" and/or "psychologically obsolete", which is when the garment fails to project and reflect an up-to-date self-image of the user (Chapman, 2015). These types of obsolescence are common mechanisms in the linear, growth-dependent economic model, to ensure that customers frequently come back for more (Goldsworthy et al., 2019). Fletcher describes how "*in the fashion sector the primary, though not exclusive, tool of obsolescence is aesthetics"* (2017, p.6), and Brand observes that obsolescence is a condition for fashion's existence, stating that *"fashion can only advance by punishing the no longer fashionable"* (1994, p.54). However, as Fletcher and Tham (2004) describe, and as Studies 1 & 2 (Chapter 5) showed, not all garments rely on fast fashion trends to stay relevant for users through a long use phase.

As with all the other GLM *ingredients,* what aesthetic characteristics will be suitable for designing a garment to be sustainable depends on which GLM quadrant one is trying to design for. It is difficult, if not impossible, to precisely predict how certain aesthetic characteristics will affect use phase pace and the level of user engagement in a garment. Regardless, the literature reviewed in this section, and findings from Studies 1 & 2, have enabled the establishment of some general principles. An overview of these is provided in Figure 32 and described in more detail below.

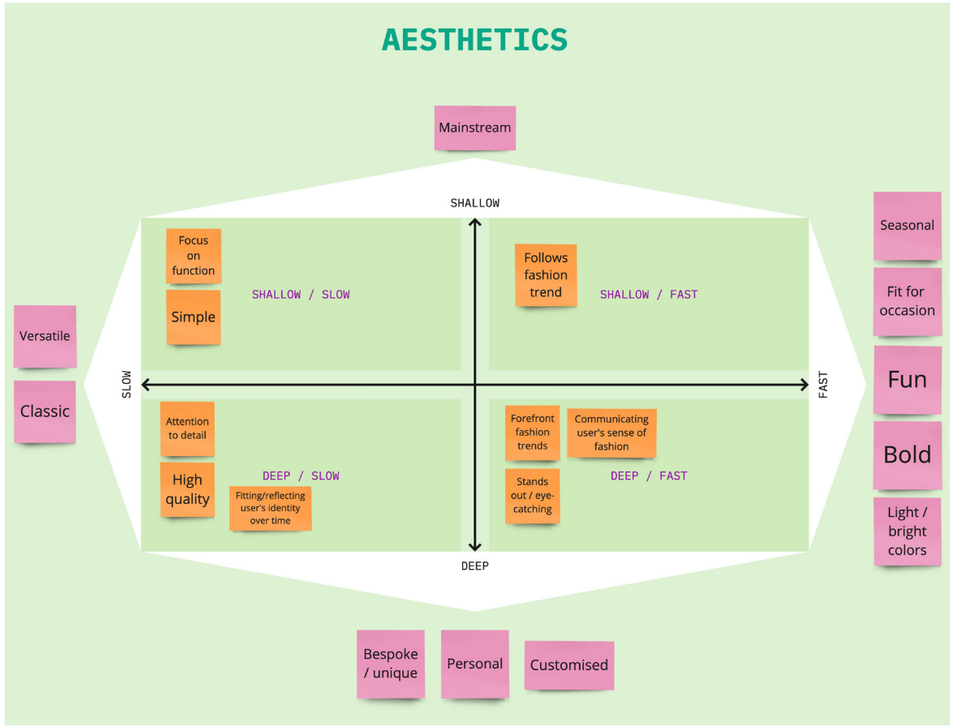


Figure 32. Aesthetic characteristics mapped in the GLM

Fast vs slow aesthetics

Dependency on fashion trends

The value of 'fast' garments will usually be highly dependent on fast-moving fashion trends. In their 'Lifetimes' project, Fletcher and Tham (2004) propose a correlation between trend and life expectancy: here, they distinguish between 'classics' that have a slow "metabolism", and in contrast, 'fashion pieces' that are "consumed" quickly and *"have high symbolism and are worn visibly ('on show') for communication with others"* (Fletcher & Tham, 2004, 'Section: The fashion offer'). This was also evident in findings from this thesis' Study 1 and 2, which showed that 'fast' garments often will have bold/ bright colours, prints and cuts that follow seasonal trends.

In the ‘slow’ end of the GLM, garments’ aesthetic characteristics are resilient to shifting trends. Long-life garments are often described with the term “classic”, “iconic” and “timeless” (Fletcher & Tham, 2004; Goldsworthy et al., 2019; BESTSELLER 2022, Chapman, 2021), referring positively to classics as things that have withstood the test of time and remained relevant despite shifting trends (Bayley, 1999; Picken 1999, Kwon, 2017). Many designers, especially those wanting to design for sustainability, have tried to encourage attributes of classic design to extend the life of garments (Shedroff, 2009; Black, 2012; Chapman, 2021), however, as Bayley points out: *“classics can’t be invented, they evolve. They have to win approval and slowly acquire value.”* (1999, para.1). Regardless, some characteristics seem to be agreed on as enabling resilience to changing trends, such as:

- Dark, neutral colours,
- Well-known, subtle prints or patterns such as houndstooth or pinstripes,
- Thick and ‘high quality’ materials (e.g., cotton, wool, silk, or leather),
- Simplicity, with subtle or no ornamentation and a clean silhouette (Smith, 2003; Kwon, 2017).

These features were also observed in Studies 1 and 2 of this project.

Versatility

As seen in Study 1 and 2, ‘fast’ garments are usually purchased and worn for a specific season or occasion. Therefore, it is an essential for ‘fast’ garments to enable consumers to quickly create a certain look or fit into an aspirational vision, allowing *“dreams of luxury to come true even without a high-price ticket”* (Joy et al., 2012, p. 286 in Aakko & Niinimäki, 2022). In contrast to this, ‘slow’ garments’ aesthetic must allow for versatility to stay relevant over time. This includes the ability to match other components from a wardrobe, and fitting the user’s shifting needs, contexts, and seasons. Concretely, this relates to characteristics such as adjustable components and subtle colours that will work well with different seasons and wardrobe combinations (Fletcher & Grose, 2012).

Colour & fabric fragility

A consequence of the bright colours often used for enabling ‘fast’ garments to keep up with fast trends, is that the aesthetic becomes fragile, showing even the tiniest stains. It could even be argued that this is part of their appeal: A crisp, perfectly bright shirt is appealing exactly because it signals newness and cleanliness.

In contrast, for ‘slow’ garments, it is not necessarily an advantage to stay unchanged. Participants in Study 1 & 2 described how, for some, especially those garments made from durable materials, such as jeans or leatherjackets, appearing worn does not detract, but in fact adds to their value. These garments often only reach their optimal colour and grain-structure once they have been used for a while, developed patina, and adapted to the user’s body. Sometimes these garments are in fact manufactured to appear worn from before they even reach the user. Fletcher and Grose describe how garments can be designed to intentionally stain or wrinkle to *“record and celebrate marks of use”* (Fletcher & Grose, 2012, p.96). Contrary to attempting to hide marks of wear, these traits leave space for garments to evolve and for the user to leave their imprint over time. A well-worn pair of jeans are appreciated for the way the denim has become softened, ripped, and perfectly shaped to the user’s legs over the years, and tell the story of their many years in use. One participant in Study 2 described that “*the history with the product is going to build up over time and make it even more than it was to start”* (Materials 2), indicating that such traits can enable emotional durability of a garment, which, according to scholars such as Fletcher and Grose (2012), and Chapman (2005), is likely to extend its lifespan. Obviously, this relates directly to the second *primary factor* of ‘Depth of user engagement’ which is discussed in relation to the *ingredient* of ‘aesthetics’ in the following.

Deep vs shallow aesthetics

As described above, a garment’s aesthetic can play an important role in eliciting deeper levels of user engagement, to enable a longer use phase. However, aesthetic characteristics can also elicit shallow levels of engagement, sometimes leading to early discard.

Expressing identity

One of the most important differences between aesthetics of ‘deep’ and ‘shallow’ garments is the way in which it reflects and expresses the user’s identity. The aesthetic of a ‘deep’ garment will serve to enable a sense of self-realisation and eudaimonic forms of well-being (Kahneman et al., 1999). Thus, the aesthetic connected to a ‘deep’ level of user engagement will rarely be dictated by fast-fashion; loudly communicating a specific trend to others. Instead, it will likely express identity through details that hold special meaning to the wearer, which might not immediately be noticed by others. In contrast, the aesthetics of ‘fast/shallow’ garments are employed to elicit more hedonic forms of happiness; quickly enabling a sense of enjoyment and fun, fitting into a certain context, and following rapidly changing fashion trends.

Poetic touches

Besides using materials and garment-structures which can develop, age with grace, and capture narratives from the user over time (as described above) to enable emotional durability of a garment, Fletcher and Grose (2012) propose designing-in what they call “poetic touches”: these are subtle details in garments where “*the emotional engagement of the designer is apparent and the same is enabled in the user”* (2012, p.86). Examples of this could be hidden messages from designer to user on labels sewn into the clothes to be discovered over time, special shapes on trimmings, or colours which deliberately develop through wear.

Adaptability
According to Belk (1988), feeling affinity with objects, that they are part of the "extended self" (cf. above p.153), is crucial for people to keep them in their possession. If the user no longer feels like the garment communicates, or even misrepresents their identity, they will likely dispossess it. Thus, a relevant design strategy for the 'slow/deep' GLM quadrant, could be to design garments with an inherent ability for the aesthetic features to be upgraded, to stay relevant for the individual user. Adaptability also can be relevant in regard to enabling sustainable consumption of 'shallow' garments: for example, in the case of a ski-jacket accessed through a rental model for a holiday: users will likely appreciate being able to adjust the shape or ornamental details to suit their body and style, even just for the week.

Uniqueness
Another important aesthetic characteristic for a garment to reach deep levels of user engagement, which emerged from findings in Study 1 and 2, is the extent to which it is perceived as "special" or "unique". In contrast, garments perceived as "standard" and easily replaceable, will likely elicit lower levels of engagement. Aesthetic "uniqueness" can either be achieved through providing "limited edition" garments, or through involving users in activities of co-design, customisation, or DIY-production, or it can emerge slowly through consistent wear over time.

Functionality
For some garments, in particular 'slow/shallow' garments, their aesthetic will be dictated by their functionality. The value of a "slow/shallow" garment, such as a black rain jacket or workwear, lies mainly in their instrumental, functional abilities, rather than intrinsic value, which is more prevalent in 'deep' garments. To stay in use for as long as possible, the aesthetic of a 'slow/shallow' garment should be almost anonymous or uniform; not sticking out to avoid the vulnerability of relying on changing trends, and instead dictated by requirements for physical durability.

6.4. Summary

This chapter has reviewed literature related to the *primary* and *enabling factors* to place this thesis' empirical findings from Studies 1 & 2 in the context of DfS literature.

The review of literature revealed plenty of sources which have investigated and described each of the *primary* and *enabling factors* that influence the sustainability of garments. Furthermore, a number of scholars have described relationships between similar factors to those described in this thesis: Chapman (2005) links deep levels of users' "psychological resonance" with product longevity (related to the *primary factors*), and Moreno et al. (2016) link certain DfS strategies with particular sustainable business models (related to *enabling factors*). One source, Goldsworthy et al. (2019) even propose that the factor of garment lifecycle speed (*primary factor*) should guide decisions around a set of other DfS factors: DfS strategies, manufacturing method and materials (related to the *enabling factors*). These sources have confirmed and refined the understanding, proposed in Chapter 5, of how the *primary* and *enabling factors* correlate. Furthermore, this review of literature has provided insight into how the *ingredients* (*enabling factors)* in each *recipe* should be adjusted to ensure their guidance will lead designers to a sustainable outcome. Thus, this chapter provides foundational support for the development of DfS support for garment designers, which is the goal of this project.

Chapter 7

The GLM tool for diagnosing current practice sustainability & discovering relevant opportunities to improve

The studies in Chapters 4-6 developed and tested the Garment Life Matrix (GLM) framework, which articulates the relationship between the *primary* and *enabling factors* for DfS.

Responding to RQ4 (*How might considerations of the primary design factors be structured to guide decision-making processes to enable efficient, systems-aware Design for Sustainability?*), the goal of this chapter (7) and the next (8), is to test and validate the proposed GLM framework's potential to support garment designers to practise efficient, systems-aware DfS.

This research question is addressed in two steps: first, in this chapter (7), two workshop studies are conducted to test and validate the new GLM tool's ability to support designers to diagnose the sustainability of their current practice and identify relevant opportunities for improving this. Then, the studies reported in Chapter 8 will be conducted to test and validate the GLM as support for designers to design efficiently with DfS strategies in practice.

7.1. Study 3a: Diagnosing sustainability and identifying opportunities for improvement - Swimwear brand

7.1.1. Study design

This qualitative exploratory study was conducted as a focus group session (Krueger & Casey, 2000) (cf. Section 5.2.1) in which participants responded to and interacted with the GLM framework. This method was particularly suitable as it allowed for focused insights into how the GLM framework enabled structured discussions around participants' current practice. The last part of the study was conducted as a design workshop (Hannington & Martin, 2012) (cf. Section 3.2.4.) to actively engage participants in generating ideas in response to the GLM framework.

Participants

The participants in this study were garment industry professionals recruited from the Innovation Team of a major international, UK-based, swimwear brand. The participants were recruited from different disciplines related to garment development. This study involved a small group of just three participants, which allowed for in-depth conversations. Two participants had previously participated in Study 2 and were therefore familiar with the basic principles of the GLM. Recruitment was conducted through invitation by the researcher via email. All participants had read and signed consent forms prior to the study. A mutual collaboration agreement had been signed between the swimwear brand and the Royal College of Art on behalf of the researcher. Participants were anonymised for analysis and given ID codes as can be seen in Table 8.

Table 8. Study 3a Participant ID

ID	Field of experience
M1	Materials Specialist
A1	Apparel Designer
D1	Design Engineer

Data collection methods and setting

This study took place at the swimwear brand's headquarters in the UK. It was recorded through photos, audio, and video. During the study, the researcher took the role of moderator to guide activities, but otherwise stepped back, interfering only to ask questions and occasionally direct conversations to retain focus on the GLM.

Methods of analysis

Thematic Analysis (Braun & Clarke, 2006) was used to identify important research themes from study data including video recordings, photos, and handwritten notes. For this study, 'familiarising' was done through watching and transcribing video recordings and selecting relevant quotes to start generating themes. The generation of themes was supported by visually analysing the GLM framework which, during study-sessions, was populated by participants. Furthermore, the GLM was used to map participants' presentations of garment concepts generated by using the GLM tool, according to which GLM *ingredients* had been applied, to evidence how participants had applied the GLM tools' *recipes*.

7.1.2. Developing the GLM - from framework to tool

In preparation for this study, the GLM framework was developed through a Research through Design (Frayling, 1993) process to propose a new DfS tool. As established in Chapter 2, a key shortcoming of existing DfS tools is that they don't "speak the language" of designers, as they are *"difficult to use"*, *"too technical and scientific"*, and *"unappealing"* (Kozlowski et al., 2019, p.15).

To address this shortcoming, the GLM tool was specifically designed to be easily accessible and usable by designers. Building on the original GLM framework, this tool comprised a matrix format which, as established in the review of existing DfS tools (Section 2.5.3.) is a particularly suitable format for designers. This format allows designers to map and understand their current practice in relation to the GLM's elements (the *primary* and *enabling factors*). Furthermore, this format offers a visual anchoring point to which designers, or other collaborators, can return and discuss ideas.

This tool was designed to have a digital, interactive format, using the online software tool 'Mindmeister'. This digital format enables comprehensible structuring of complex information in a Mindmap (Hannington & Martin, 2012). A screenshot can be seen in Figure 33 below, and enlarged in Appendix (B1), but it is strongly recommended to experience its interactive format by clicking the button below. This will open a copy of the original tool. You are invited to open and explore the *recipes*.

Click to open
the GLM tool

Figure 33. Garment Life Matrix tool overview

Strategies related to 'Design for slowing loops' explored by clicking button in recipe

'Fast/shallow' recipe. Six ingredients revealed by clicking 'recipe' button. 'Key strategy' for this recipe shown in white box (top)

The ingredient of 'Design Strategy' opened to explore relevant strategies

SHALLOW ENGAGEMENT
Weak user bond

SLOW
Use phase pace

FAST
Use phase pace

DEEP ENGAGEMENT
Strong user bond

Garment Life Matrix

RECIPE

SLOW SHALLOW

FAST SHALLOW

SLOW DEEP

FAST DEEP

KEY STRATEGY
Fast, leak-free loops
Material longevity instead of product longevity

Ingredients
- Design Strategy
- Business model
- User Engagement
- Materials
- Production Method
- Aesthetics

Design for Sustainability strategy
- Design for CLOSING loops
- Design for NARROWING loops
- Design for MULTIPLE loops
- Design for SLOWING loops (Go to left Matrix quadrant)

Design for SLOW
- Simplify - Reduce overall number of components
- Remove or strengthen any high-risk/ abrasion areas
- Design for PHYSICAL durability
- Design products that need little/no maintenance
- Click link for examples & inspiration
- Design for ageing well: Maintenance, repair & upgrade
- Design for EMOTIONAL durability: Product attachment and trust - Deep user engagement
- Design for dematerialising products

Design for MULTIPLE loops
- Design for up-cycling / recycling of material
- Design for easy separation of materials
- Embedding digital ID / protocol tag
- Use modular structures
- Design for remanufacturing, dis- & re-assembly of components
- Avoid difficult-to-handle components ar fasteners
- Prioritise the disassembly of:
- Use removable/soluble adhesives or stitches
- Embedding digital ID / protocol tag
- Click link for examples & inspiration
- Design for cascade use (more relevant for products with deeper user engagement)
- Design for easy end-of-life cleaning, collection and transportation (more relevant for long-life products)

KEY STRATEGY
Slowing loops
Product longevity

Ingredients
- Design strategy
- Business model
- User engagement
- Materials
- Production method

Design for Sustainability strategy
- Design for CLOSING loops
- Design for NARROWING loops
- Design for MULTIPLE loops
- Design for SLOWING loops

The ingredient of 'Design Strategy' opened to explore relevant strategies

'Slow/deep' recipe. Six ingredients revealed by clicking the 'recipe' button. Key strategy for this recipe shown in white box (top)

Relevant strategies related to 'Design for multiple loops' explored by clicking button in recipe

This interactive format allows comprehensible communication of information. The various strands in the map can be collapsed, which allows for reducing the amount of visible information when an overview is needed, whilst still offering layers of detailed information. This can then be explored by unfolding strands related to each *ingredient* as shown in Figure 33.

The contents of *recipes* and *ingredients* was based on findings from Chapters 5 (empirical studies) and 6 (literature review), i.e., how the *primary* and *enabling factors* for DfS are defined, how they correlate to affect garments' lifecycles, and importantly, how these *factors* should be configured in the GLM *recipes* to provide guidance for efficient DfS. In accordance with the recommendation from literature on DfS tools (Baumann et al., 2002; Lofthouse, 2006; Connor-Crabb, 2017; Kozlowski et al.,2019), the tool's recipes were reduced to short prompts, using a minimum amount of written information.

To provide designers with quick and easy understanding of the forces at play in each GLM quadrant, a key strategy which, using only a few words, describes the overarching approach that guides the *recipes* in each GLM half (i.e., either 'material' or 'product longevity'). The key strategy was placed at the top of each *recipe a*s can be seen in Figure 33b.

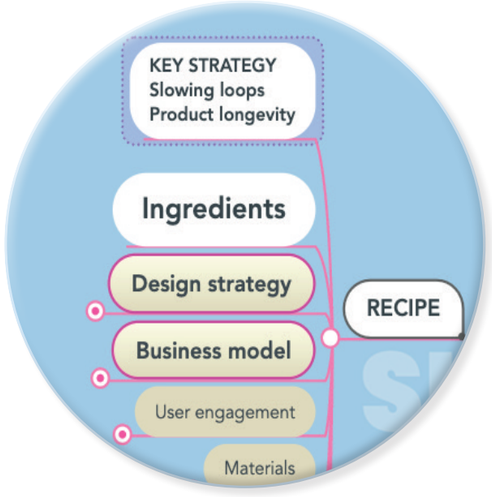


Figure 33b. Key strategy shown in white box, GLM tool

In line with findings from Chapter 6, which established how the *recipes* in each quadrant of the GLM should vary to provide appropriate DfS guidance depending on the *primary factors*. The goal here was to convey, as clearly as possible, the relationship between the *primary* and *enabling factors*, to enable designers to competently negotiate them in a DfS process.This is demonstrated in Figure 33, which shows the difference between the *ingredient* of 'Design structure' in two different *recipes* ('slow/shallow' and 'fast/shallow').

Another learning from the review of existing DfS tools (Chapter 2) which informed the design of the GLM tool, was the recommendation from Lofthouse (2006) for DfS tools to use inspirational examples to provide information. For designers, a common, important step in their process, is to collect images of existing examples of design, to build their knowledge for future design problems, and to discover new inspiration (Lawson, 2004), and these images are often compiled on design "mood boards" (Eckert & Stacey, 2000).

Many designers use digital tools to gather examples from the internet, and a commonly used tool for this is Pinterest (Izadpanah, 2021), a "*visual discovery engine for finding ideas*" (Pinterest, 2022). Therefore, Pinterest was employed in the GLM tool to communicate the *ingredient* of 'DfS strategy', through real-world examples. As shown in Figure 34, each DfS strategy suggested in the GLM tool was supplied with a hyperlink which, if selected, opens a Pinterest board with examples of its application in practice. The examples chosen for these Pinterest boards were identified throughout this research, especially during the review of practice in Chapter 4.

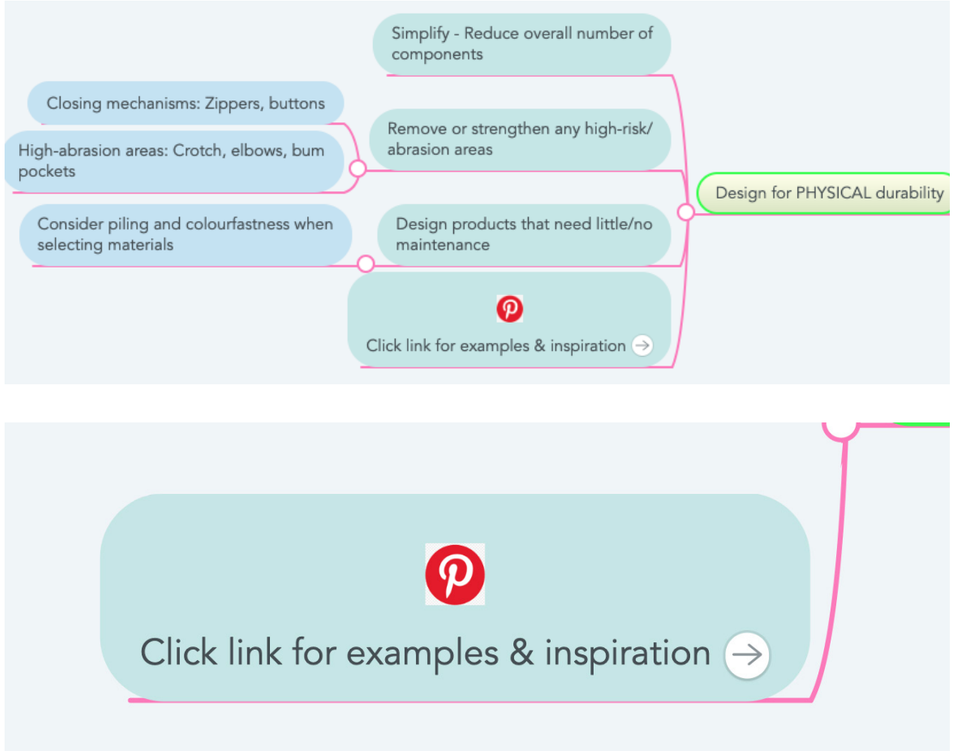


Figure 34. Hyperlink to a Pinterest board embedded in GLM tool

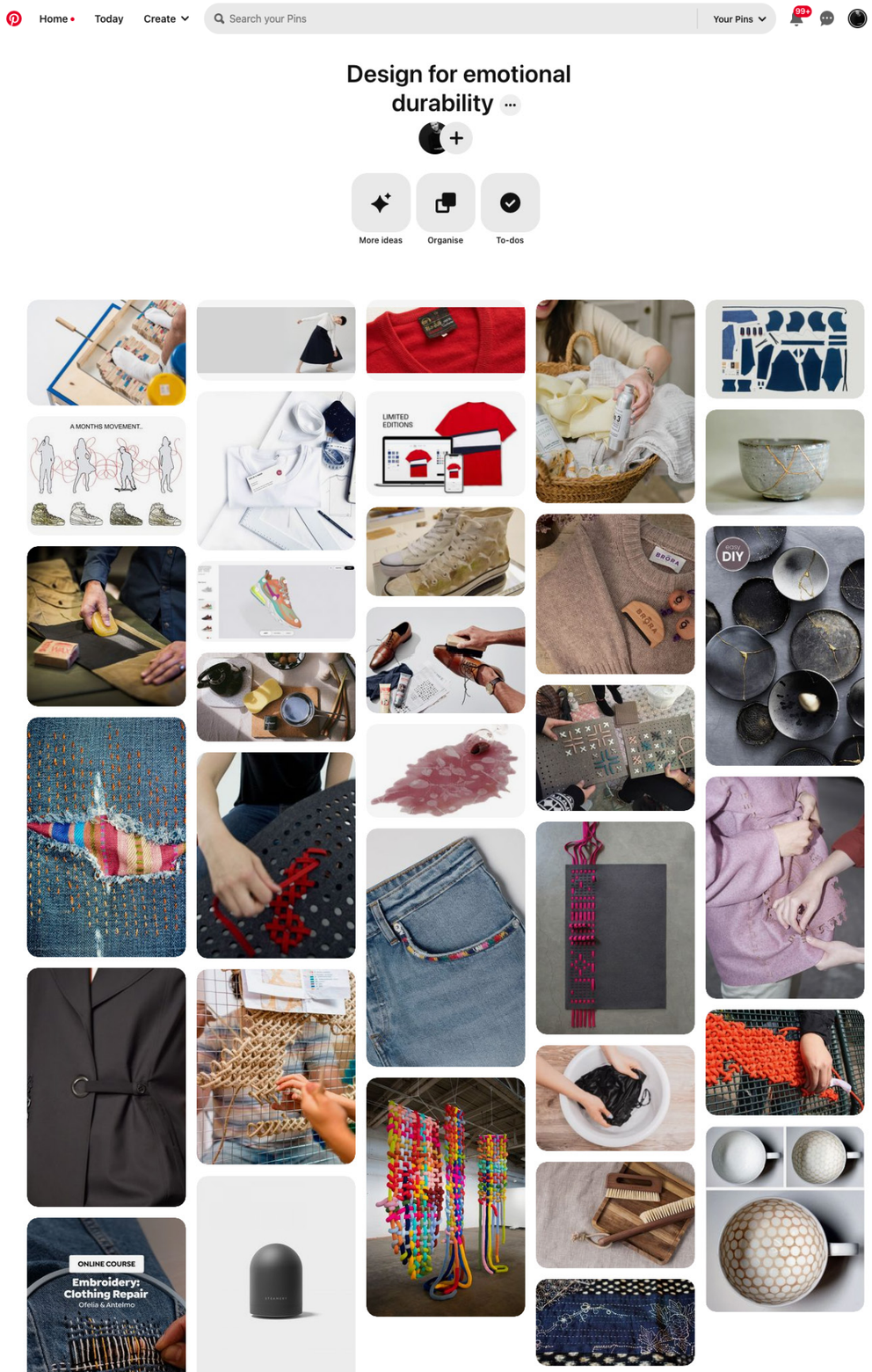


Figure 35. Pinterest board with practice examples of Design for emotional durability, connected to the GLM ingredient of 'DfS strategy' through a hyperlink.

Direct links to the Pinterest boards are listed below, click buttons if you wish to access

Table 9. *Direct hyperlinks to Pinterest boards*

Design for closing loops	Design for narrowing loops	Design for multiple loops	Design for physical durability	Design for emotional durability

7.1.3. Study activities

The goal of this study was to test and validate the new GLM tool's ability to support designers to diagnose the sustainability of their current practice, and identify relevant opportunities for improving this (i.e., proposing routes towards more environmentally sustainable practice).

Activity 1) 'Diagnosis'

This activity began with a mapping exercise, where participants placed products from swimwear brand's current range in the GLM. To enable collaboration, the simple GLM framework, showing only the two axes, was enlarged, and drawn up on a whiteboard.

Once the garments had been placed in the GLM, the participants were tasked with annotating each garment with an estimated life expectancy (minutes / months / years). As they progressed, participants were encouraged to iteratively adjust the garments' placements in relation to each other. Eventually, to form a timeline along the 'pace axis', while also considering their position in relation to the 'depth axis'. The purpose of this task was to enable participants to gain an overview of their current product portfolio; the speed at which their products are consumed and the depth at which users engage with them.

After finalising the map, the participants stepped back to diagnose the sustainability of their current practice, based on the visual landscape that had emerged. The participants were tasked with identifying relevant discrepancies between how the products currently are designed, produced, and sold, and how/for how long consumers actually use them.

To conclude this activity, the participants selected a few products from their range whose design characteristics were particularly ill-matched with the 'pace' and 'depth' at which they expect consumers to use them. Thus, the selected garments were deemed particularly "unsustainable" and obvious candidates to redesign.

Activity 2) ‘Discovering opportunities’

Here, the participants used insights from the previous activity as a starting point to explore new ideas for DfS, supported by the GLM tool. This session started with an introduction to the interactive GLM tool; the *ingredients* and *recipes* of the GLM. The GLM tool was made available on a laptop and projected onto a large screen for everyone to see. This session tested the GLM tools’ ability to support garment designers to systematically select and discuss appropriate DfS strategies, to explore opportunities to efficiently improve the sustainability of their range.

To clarify the task of this activity and enable participants to easily navigate the GLM tool, the participants were instructed to either:

Stay in the Garment Life Matrix quadrant to redesign the product in its current placement by following the *recipe* within that same quadrant, or

Go to a slower and/or deeper quadrant of the Garment Life Matrix.
This option requires fundamentally changing the product’s *ingredients* according to the *recipe* within the new GLM quadrant.

These instructions were later developed into a complementary method to use with the GLM tool. This is reported at length in Section 8.1.

Once briefed, the participants spent 20 minutes individually to sketch and brainstorm on new sustainable concept-ideas for redesigning the “unsustainable” garments (identified in Activity 1). During this exercise, the participants used the interactive GLM tool alongside sketching on paper. Finally, the ideas were presented and discussed with the group.

At the end of this study, participants were invited to feedback and respond to their experience of using the GLM tool.

7.1.4. Findings

Activity 1 - Diagnosis

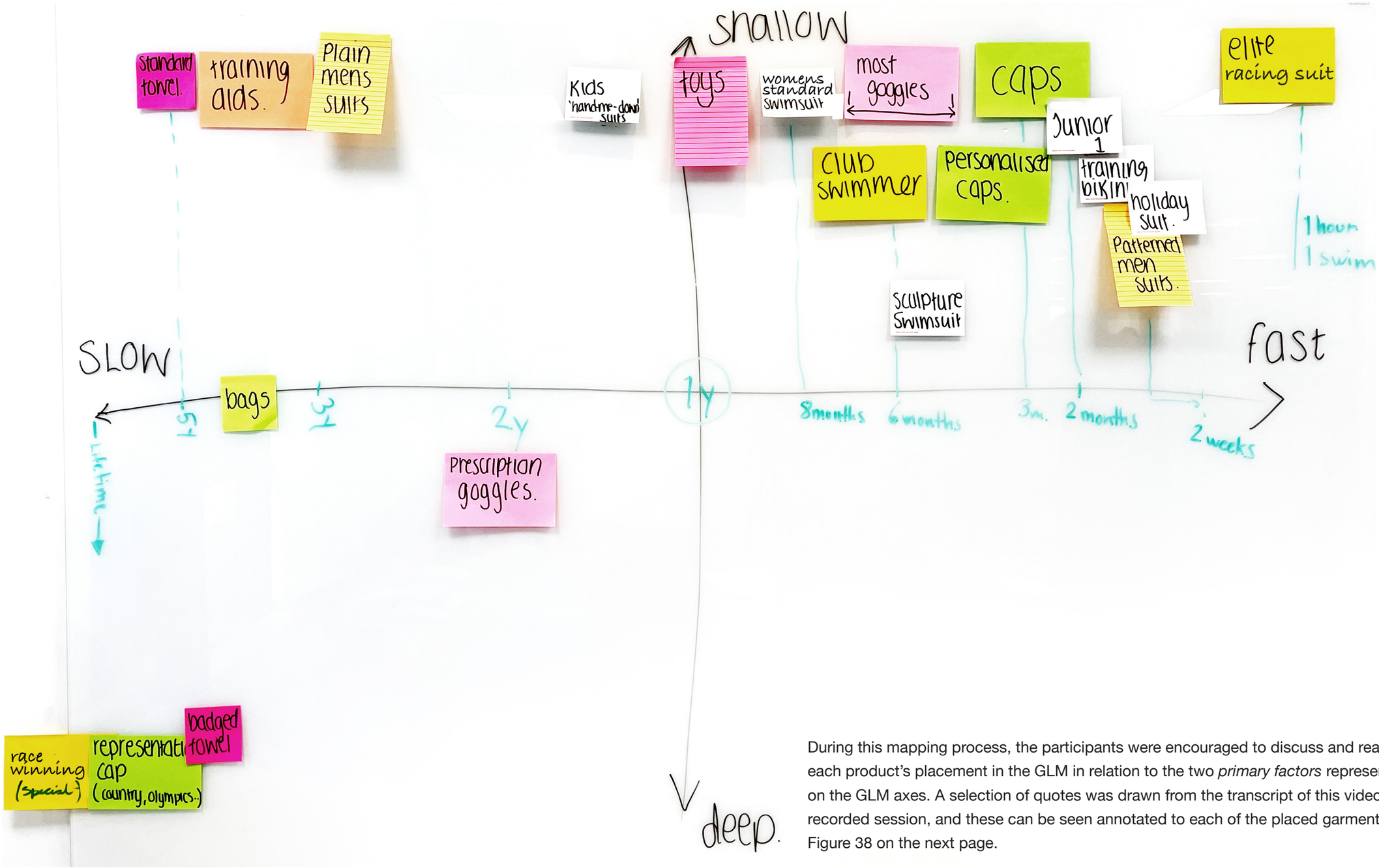
Participants started this activity by picking garments from different product categories to broadly represent the brand’s range and placing them in the GLM as pictured in Figure 36.

Figure 36. Participants mapping the swimwear brand’s range into the GLM

Generally, the participants would agree on placements and the length of product’s use phases. However, they admitted not knowing exactly how long the products are used for. During this process, participants were particularly focused on the context of use and consumers’ needs when discussing garments’ placements in the GLM. They were particularly interested in the frequency of use, as they thought this had a significant impact on the length of the use phase. As one participant explained about swimming goggles: *“it depends how often you swim [...] If you swim two-three times a week, you will need a new pair of goggles every six months at least. If you swim once a year, people tend to buy a new pair every time they want to swim”* (M1). This is arguably true for garments in general, but particularly relevant for swimwear, as A1 explained: *“A lot of the reason why our products are short-life is [...] because of the chlorine and the seawater [...] the reason why they put chlorine in the pool is to kill things, and we put our products in there”*.

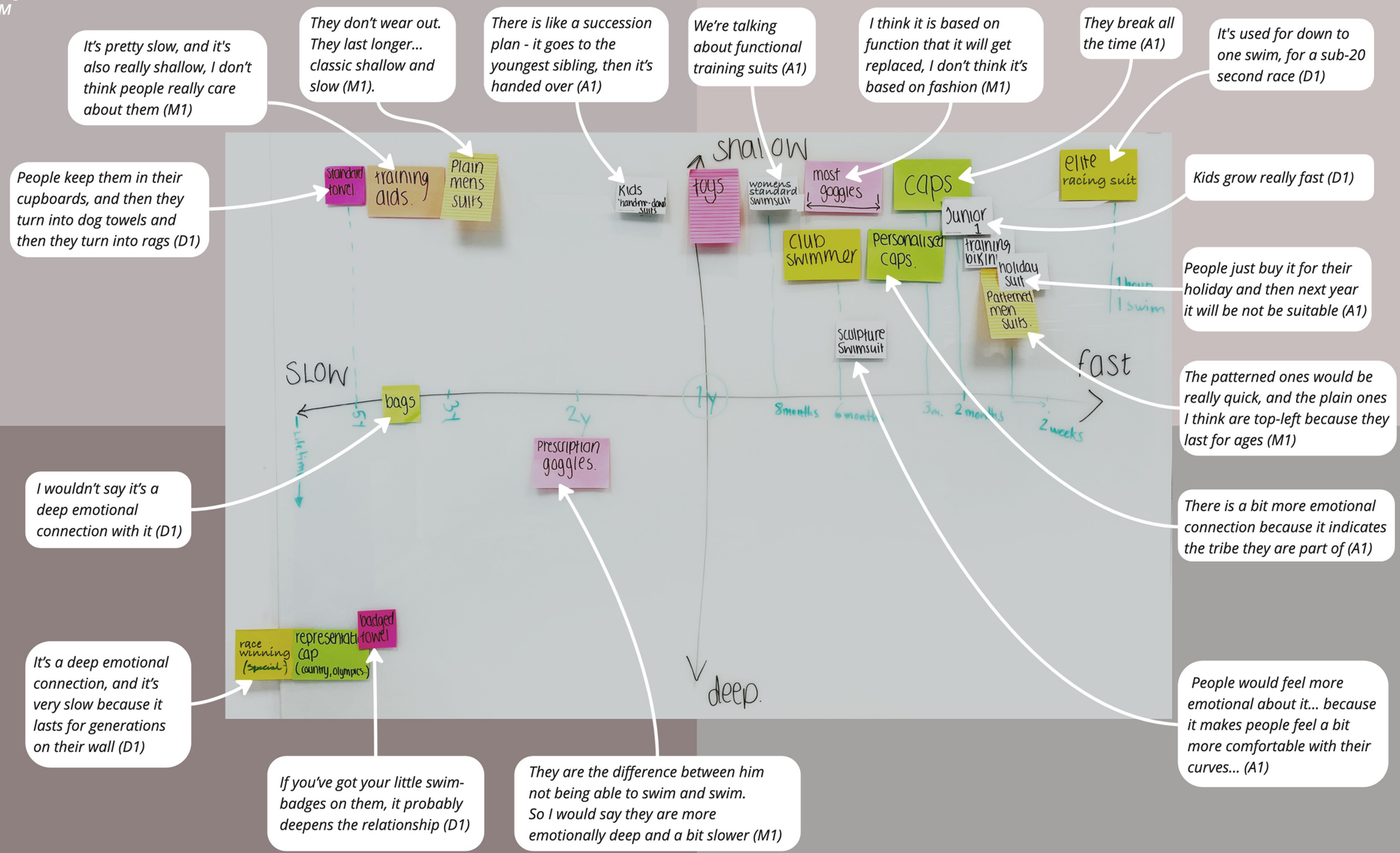
As the garments were placed in the GLM, the participants iteratively adjusted their positions in relation to each other, until they felt they had a good representation of the brands' range. To conclude this activity, the length of each garment's expected use phase (based on participants' estimates) was specified and noted along the 'pace' axis (from years to less than one hour). This resulted in a timeline as can be seen in Figure 37.

Figure 37. Photo of the GLM populated by participants with the swimwear brand's products



During this mapping process, the participants were encouraged to discuss and reason each product's placement in the GLM in relation to the two *primary factors* represented on the GLM axes. A selection of quotes was drawn from the transcript of this video-recorded session, and these can be seen annotated to each of the placed garments in Figure 38 on the next page.

Figure 38. Participants' reasoning for garment placements in the GLM



As the GLM was filled, it emerged that the slowest group of products, in the bottom left quadrant of Figure 38, were "race-winning items'' - special garments which have been worn by athletes while winning an important race, such as the Olympics. As one participant described: *"They will frame that suit immediately after, so it's a deep emotional connection, and it's very slow because it lasts for generations on their wall"* (D1). The runner-up for longest use phase was towels that had been personalised with milestone-badges for swimming achievements. The team agreed that the badges added a deeper level of user engagement, and a slower use phase pace: *"Your general towel is probably slow and shallow, but if you've got your little swim-badges on them, it probably deepens the relationship"* (D1).

On the opposite 'fast' end of the spectrum, was a special suit worn by elite athletes to optimise their performance. This suit was estimated to have a life expectancy *"down to one swim, sometimes for a sub-20 second race"* (D1). Another, very short-lived, product type, was the "holiday suit" bought specifically to wear on vacation. One participant described how consumers *"just buy it for their holiday and then next year it will not be suitable or the right size anymore"* (D1). These "holiday suits" were described as "fashion-based", which according to one participant *"is about the pattern on them"* (M1). The participants expected this would cause these garments to have *"an expiry date in terms of fashionability"* (M1). D1 pointed to plain version of the same garment (placed in the 'slow/shallow' quadrant) and said: *"the black suit is never really going to go out of style… but the patterned one might only last one season",* although the two suits are almost identical in terms of materials, shape and production method.

Diagnosis

The filled-in GLM framework from the mapping exercise (Figure 37), provided a visualisation of the company's range: most products were placed in the top right, 'fast/ shallow' quadrant, but none were placed in the 'fast/deep' quadrant, and only very few garments were placed in the 'slow' half in general.

As the team stepped back and evaluated the finished GLM map, they were asked to consider: "*what does this make you think about the sustainability of your current practice? - Any surprises or realisations?"* by the researcher.

The participants did not express surprise at seeing that the garments in their range have a generally short lifespan. However, it did make an impression on them to see the extent of this across their range, visualised in the GLM: *"this has been a very simple way of showing us that we don't have a very diverse portfolio…we could diversify the product portfolio to have products that are a bit slower and more emotionally deep"* (M1). In relation to this, the team reflected on the fact that almost none of the company's products are recyclable. One participant laughed and said: *"We better start doing some recycling!"* (M1). To this, another participant added: *"a lot of the reason why our products are short-life is because they are not very durable, because of the environment they are used in…So even if we made them less shallow, the products' function might fail before people don't want them anymore"* (A1). To this, M1 responded: *"That probably means we need to work on making our products more durable. And, if we can't do that, we need to work on how we can make them* [moving arm in a circle] *so we can reuse the same material".*

Identifying current discrepancies between design and use

Based on the generated GLM map, the participants were tasked with selecting four particularly "unsustainable" products: products with particularly strong discrepancies between the way they currently are designed, produced and sold, and how/for how long the garments are used by consumers. The participants chose to focus on four "unsustainable" products:
1) The elite racing suit for athletes
2) The patterned men's' holiday suit
3) The standard fitness women's' suit
4) Goggles in general.

These products had all been placed in the 'fast/shallow' GLM quadrant during the mapping exercise. The reasoning for why the participants saw these products as particularly unsustainable is annotated as quotes in Figure 39 on the right.

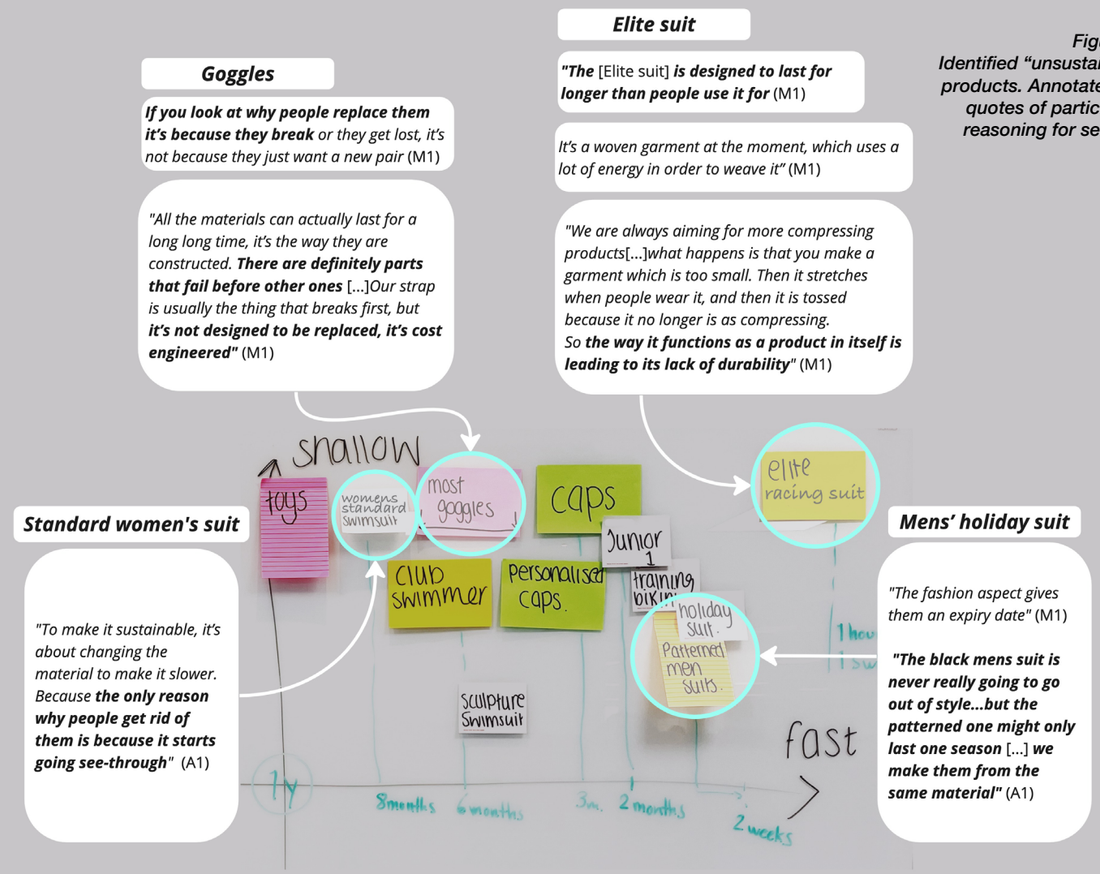


Figure 39. Identified "unsustainable" products. Annotated with quotes of participants' reasoning for selection

As seen in Figure 39, the main sustainability issue for the elite suit, according to the participants, is that it's *"designed to last for longer than people use it for"* (M1). In the sense that "*it's a woven garment at the moment, which uses a lot of energy in order to weave it"* (M1). However, it was also argued that the suit wasn't durable enough: *"it stretches when people wear it, and then it is tossed because it no longer is as compressing. The way it functions as a product in itself is leading to its lack of durability*" (M1).

For the men's holiday suit, the main identified issue also lay in the discrepancy between how long it is designed to last for, and the short time it's expected to stay kept in use by consumers. Here, the team explained that this brightly coloured, patterned garment, which *"might only last one season"* (A1) is made from the same material as the black version of the same product, which *"is never really going to go out of style"* (A1).

For the standard fitness suit, there was a similar discrepancy between the way it is designed and how/how long it is used for. However, in this case it breaks before the user doesn't want or need it anymore. This was also the main sustainability issue for goggles, which also lack durability compared to how long people want to keep using them. As one participant explained: "*If you look at why people replace them it's because they break or they get lost, it's not because they just want a new pair"* (M1).

Activity 2 - Discovering routes to improving sustainability

In this session, the participants spent 20 minutes individually to sketch and brainstorm on new ideas to redesign the four identified “unsustainable” garments. During this process, participants frequently reached for the laptop to click through the *recipes* in the GLM tool, alternating between looking at the recipes, writing notes and sketching ideas. In some cases, as seen in Figure 40, participants would map their ideas directly into the GLM framework.

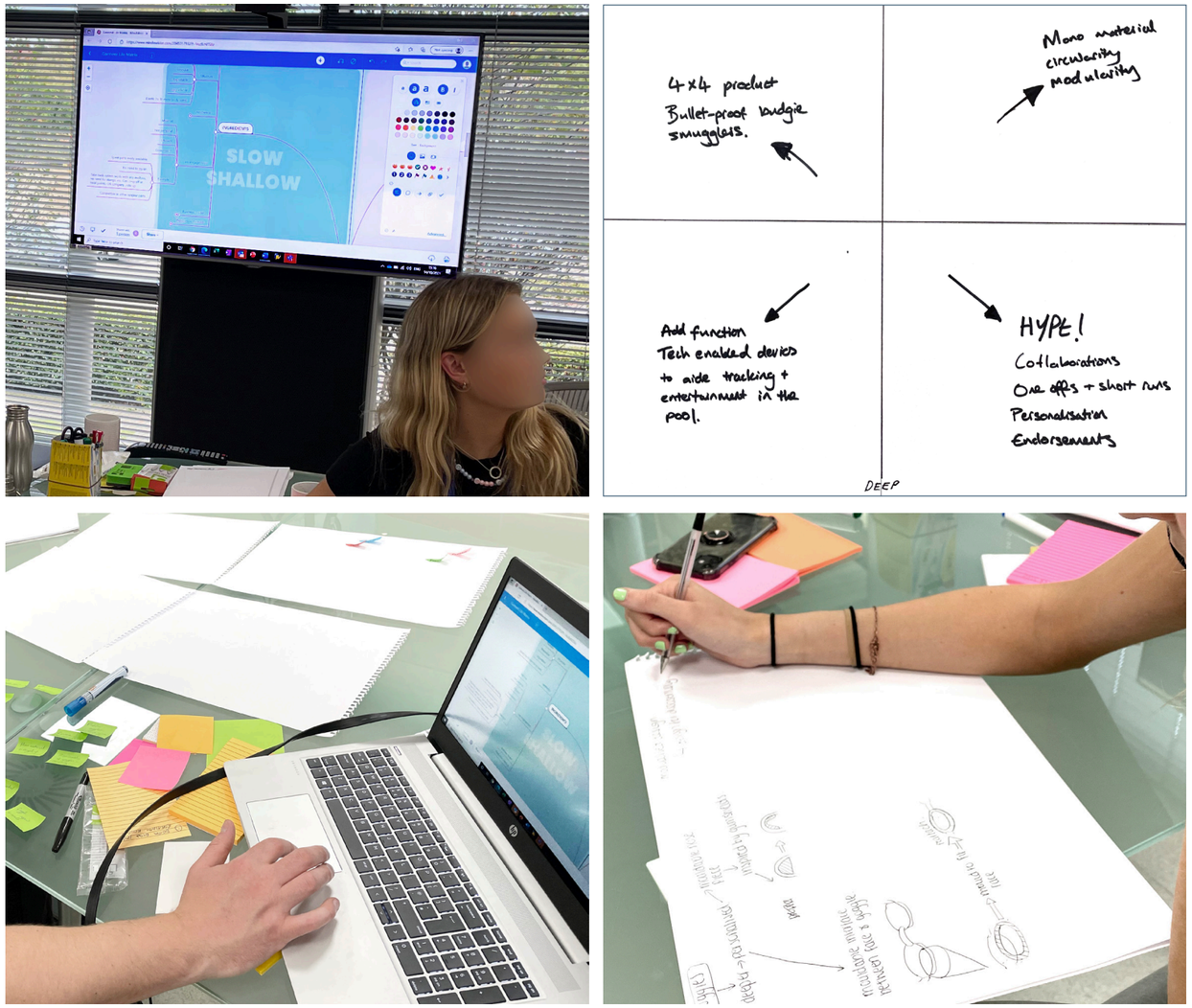


Figure 40. Participants sketching concept ideas and using the GLM digital interactive tool

During this process, the participants followed the instructions to either ‘Stay’ or ‘Go’ to either change some *ingredients* to make the product suitable for staying in its current GLM quadrant (i.e., following the quadrant’s *recipe*), or moving across to the ‘slow’ GLM half to follow an entirely different GLM *recipe*. The participants used the *recipes* to guide their idea-generation process in different ways: some considered the *ingredients* one by one (clicking through them in the GLM tool). Others used the *recipes* sporadically, looking up and exploring the *ingredients* along the way.

To provide an overview of the outcomes from this process, the concepts were mapped (by the researcher) in the GLM as can be seen in Figure 41. Here, the white boxes represent the original products, and the coloured post-it notes represent the generated concepts. Placements were based on the participant’s presentations of their concepts.

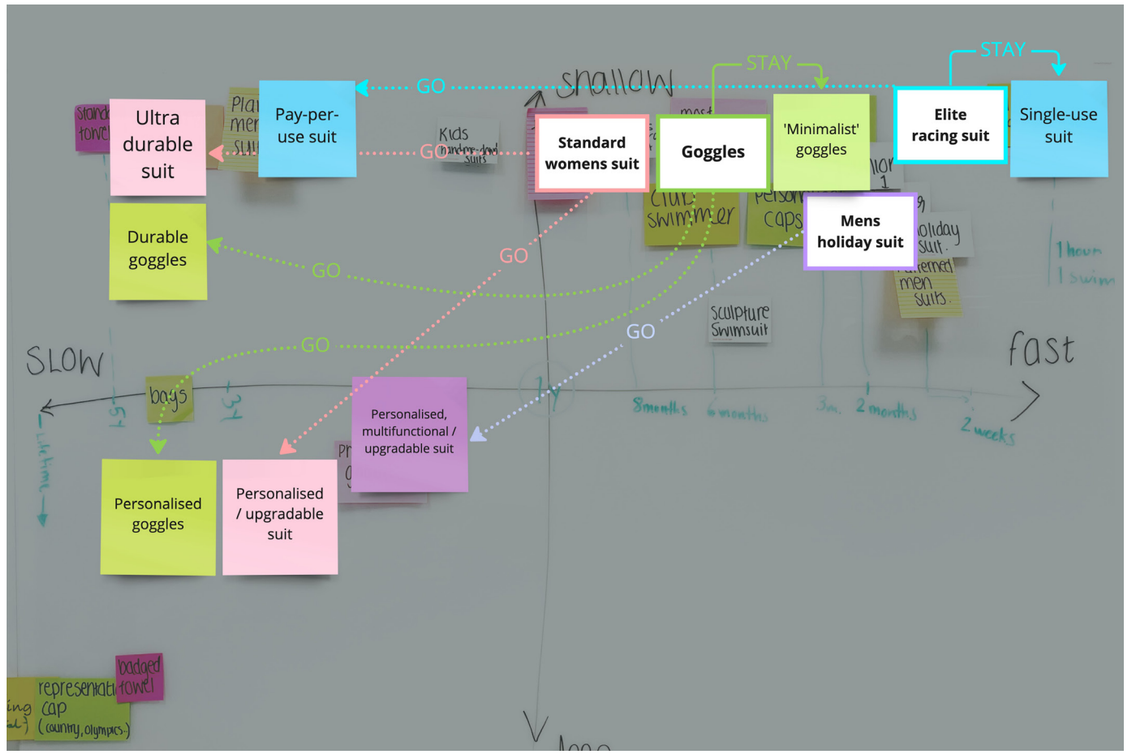
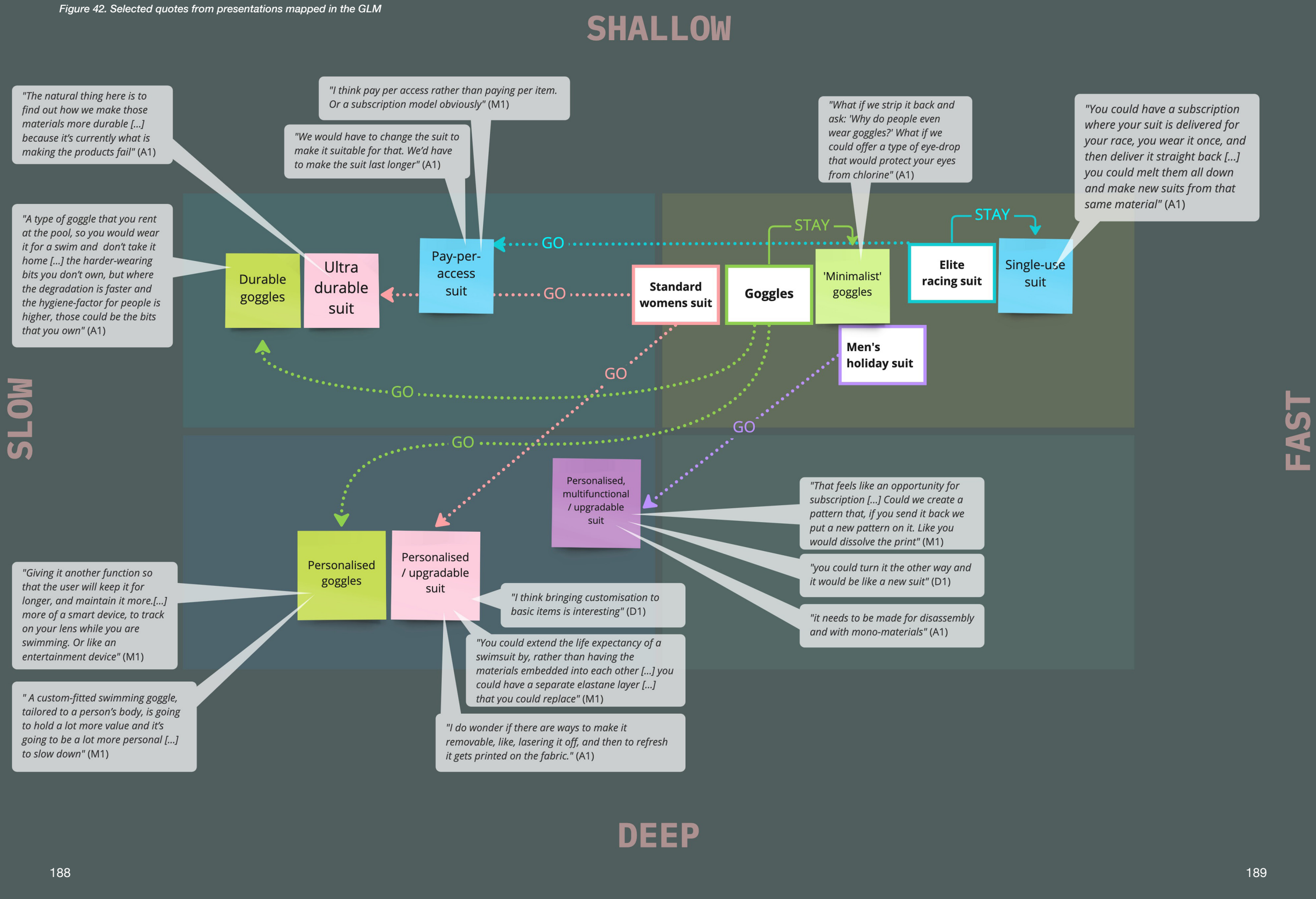
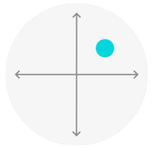


Figure 41. Concept ideas mapped in the GLM

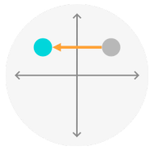
When presenting their ideas to the group, the participants expressed feeling inspired and showed many concept-ideas for both options of ‘Stay’ and ‘Go’. Most ideas followed the ‘Go’ approach, moving the garment to a slower and often deeper GLM quadrant. Despite the short 20-minute time frame of the idea-generation session, these ideas were presented with a high level of detail. To capture this, selected quotes from presentations are mapped in Figure 42 below. A more detailed map with more quotes, is presented in the appendix on p.62.

Figure 42. Selected quotes from presentations mapped in the GLM





Starting with the **elite suit** (pictured on blue post-it note, Figure 42), the participants addressed the identified discrepancy that this suit is *“made to last for longer than people use it for”* (M1). In response to this issue, the designers first took the approach of ‘Stay’ to come up with suggestions for how the garment could be designed to be sustainable in the ‘fast/shallow’ GLM quadrant. One designer presented an idea for a single-use, mono-material suit: "*you could have a subscription where your suit is delivered for your race, you wear it once, and then deliver it straight back [...] you could melt them all down and make new suits from that same material [...] It might not be ideal in terms of energy-use and chemical processes, but it would make it fresh for every person*" (A1).



Another identified issue for the **elite suit** was the fact that its compressing function causes it to stretch or break. To address this issue, the team had used the other approach of ‘Go’ to propose a long-life version. This approach led to ideas such as *“a mechanism to tighten it rather than the material just getting looser”* (D1), or a suit which would be rented out to athletes through a pay-per-access business model, with durable, refreshable materials and structure.

For the **men’s holiday suit** (purple post-it note, Figure 42), the identified issue was the fact that the garment is used less than it is designed for caused by the fashion-based patterns and bold colours. As a response, the designers chose the approach of ‘Go’ to design a ‘slower/deep’ garment. One idea focused on the ability to make a double-sided garment, one plain and one patterned, to allow for versatility and prolonging its relevance. Other solutions included ideas for updating the pattern and colour over time.

The main identified sustainability issue with the **standard fitness suit** (pink post-it notes, Figure 42), was its insufficient durability, compared to how long users would want to keep it in use. Here, the team chose the ‘Go’-approach to come up with concepts in the ‘slow’ GLM half. One suggestion for the ‘slow/shallow’ quadrant, focused on making an ultra-durable suit with ultra-durable materials. In the ‘slow/deep’ quadrant, they proposed a customisable suit, with replaceable components such as *“an inside layer of elastane that you could replace*" (M1).

For **goggles** (green post-it note, Figure 42) the main identified sustainability issue also lay in their lack of durability. Here, the designers took the ‘Go’-approach, to design for the ‘slow’ GLM half. For the ‘slow/shallow’ quadrant, they came up with concepts such as goggles designed for disassembly, *“so you could remove the bits that have a shorter life, so they*

could be replaced instead of replacing the whole product" (D1). Furthermore, a model for renting goggles at the pool was proposed: “*you would wear it for one swim and then you don’t take it home”* (D1). For the ‘slow/deep’ quadrant, they thought about goggles with a personalised fit, functionality and aesthetic.

Although many of these concepts weren’t seen as immediately feasible, the participants expressed wanting to bring elements of these ideas into practice. Two of the concepts were particularly favoured: a modular goggle, designed for the ‘fast/shallow’ GLM quadrant, and a redesign of the standard fitness swimsuit to be multipurpose and long lasting. Chapter 8 will describe how one of the designer-participants used the GLM *recipes* to take these selected ideas to a prototype stage.

Feedback and discussion the GLM tool

To conclude this study, the participants were invited to discuss and feedback on their experience of using the GLM tool. This session was conducted as a group discussion with a few prompting questions from the researcher. Below is a summary of this discussion, based on the Thematic Analysis of audio recordings.

A framework for conversation and collaboration

One of the first things the designers mentioned regarding their experience of using the GLM tool was that they found it easy to understand and use. They felt that its format made the GLM tool particularly suitable for involving people from many different backgrounds in collaborating around DfS. The participants found the diagnosis exercise (Activity 1, Study 3a) of mapping the company’s products in the GLM specifically useful for increasing understanding and collaboration. One participant said: *“previously we’ve had no canvas to hold this conversation on [...] unless you're doing this every day, people just don’t think in this way about products”* (M1). The matrix structure, and the capacity for mapping the company’s range was seen as particularly useful: *“It's very easy to talk around these things, but when you actually see them on a grid, you can see ones that are standing out quite dramatically. It’s hard to argue with [...] I think it might start to challenge some mindsets”* (A1).

The participants saw an opportunity to involve and encourage different stakeholders such as brand leaders, innovation team members, consumers and retailers to take part in a GLM ‘diagnosis’ session: “*I think holding that mirror up to all these different people and using it to have a conversation about brand building, but also product lifetimes and how we could design products to last for longer would be really a useful tool”* (M1). This was important as participants saw buy-in from retailers and managers as critical to implement changes for sustainability. As one participant expressed: “*If we can get the managers on board and it filters down, the designers are more than capable of doing it [...] If we could have both of them involved, we’re looking at success”* (A1).

Enabling a systematic approach

The participants described that their team previously had been working with ideas for sustainable concepts, but as one participant said: "*we've never really had a framework to allow us to organise them in our heads and create a strategy to explore them and understand what works"* (M1). In connection to this, one participant said about his experience of working with GLM tool: "*this model allowed me to really articulate my thoughts [...] It gave me a framework to stay on track"* (M1).

The participants mentioned using other DfS guidelines and tools in the past, such as the Circular Design Guide by the Ellen MacArthur Foundation & IDEO (2017), but described that these current tools lack support for designers to select DfS strategies that are relevant for the particular project at hand: "*what it doesn't do is help you make the leap from; 'my product is this', to: 'therefore these are the things that I should be doing to improve'"* (M1). In comparison, the participant said about the GLM tool: *"rather than just making lots of suggestions to what you should think about, this is a tool which will really help and guide your thought-process to think about the products you have, the materials you have, the business model [...] and then suggest the things you can do to improve it"* (M1).

This participant had previously been involved in developing the current sustainability strategy for the conglomerate company which the swimwear brand is part of. Regarding this experience, he described a clear lack of a systematic approach. He expressed that he thought the GLM could be helpful for this: "*if we'd had a model like this, and we had plotted out the products and been able to think about the actual things that we need to do [...]That would have been useful for me"* (M1)

Empowering a holistic perspective

Participants also described how the GLM could help them to keep a systems perspective, which, as they explained, is rare in fast-fashion design teams: "*staff are so busy focusing on making sure they're hitting their KPI's* [Key Performance Indicators] *so they're not looking at the bigger picture"* (A1). Participants felt that the GLM tool could help to make these complex considerations manageable: *"I think this model is a really good framework for arranging ideas and thinking about how and why you should innovate. Thinking about the consumer's needs and how this relates to sustainability and the business model"* (M1).

7.1.5. Discussion of findings Study 3a

This study aimed at testing the GLM tool's ability to support designers to diagnose the sustainability of their current practice and identify relevant routes for improving this through two activities.

Activity 1, where participants mapped their company's current range in the GLM framework enabled them to 'diagnose' its sustainability, and pinpoint products which were particularly relevant to redesign for improved sustainability. The GLM enabled these activities in two main ways:
Firstly, through its visual layout. The ease with which participants were able to map their current range into the GLM to gain an overview of their current practice (Figure 37), and their comments during the feedback-session, confirmed the GLM as easy to understand and use, and thus efficient for communicating DfS principles to garment industry professionals. Secondly, through its framework-format. The recordings of this activity, as well as feedback- statements, demonstrated how the activity of visually mapping their practice into the GLM framework (which articulates the relationship between the two *primary factors* for DfS*)* enabled participants to directly consider and discuss their practice in relation to the two *primary factors*. As observed in Chapter 5.5., considering the *primary factors* is an ideal starting point for further decision-making in a DfS process, as consideration of these factors should guide designers' decisions around the other enabling factors, for them to design efficiently for sustainability.

Furthermore, the tool's ability to let participants visually "record" their current range in the GLM, enabled participants to discuss discrepancies between their position in the GLM, i.e., how/for how long the garments are used by consumers, and the way they currently are designed, produced, and sold. This activity led participants to collaboratively pinpoint products which were particularly relevant to redesign to be more sustainable, and thus enabled a shared vision for improving sustainability of the company's range.

Activity 2, where the participants used the GLM tool to support a quick design-experiment to discover relevant opportunities for improving sustainability of their current practice, confirmed the GLM tool as useful for them to take a holistic approach to design efficiently with DfS strategies. These abilities of the GLM tool were demonstrated in the following ways.

Firstly, the ability to enable a holistic approach was demonstrated through the generated garment concepts, and the communication of these. To clearly demonstrate how participants used the GLM *recipes* to support their ideas, the quotes from participants' presentations (building on Figure 42) were colour-coded, according to the GLM *ingredients* they include. This can be seen in Figure 43 below. A fully detailed version of this map, with participants' quotes, is presented in the appendix Section F2.

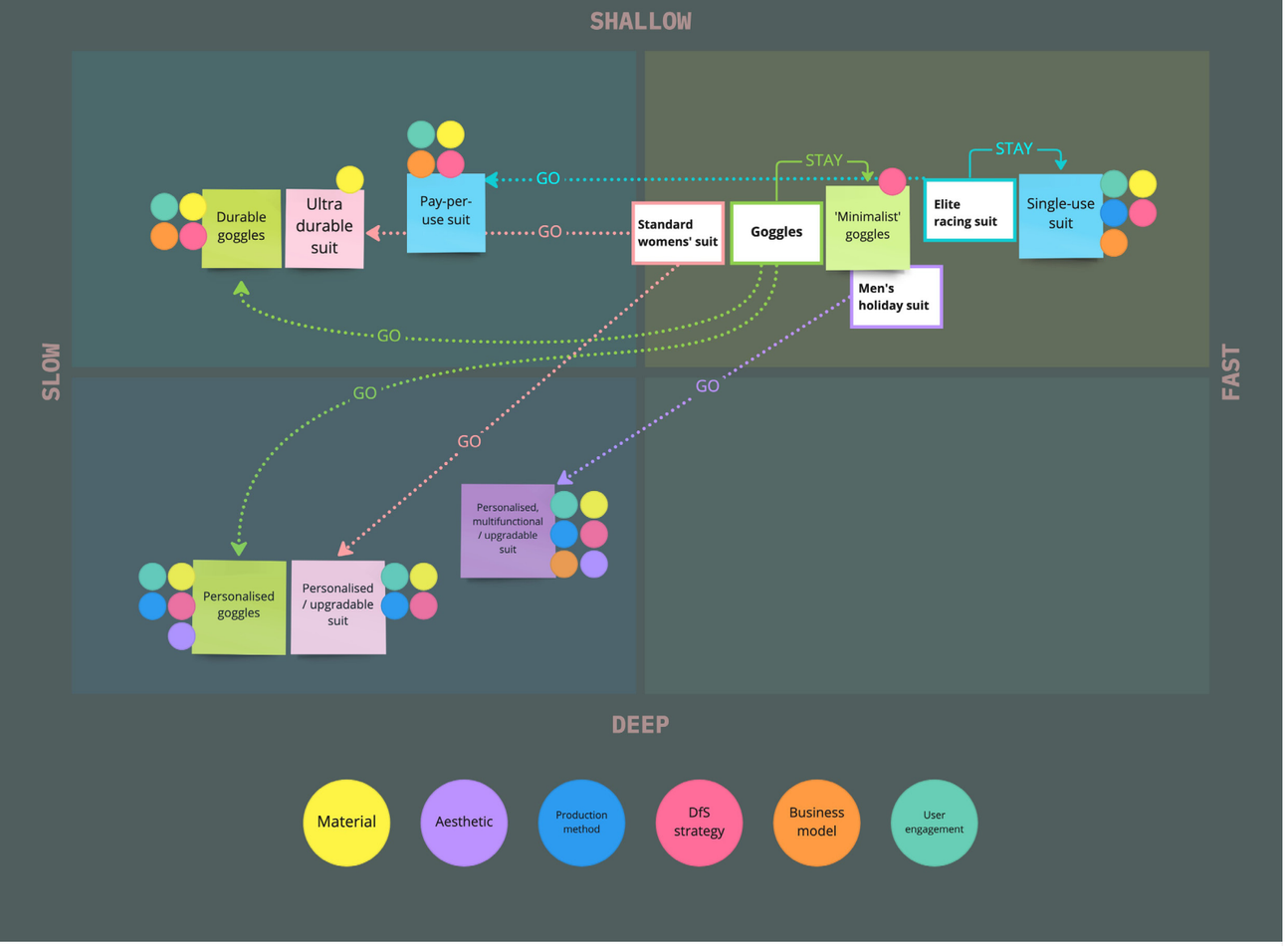


Figure 43. Concepts generated from Activity 2, mapped in GLM and annotated with use of ingredients

The spectrum of coloured dots in Figure 43 demonstrates that the participants had included consideration of all GLM *ingredients,* and thus the full spectrum of *enabling factors*, in their ideas. In fact, most of the presented concepts included all, or the majority, of the *ingredients*, therefore indicating that the GLM tool had supported participants to take a holistic approach.

As an example, one of the garment designers (A1), came up with an idea for a pay-per-use model for the elite suit (cf. blue post-it notes in the 'fast/shallow' quadrant, Figure 43). This take-back model included a form of vending machine, set up at pools on race-days, where athletes could pick up and return single-use, recyclable, racing suits. The participant included consideration of multiple parts of the garment's system in her idea: combining the *ingredient* of 'business model' with consideration of the *ingredients* of 'materials' (recyclable mono-materials) and 'design strategy' (a minimalist one-piece structure).

Besides enabling a holistic approach, this activity also demonstrated how the GLM tool enabled participants to work systematically to select and combine DfS strategies which were particularly appropriate for each garment being designed. By consulting the *recipes* (which sit embedded within the same framework as the one used to conduct the diagnosis), the participants were able to link insights from this activity regarding *what* aspects needed to change, with *how* they might approach this in practice. This was demonstrated through the workshop-outcomes and participants' communication of these ideas. For example, in the case of the take-back model for the elite suit (cf. above paragraph): the various *ingredients* had been specifically selected and adjusted to follow the GLM *recipe* in the 'fast/shallow' GLM quadrant. During the feedback-session, one participant described this ability of the GLM tool in a nutshell: *"rather than just making lots of suggestions to what you should think about, this is a tool which will really help and guide your thought-process [...] and then suggest the things you can do to improve it"* (M1).

Furthermore, participants' presentations and descriptions of their process in the feedback-session showed how using the GLM in combination with the instructions to either 'Stay' or 'Go' to a different quadrant (to follow a different *recipe*) had enabled them to work systematically and provided *"a framework to stay on track"* (A1)

As swimwear generally has a short life expectancy, it has only allowed for testing the 'fast' half of the GLM. The range of garments presented in the next study will include garments in the 'slow' GLM half to test a broader spectrum of the tool.

7.2. Study 4a: Diagnosing sustainability and identifying opportunities for improvement - Rohan

This study was the second of two to test the GLM as a tool for supporting designers to diagnose the sustainability of their current practice and identify relevant opportunities for improving this. The activities in this study were almost identical to Study 3a, but in this study, the GLM was tested with a different brand whose range allowed for testing the full spectrum of the GLM from ‘slow’ to ‘fast’. This brand was Rohan Designs Ltd., a UK-based supplier of outdoor and travel clothing, equipment, and footwear. Since its foundation in 1972, design for durability has been part of Rohan’s “DNA” (Rohan, 2022, p.2).

7.2.1. Study design

As mentioned, the design of this study was almost identical to the previous study (3a); conducted as a combination of a group session (Krueger & Casey, 2000), and a design workshop (Hannington & Martin, 2012). It was also structured into the two same activities: 1) ‘Diagnosis’, and 2) ‘Discovering opportunities’ as described on p.177.

The GLM tool was made available on a laptop that all participants could see and reach. Like Study 3a, they were instructed to either ‘Stay’ in the GLM quadrant, to redesign the product in its current placement, following the *recipe* within that particular GLM quadrant, or ‘Go’ to a slower and/or deeper quadrant with a different *recipe*. To support this approach, the participants were handed small, printed versions of the GLM framework, in which participants were encouraged to sketch and note ideas, and a summary of the instructions to either ‘Stay’ or ‘Go’.

At the end of the sessions, the participants were invited to discuss and give feedback on their experience of using the GLM tool. Due to time constraints, this session was less extensive than the equivalent session in Study 3a.

Participants

The six participants in this study were mainly recruited from Rohan’s Design and Innovation Team. They represented a variety of backgrounds and different layers of the company including a Corporate Social Responsibility Manager, a Technical Manager, and apparel designers. The participants’ names were anonymised for analysis and given ID codes as can be seen in Table 10.

Table 10. Study 4a Participant ID

ID	Field of experience
M1	Design Manager
M2	Corporate Social Responsibility Manager
T	Technical Manager
D1	Apparel Designer
D2	Apparel Designer
D3	Apparel Designer

Data collection and setting

The study took place at Rohan’s headquarters in the UK. It used an almost identical setup to Study 3a: a large whiteboard for the GLM framework to be displayed and filled in by participants, as well as a laptop connected to a large screen, for participants to interact with the GLM tool during the workshop. The session took place in Rohan's ‘display-room’ where most of the company’s garment range was on display, as pictured in Figure 44. This was beneficial for the study, as it helped focus the conversation on the garments and enabled participants to remember and explain garment characteristics by holding up the actual product. The session was audio, photo and video recorded. All participants had received and signed participant information sheets and consent forms prior to the study. This study was approved by the RCA ethics committee.

Analysis

This study used the same methods of analysis as Study 3a: a combination of Thematic Analysis and using the GLM framework for visual analysis and mapping, as reported on p. 171.

Figure 44. Study 4a setting: Display room with Rohan’s garment products

7.2.2. Findings

Activity 1 - Diagnosis

The first task in this study was to map Rohan's garments in the GLM. The participants took turns to pick a product to insert in the framework, until the group agreed that they had reached a good representation of the company's range. The participants discussed each garment's placement carefully before finalising the position. All the participants were keen to contribute, and seemed to intuitively understand the GLM framework, despite never having seen it before.

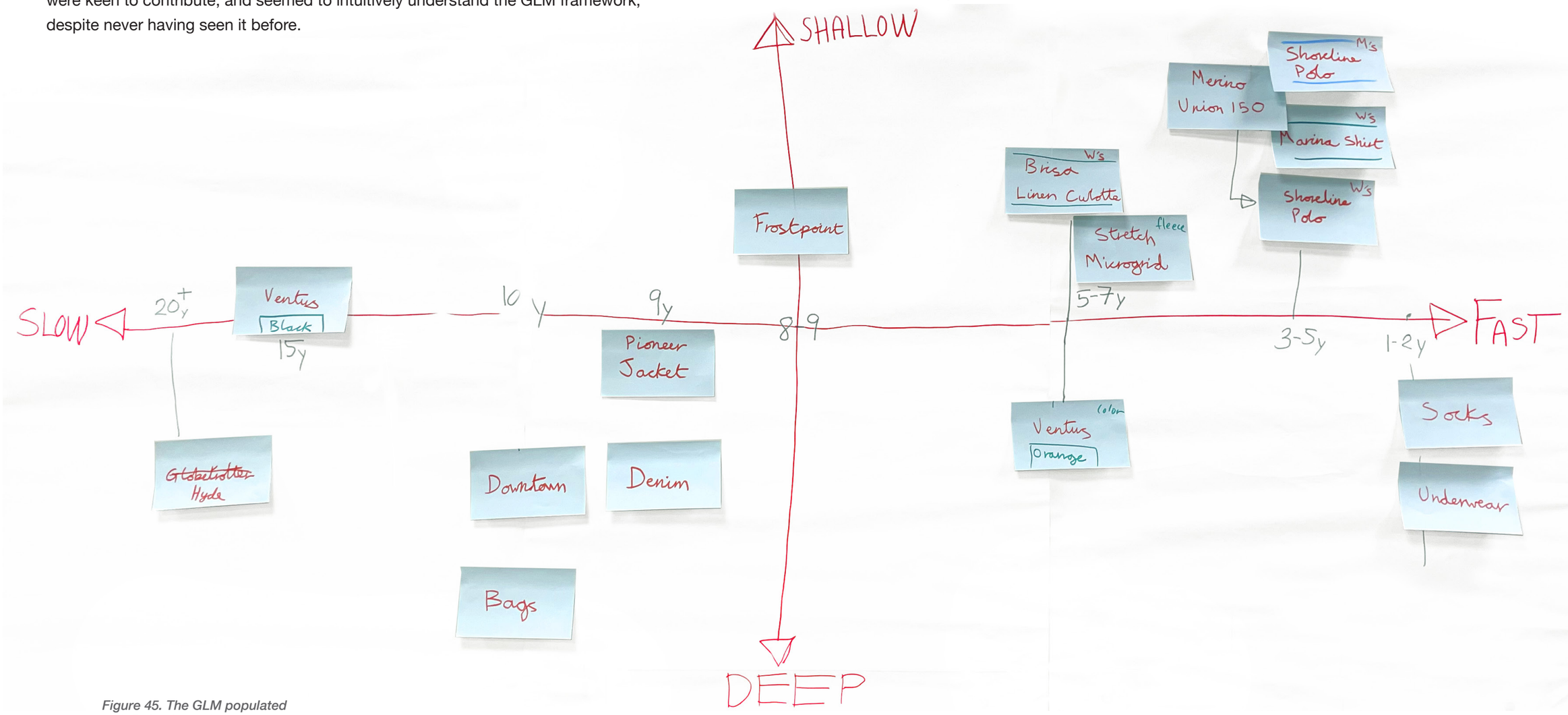
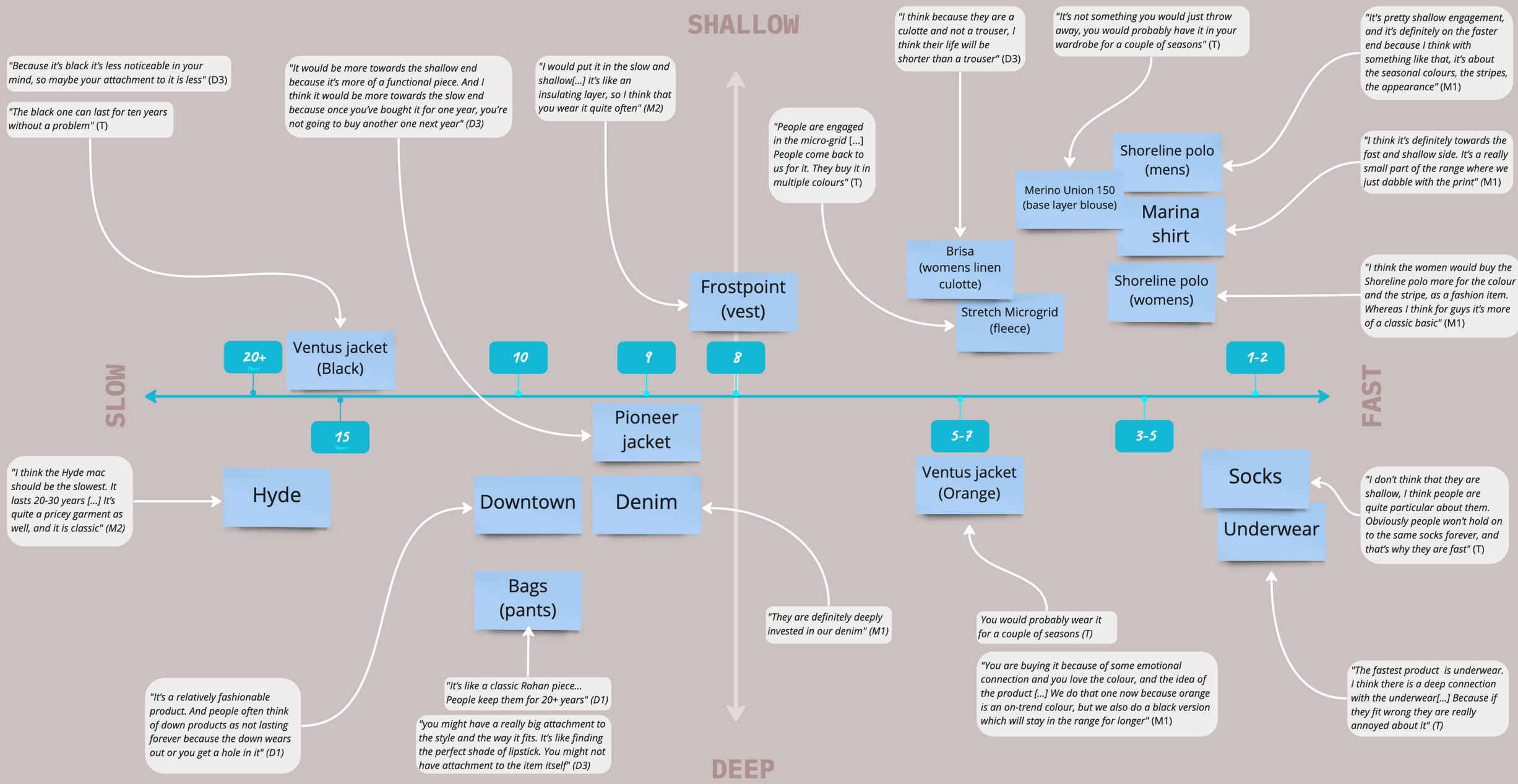


Figure 45. The GLM populated with Rohan's products

As the GLM was filled in, a diagonal pattern from the bottom left to the top-right began to form (Figure 45). This pattern was very similar to those which emerged in previous exercises mapping garments in the GLM: Studies 1 (Figure 16, p.119) , 2 (Figure 25, p.130) and 3a (Figure 37, p.181), which confirms that most of garments tend to be either 'slow/deep', or 'fast/shallow'. As also seen in the other studies, a few products did not follow this pattern. Once the placement of the garments in the GLM had been adjusted by the group, and a timeline had been established from slowest to the fastest garment use phase pace, a time spectrum emerged, spanning from a minimum of 1-2 years up to 20+ years.

During the mapping process, participants were encouraged to explain the reason for each of the garment-placements in GLM. A selection of quotes was drawn from the transcript of this video-recorded session, and these can be seen annotated in Figure 46 on the following page.

Figure 46. Visualisation of GLM populated by participants, annotated with reasons for garment placements



The ‘slowest’ garment in the GLM map was the ‘Hyde’ mac, a full-length, light-weight waterproof polyester coat, with an estimated life expectancy of at least twenty years. This impressive estimate was based on the coat’s versatility: *“people wear it everywhere”* (D1). As well as the fact that “*it is a classic”* (M2).

The ‘fastest’ garment types were underwear and socks, in sharp competition with the ‘Marina’ shirt. The ‘Marina’, a light printed shirt, is one of the rare fashion-focused products in Rohan’s range where they *“dabble with the print, compared to the technical side of things”* (M1). The team expected its use phase to end due to changing fashion and the user tiring of it. In contrast, the fast pace of socks and underwear was attributed to high-frequency use.

The product placed at the ‘deepest’ part of the GLM was the multi-functional outdoor ‘Bags’ trousers. These trousers, first introduced in 1982 (Rohan, 2022), hold a special place in the company’s range. According to participants, the ‘Bags’ have a *“cult following”* by customers: *“the Bags are like the original product. And in terms of design, we can’t touch it”* (M1).

One product was particularly tricky for the participants to place in the GLM: The ‘Ventus’ waterproof jacket, which is one of the most advanced and expensive items in the range (£300). The jacket comes in two colours, orange and black, and it was exactly the colour which made its positioning in the GLM tricky. The Design Manager described the difference between the two colours: *“we do the orange one now because it is an on-trend colour, but we also do a black version which will stay in the range for longer”* (M1). The participants saw a clear difference in depth of user engagement between these colours: “*people will be more engaged in that colour* [orange] *because they are buying it because they love that colour”* (T). In comparison they said about the black that: “*it’s less noticeable in your mind, so maybe your attachment to it is less* (D3).

Secondly, the length of the use phase was entirely different dependent on the jacket’s colour. The black jacket was expected to be used for up to fifteen years. In comparison, the orange jacket was expected to be used for a maximum of five years. Orange was seen as a trend-dependent colour, which might not age well to keep its brightness over time. After a lengthy discussion, the team ended up splitting the placement of the jacket so that the black version was placed in the ‘shallow/slow’ GLM quadrant, and the orange version in the ‘deep/fast’ quadrant (cf. Figure 46).

Identifying current discrepancies between design and use

The first reaction from participants to the map which emerged from the exercise was surprise. The Design Manager pointed to the ‘fast/shallow’ quadrant and said: “*it’s a little bit of a pack there, isn’t it”* (M1). Another participant responded: “*I’m surprised that we have more in the shallow/fast than in the slow section”* (D3). They were surprised with the number of garments in the ‘fast/shallow’ quadrant, as durability is “*one of the core principles of the brand”* (M1). Secondly, they all agreed that there seemed to be a clear relationship between those products that customers were deeply engaged with, and the expected use phase length. Finally, the participants also noted the tendency that*: “we’ve got the cheaper products on the fast end, and the more expensive ones on the other end, so you’re kind of paying for that extra time with it”* (M2).

At this point, the participants were tasked with selecting four particularly “unsustainable” products; products with particularly strong discrepancies between the way they currently are designed, produced, and sold, and how/for how long the garments are expected to be used by consumers. The participants chose three products:

1) The orange ‘Ventus’ jacket
2) ‘Denim’ jeans
3) the ‘Microgrid’ fleece jacket

The reasons behind why the participants saw these garments as having particularly strong discrepancies between a) how/for how long they are used, and b) how they currently are designed, produced, and sold, are visible as quotes in Figure 47:

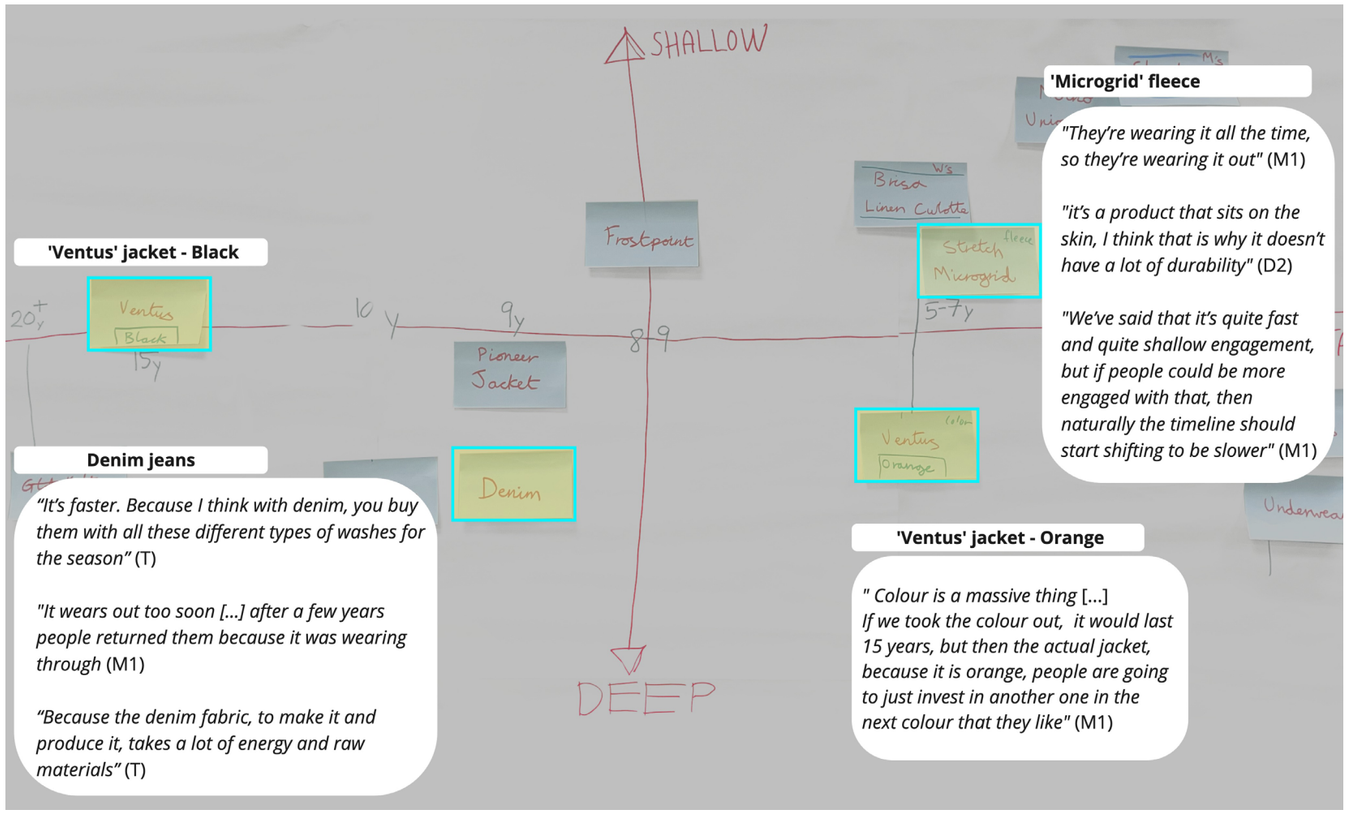


Figure 47. Use/design discrepancies described by participants

The selected “unsustainable” products were either products that wear out prematurely, or products that are used less than they have potential for.

The first selected product, ‘Denim’ (jeans), was seen as unsustainable due to both reasons: firstly, because of changing style and trends: *“people buy them with all these different types of washes for the season”* (T). Secondly, because the denim *“wears out too soon”* (M1). The participants saw the denim jeans as particularly unsustainable because of the resource-intensive manufacturing methods and materials it takes to make them. They felt this could not be justified by the relatively short time it is expected to be used for.

The ‘Microgrid’ fleece was the type of product that wears out prematurely. As one participant explained about users: "*they’re wearing it all the time, so they’re wearing it out*" (M1). One participant said that "*it’s a product that sits on the skin, I think that is why it doesn’t have a lot of durability*" (D2), to which another participant agreed and added: "*washing is a big thing which degrades the product*" (T).

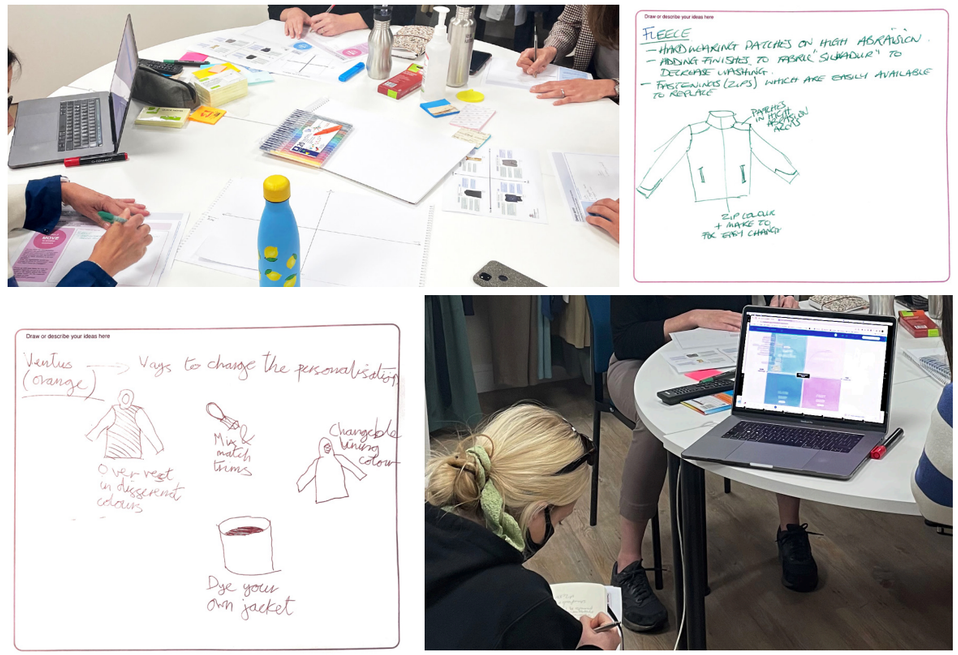
The much-debated ‘Ventus’ jacket, specifically the orange version was also chosen as particularly unsustainable. Participants explained that *“orange is an on-trend colour”* (M1) which is vulnerable to changing fashion trends. Compared to the 15-year use phase of the black version, the maximum 5-year use phase of the orange version was seen as out of proportion with the huge amount of resources, chemicals and labour that go into producing this jacket. Participants pointed out that both the orange and the black version are physically identical, but as one participant explained: *“if we took the colour out, it would last 15 years”* (M1).

Activity 2 - Discovering opportunities to improve

In this session, the participants were tasked with coming up with ideas for sustainable redesigns of the identified “unsustainable” garments (the orange ‘Ventus’ jacket, the denim jeans and the ‘Microgrid’ fleece jacket). During the idea-generation session, the participants took turns to click through the guidance in the GLM tool, taking notes from the *recipes*, using it as support and inspiration. Images from this process can be seen in Figure 48.

After 20 minutes of individual sketching, the participants discussed their ideas with the group. They were energetic and had many ideas. When describing their concepts, they would often structure their presentation according to whether they had chosen the option to either ‘Stay’ or ‘Go’ (cf. p.196), often beginning with ‘Stay’ and then describing concepts where they had used the ‘Go’-approach to move to another GLM quadrant and follow another *recipe*.

Figure 48. Participants sketching new sustainable concepts supported by the GLM



The workshop outcomes were analysed through Thematic Analysis (Braun & Clarke, 2006) complemented by visual mapping (Hannington & Martin, 2012). The concept-outcomes are mapped and displayed in Figure 49, according to whether they were a result of the ‘Stay’ or ‘Go’ approach. The original “unsustainable” garments (the ‘Ventus’ jacket, the ‘Microgrid’ fleece and the ‘Denim’ jeans) are shown in white squares, and the concept ideas on coloured post-it notes. Figure 49 demonstrates that the participants had used both approaches of ‘Stay’ and ‘Go’ to generate concepts. For concepts where the approach of ‘Go’ had been used, it was always the intention to move them towards the ‘slow’ GLM half, and most frequently to the ‘slow/deep’ quadrant.

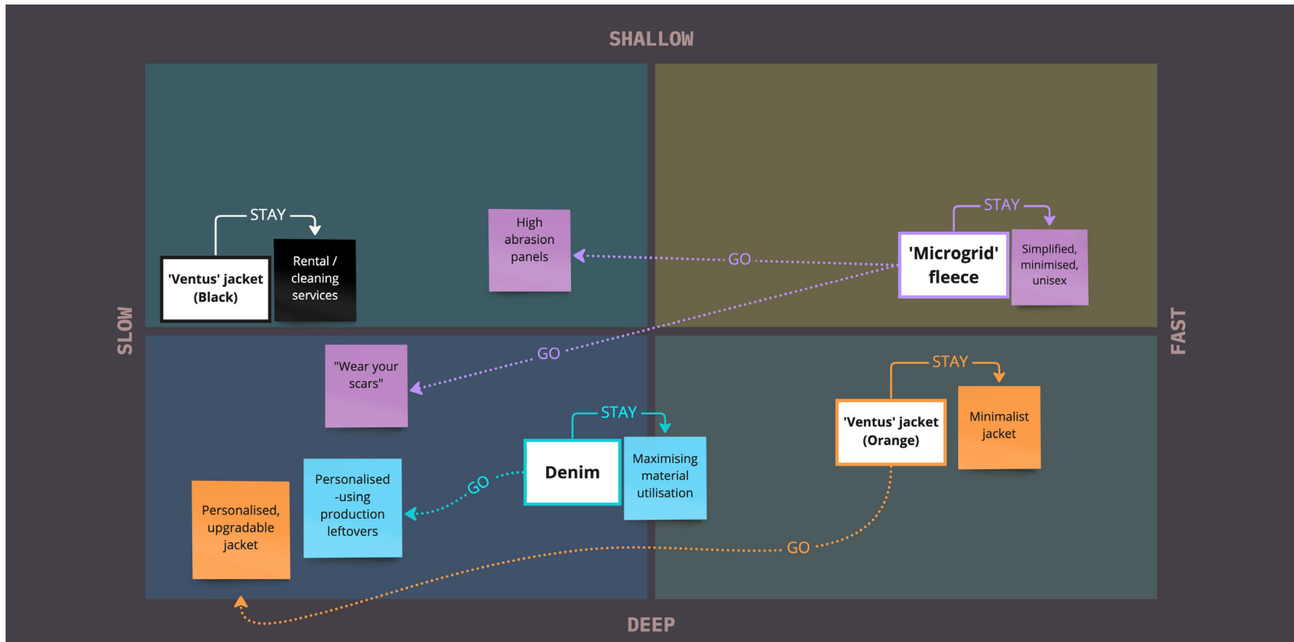
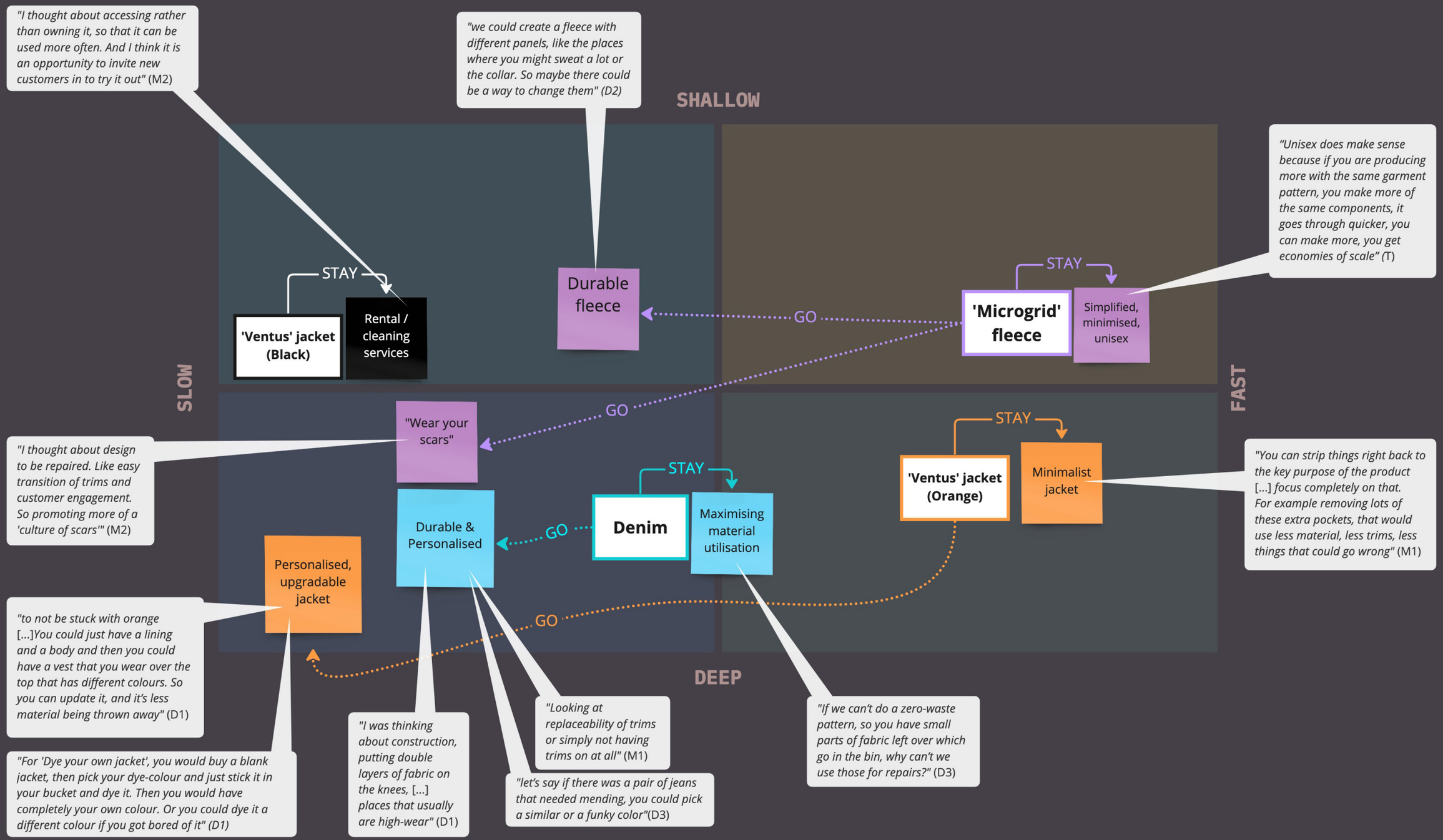


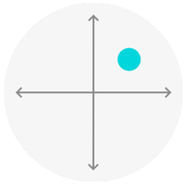
Figure 49. *Concepts generated from Study 4a, Activity 2, mapped in the GLM*

To capture salient points from participants' presentations, a set of quotes were selected from the transcript and mapped onto each concept as seen in here Figure 50.

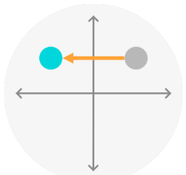
***Figure 50.** GLM annotated with quotes from participant resentations*



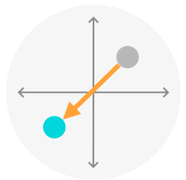
The ‘Microgrid’ fleece was identified as one of the three particularly “unsustainable” garments from Rohan’s range due to its lack of durability. Specifically, its lack of resilience to users wearing it frequently and close to the skin. However, one participant also thought that the short use phase could be caused by shallow levels of user engagement with the jacket.



In response to these issues, some participants had taken the approach of ‘Stay’ to come up with a more sustainable garment in the ‘fast/shallow’ quadrant. Here, they had developed ideas for minimising the number of components of the fleece, as well as simplifying the range by only producing it as a unisex garment. One participant, a Technical Manager, explained that: *“unisex does make sense because if you are producing more with the same garment pattern, you make more of the same components, it goes through quicker, you can make more, you get economies of scale”* (T).

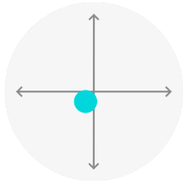


The participants had also come up with concepts which followed the approach of ‘Go’ to move to the ‘slow’ GLM half. For the ‘slow/shallow’ quadrant, participants focused on increasing the garment’s physical durability by constructing it with high abrasion, and interchangeable panels, in "*the places where you might sweat a lot or the collar*" (D2). Another mentioned factor for this fleece garment’s longevity was laundering. To address this issue, one participant proposed to *“put different finishes in, like antibacterial [...] So people don’t have to wash it as much*" (T). Another participant had been thinking about ways to wash clothes less and mentioned a new type of *“machine that sterilises [...] like an antibacterial steamer* " (D2).

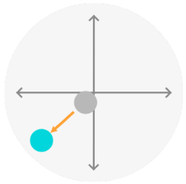


Another set of ideas concerned with designing the fleece for the ‘slow/deep’ GLM quadrant, also focused on physical durability, but employed the DfS strategy ‘Design for repair’ to deepen consumer engagement. For example, through: *“easy transition of trims and customer engagement. So promoting more of a ‘culture of scars’ - promoting the well-worn and repaired look*" (M2).

The denim jeans were deemed “unsustainable” because of their short expected use phase, due to the garment’s reliance on changing trends, but also because of their lack of physical durability.

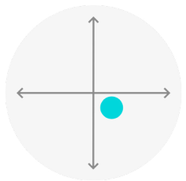


To address these issues, participants first presented concept-ideas which had used the ‘Stay’ approach, to stay in its position close to the middle of the GLM. One participant suggested changing the raw materials and *“looking at organic hemp, recycled fabrics [...] mono materials* (M2). Another participant had ideas for zero-waste pattern cutting to *“reduce the wastage of materials”* (T). Building on this idea, another participant suggested that *“if we can’t do a zero-waste pattern, and we have small parts of fabric left over which go in the bin, why can’t we use those for repairs?”* (D3).

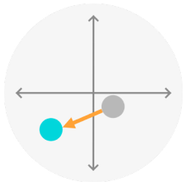


The participants also presented concepts where the approach of ‘Go’ had been used to move the denim jeans to the ‘slow/deep’ quadrant. These concepts focused on physical durability through more durable materials and construction, for example by "*putting double layers of fabric on the knees, or maybe extra layers like a laminate that would go over the places that we usually high wear*" (D1). One participant suggested that components from faulty goods could be used for repairs in the company’s on-site repair shop. She also saw this as a way to offer personalisation to encourage a deeper level of user engagement: "*if there was a pair of jeans that needed mending, you could pick a similar or a funky colour*" (D3).

The orange ‘Ventus’ jacket was seen as particularly unsustainable because of the discrepancy between the large amounts of resources required to produce it, and its relatively short use phase. It was particularly the “on-trend colour” of this garment, which was seen as causing the garment to be discarded before being worn out. This was highlighted by the fact that its black counterpart was estimated to stay in use for up to ten years longer.

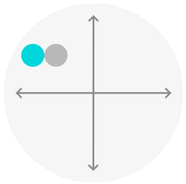


In this case using the approach of ‘Stay’ meant designing for the ‘fast/deep’ GLM quadrant. To do this, the participants had looked at options for simplifying the jacket. One participant suggested: "*strip things right back to the key purpose of the product [...] For example removing lots of these extra pockets. That would use less material, less trims, less things that could go wrong*" (M1). Another participant suggested on-demand production and customisation.



By taking the approach of ‘Go’, the participants had also come up with concepts for the ‘slow/deep’ GLM quadrant. Here, they had looked for *“ways to create an option for personalisation to not be stuck with orange”* (D1). For this, it was suggested to *“just have a lining and a body and then you could have a vest that you wear over the top that has different colours...So you can update it, and it’s less material being thrown away”* (D1).

Another participant suggested a more versatile, reversible jacket so that *“if the customer no longer wants to wear orange, they can flip the jacket around”* (D2). Other ideas for deeper consumer engagement included an idea for allowing consumers to *“pick your zip, pick your puller and bungee-cord”* (D2). As well as a ‘ye your own jacket’-concept, where consumers could *“buy a blank jacket, then pick your dye-colour and just stick it in your bucket and dye it”* (D1).



Finally, one participant suggested an idea for the black version of the ‘Ventus’ in the ‘slow/shallow’ GLM quadrant. She suggested: *“accessing rather than owning it, so that it can be used more often. And I think it is an opportunity to invite new customers in to try it out”* (M2). The other participants really liked this idea, and one added: *“If you are going on a big walk but you have no idea, you’re never going to buy a £300 jacket, you’re more likely to go to* [omitted] *and buy a crap one”* (M1). One participant commented that this would work particularly well for Rohan’s products because *“people trust that it lasts really well”* (D1).

Feedback and discussion the GLM tool

Due to time constraints, this part of the study was not as such an independent session. Instead, it was limited to a short discussion amongst participants. Below is a summary, based on the Thematic Analysis of audio recordings.

First, the participants discussed how using the GLM had supported them to identify key places that would be relevant for improving environmental sustainability of their current practice. For example, how and where emissions currently are produced, and where they might intervene to affect this: “*a key thing on all of this, which we can directly influence, is the customer. Because it’s one thing that keeps coming up: Quite a large part of the footprint of the products is after we’ve sold it.”* (M1)

Next, participants discussed how they were expecting the tool might be implemented in their current practice. One designer said: “*it would work with loads of the things I am designing now, which is good”* (D3). This was broadly agreed on amongst the participants, and they expressed wanting to work more with the GLM. The Design Manager said: “*I think a lot of the thinking we’ve got here will be applied in some of the design work* (M1). He also described how this session of using the GLM tool, had enabled them to *“talk about these ideas that we’ve come up with, and show how we’ve applied it, and give the rationale behind that”,* and that he believed this potentially could enable collaboration with other stakeholders in the company: “*these things that we’ve talked about, we can mention to other people to have an open conversation about this”* (M1).

7.2.3. Discussion of findings Study 4a

This study further tested the GLM tool’s ability to support designers to diagnose the sustainability of their current practice, and identify relevant routes for improving this, through two activities.

Activity 1: Diagnosis

The findings from this activity confirmed the GLM as support for garment designers to diagnose the sustainability of their own practice and pinpoint products which were particularly relevant to redesign for improved sustainability. Similar to Study 3a, the GLM enabled these activities in two main ways:

First, through the visual layout. Despite never having seen the framework before, and coming from a variety of professional backgrounds, the participants were easily able to understand and collaboratively map their current range in the GLM (cf. Figure 45, p.198).

Secondly, through the tools' framework-structure which allowed participants to map their company's range in relation to the two *primary factors*, which comprise the GLM axes. This activity (Activity 1) prompted participants to discuss their range in relation to these *factors*, using wording from the GLM, to reason each garment's placement in the GLM framework, as shown in Figure 46 (p.200). This is particularly useful for DfS, as, as established in Section 5.5., consideration of the two *primary factors should* guide decision-making in a DfS process, for a designer's efforts to have the optimal, positive impact on sustainability.

Additionally, by providing a central framework for the team to visually "record" their range in relation to the *primary factors*, the GLM was able to support the team to identify discrepancies between how/for how long the garments in their range are used, and the way they currently are designed, produced, and sold. Ultimately, this enabled participants to pinpoint products which were particularly unsustainable, and thus particularly relevant to redesign to improve sustainability of the company's range. An example of one of these "unsustainable" garments was the orange 'Ventus' jacket, whose durable physical features and emissions-heavy production was at odds with its lack of emotional durability. Participants described the process of this mapping process as a *"powerful eye-opener"* (M1), enabling them to grasp the importance of designing with suitable strategies for each garment and its context of use**.** The visual "recording" of this activity in the GLM (Figure 47, p.203), enabled participants to establish a shared vision for how sustainability of the company's range might be improved.

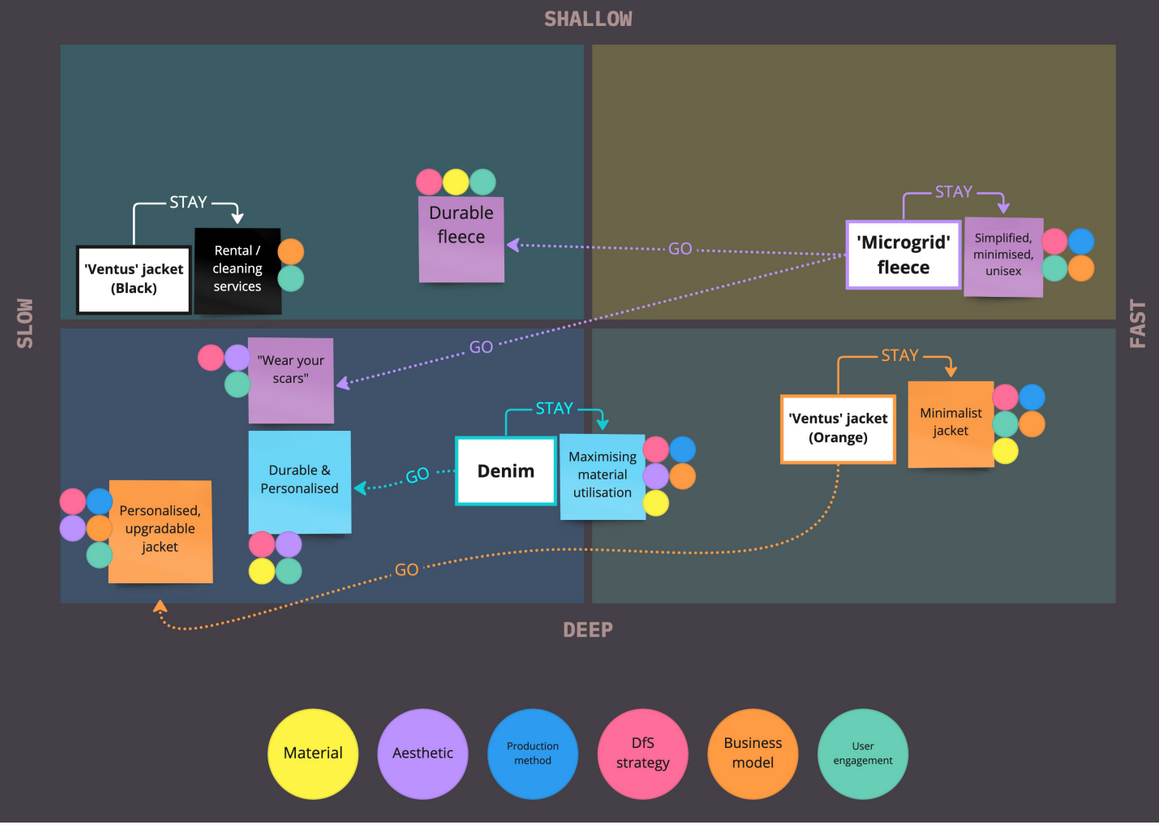
Activity 2: Discovering opportunities to improve

This second activity confirmed the GLM tool as useful support for designers to take a holistic, yet systematic approach to select relevant DfS strategies to come up with concept-ideas for new sustainable garments.

The GLM aims to support a holistic approach through the GLM *recipes*, whose *ingredients* prompt consideration of the full spectrum of *enabling factors*. The ability to support a holistic approach was thus demonstrated through how participants had incorporated the *ingredients* in their ideas. To evidence this, the generated concepts were colour-coded according to the GLM *ingredients* they apply, based on selected quotes from participants' concept-presentations, in Figure 51on the right. A detailed version of this map with participants' quotes, is presented in the appendix, p.80.

As Figure 51 illustrates, all six GLM *ingredients* had been considered during this second activity, and almost all *ingredients* had been considered in each concept. Thus, this activity confirmed the GLM tool as support for designers to take a holistic approach to DfS. Besides enabling a holistic approach, this activity also demonstrated how the GLM tool enabled participants to work systematically to select and combine DfS strategies

Figure 51. Generated concepts colour-coded according to use of GLM ingredients, based on participants' presentations



which were particularly appropriate for each garment being designed. This is evident in the design-outcomes and the way participants presented these ideas.

For example, in the case of the 'Ventus' jacket-idea ('slow/deep' quadrant, Figure 51), it was clear how the participants had selected and adjusted the various aspects of their idea by following the relevant *recipes* for this garment's position in the GLM ('slow/deep'), to ensure all aspects contributed to a sustainable solution. For example, considerations of 'aesthetic', 'DfS strategy', 'user engagement' and 'business model' had been aligned to offer a garment which is able to stay in use, and be attractive for a long time, due to its ability to be personalised and upgraded to suit the users' changing needs and style.

Lastly, the study also validated the GLM as support for participants to communicate and discuss their ideas during the DfS process. The GLM served as a "common language" through which the participants, who came from different disciplines and layers of the company, could systematically discuss DfS decisions. The participants would frequently include prompts from the GLM in their discussions. For example, one participant commented that *"The fleece was quite **fast** and had **shallow engagement**, but if we could get people **more engaged** with that, then naturally, the timeline should start shifting to become **slower**"* (M1).

7.3. Chapter summary

At the beginning of this chapter, in Section 7.1.2., the findings from Chapters 4-6 were used as input for developing a new, interactive GLM tool, proposed in response to the identified gap in knowledge (cf. Section 2.6.), to support garment designers to take a holistic approach to DfS. Specifically, to enable them to: i) negotiate the multiple factors that affect garment sustainability, and ii) instrumentalise this knowledge to select, combine and employ appropriate DfS strategies for the particular garment and its use-context.

The GLM tool was tested through the two Studies 3a and 4a, which each comprised a workshop with a team of garment industry experts (3a with a global swimwear brand and 4a with outdoor brand Rohan). The findings from these studies validated the GLM tool as useful support for garment designers to diagnose the sustainability of their current practice by considering it in relation to the *primary factors* for DfS, and based on this activity, pin-point areas, or products, which were particularly relevant to redesign for sustainability.

The analysis of these discussions also revealed the new insight, that participants also saw potential for the GLM tool to support stakeholder collaboration across disciplines and company-levels, to empower efficient collaboration around DfS, and to potentially support a brand-wide sustainability strategy.

The creative outputs from Activity 2 in these studies demonstrated that the GLM tools' *recipes* had empowered designers to take a holistic approach to DfS. The participants had included consideration of the entire range of *enabling factors* (represented in the GLM *ingredients*), in the proposed garment-concepts.

Finally, these outcomes, and how they were discussed and presented, confirmed the GLM tool as support for participants to work systematically to select and combine DfS strategies which were particularly appropriate for each garment being designed.

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Chapter 8

The GLM tool & ‘Stay or Go’ method as support for effective Design for Sustainability

- Testing and confirming support in practice

In response to RQ4 (*How might considerations of the primary design factors be structured to guide decision-making processes to enable efficient, systems-aware Design for Sustainability?)*, the previous chapter (7) proposed the interactive Garment Life Matrix (GLM) tool. This tool was tested as support for designers to diagnose the sustainability of their current practice and identify relevant opportunities for improvement through Studies 3a and 4a.

To fully respond to RQ4, this chapter will test and validate the GLM tool as support for garment designers to take a holistic approach to effectively select and implement appropriate DfS strategies for each garment case. This research will be conducted through two action research studies: Study 3b and 4b. Initially, this chapter describes a Research through Design (RtD) process, conducted in preparation for Studies 3b and 4b, which developed the supplementary ‘Stay or Go’ method for using the GLM tool. This method was tested, along with the GLM tool, in Studies 3b and 4b.

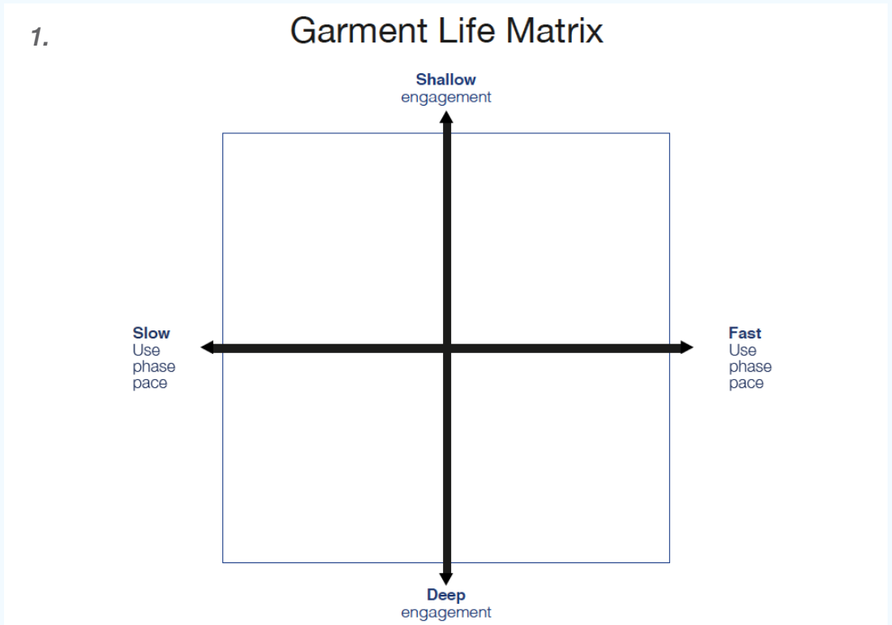
8.1. Preparing material for Studies 3b & 4b

Preparations for these studies constituted a Research through Design (RtD) (Frayling, 1993) approach of ideation and design, to develop support-material for participants during the two studies in this chapter. As these studies aimed to test the GLM tool as support for a designer's process without the researcher present, it was important to equip the designer-participant with sufficient instructions.

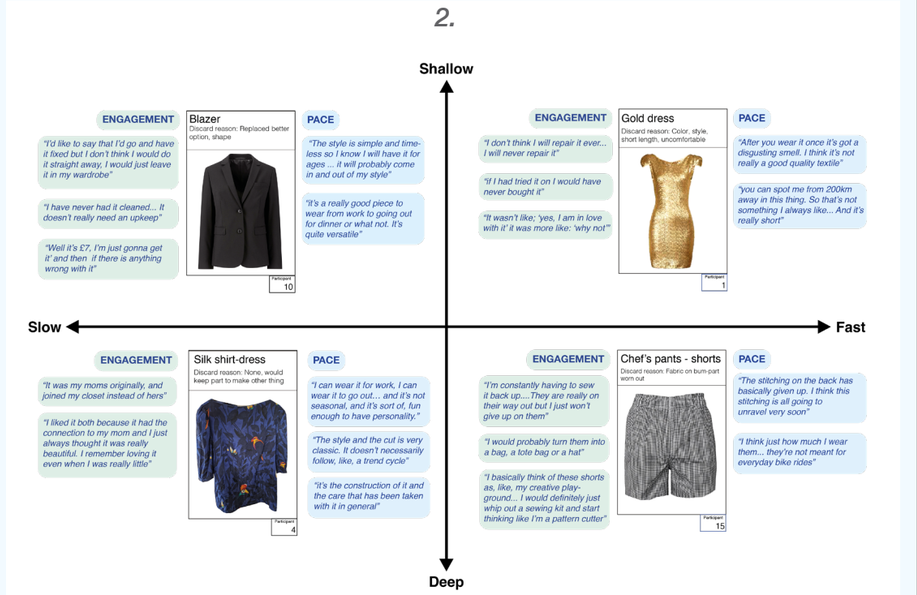
These instructions took the shape of a very simple compendium, shared with participants before the studies. The first three pages (seen in Figure 52 below) showed images of three graphics which the participant had seen during the previous study (3a or 4a), and a photo of the previous 'diagnosis' activity where they had mapped their company's range in the GLM, to remind them of the GLM's structure and logic.

Figure 52. Three first pages of Study 3b compendium to support participant's process. 1) Simple version of GLM, 2) Photo from mapping exercise, 3) GLM with archetype garments and supporting quotes.

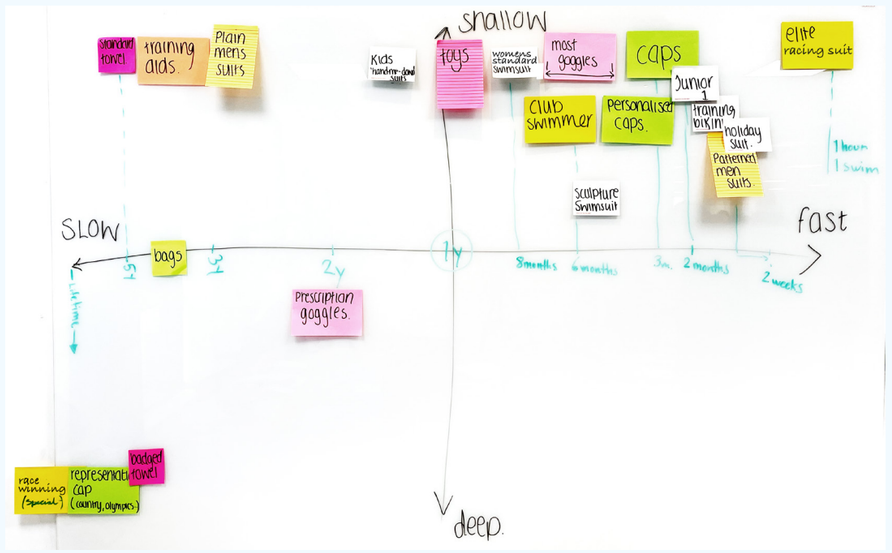
1.



2.



3.



The Stay or Go method

The last two pages of the compendium, pictured in Figure 53, contained worksheets with guidance for using the 'Stay or Go' method, intended to enable the participant to take a systematic approach to using the GLM tool, specifically, by breaking design activities down into smaller, manageable parts.

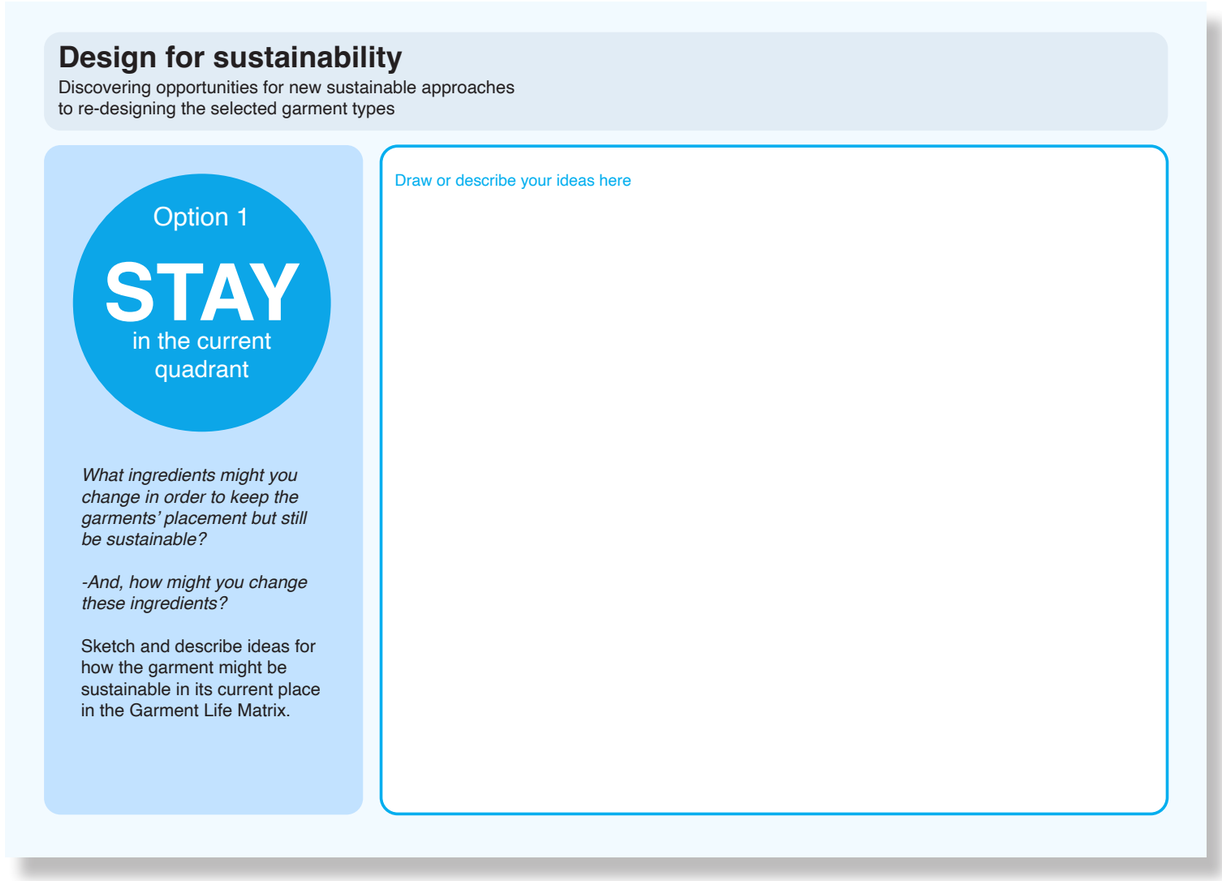


Figure 53. 'Stay or Go' method worksheets

The first ideas for the 'Stay or Go' method emerged during Study 3a and 4a, as a result of attempting to provide comprehensible instructions for designers to use the GLM tool. The 'Stay or Go' method consists of two options, or steps where designers can choose to either:

Stay in the current GLM quadrant in which the original existing product has been positioned (during the mapping exercise in Study 3a), and then redesigning it for greater sustainability by following the *recipe* in that particular GLM quadrant. This means finding ways to adjust the *ingredients* of the current garment to be more suitable for this GLM quadrant

Or,

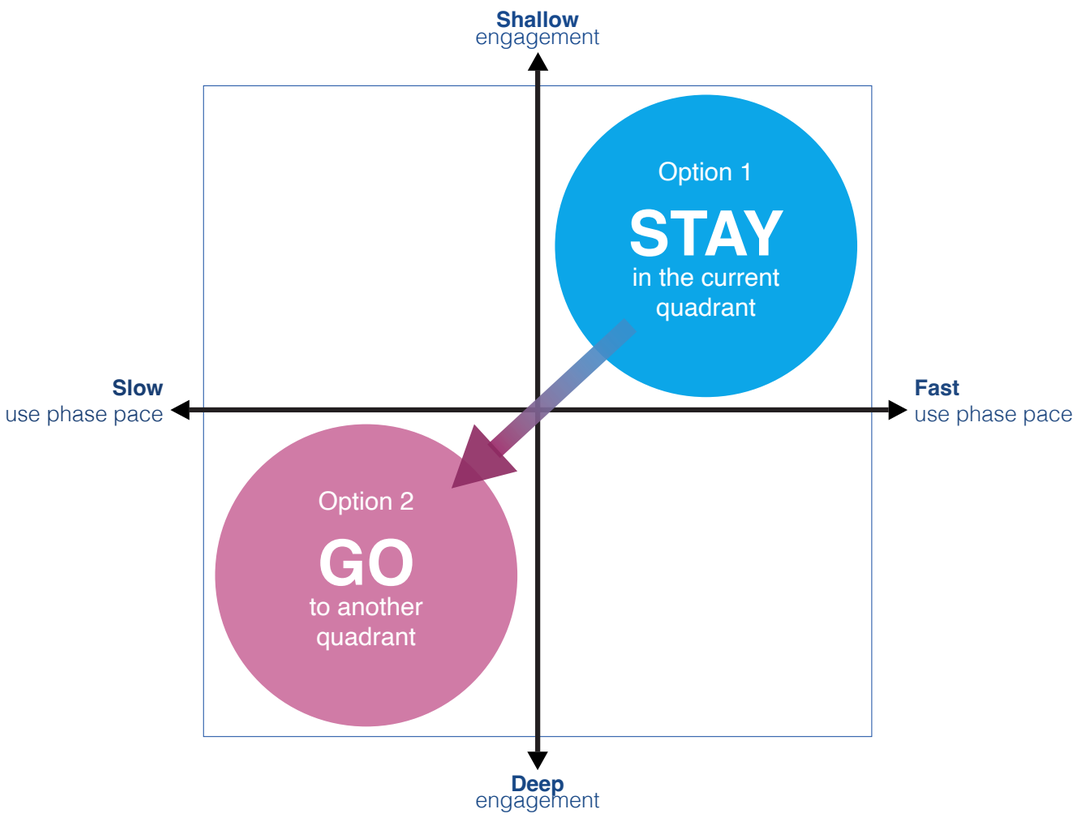
Go to a slower and/or deeper quadrant of the GLM. This option requires the designer to fundamentally change the product's *ingredients* according to the *recipe* of the new GLM quadrant.

It is intended that the 'Stay or Go' method will lead designers to change the design characteristics of the garment to enable a slower pace and/or a deeper level of user engagement. However, the method does not dictate that designers always must take the approach of 'Go' to move from 'fast' to 'slow'; it also provides the option to use the approach of 'Stay'.

It is possible for products with a fast use phase pace to be sustainable, but as established in the literature review (Section 2.4) this is difficult to achieve. The sustainability of a 'fast' garment is entirely contingent on the ability to be, if not directly, then quickly and using minimal resources, used as part of another product assemblage or as a nutrient for the wider system. This requires extremely low-impact

production processes and demands product properties, such as the ability to easily be disassembled/disintegrated. Otherwise, the more sustainable choice for the designer will likely be to aim for extending the garment's use-phase. In line with this logic, the *recipes* in the 'fast' half of the GLM are significantly stricter*,* i.e., they only "allow" for use of biodegradable materials, or mono materials which can be recycled with minimal emissions and resources. In contrast, a much wider range of materials are prompted as options in the 'slow' GLM *recipes*. The reason for this is that a significantly prolonged product life expectancy sometimes can outweigh the effects of using resource-heavy materials (although this is never ideal regardless of how long the product is used for). In this way, the proposed method does not discriminate between 'Stay' or 'Go', but the content of the GLM's *recipes* will likely urge designers to 'Go' towards the 'slow' GLM half, simply because the *recipes* in this part of the GLM will be easier to follow. This expected movement is illustrated in Figure 54 below. One cannot help but observe that it is the exact opposite direction to the approach on which the entire culture of the current fashion industry is based.

Figure 54. The assumed natural movement across the GLM from 'fast/shallow' to 'slow/deep' when using the 'Stay' or 'Go' method



The effect of using this supplementary method in combination with the GLM tool was tested in Study 3b and 4b as reported in the following sections.

8.2. Study 3b: Testing the Garment Life Matrix as DfS support
- Swimwear brand

8.2.1. Study design

To test and validate the GLM tool and the 'Stay or Go' method as support for DfS, it was given to a designer from a global swimwear brand to guide her process of redesigning a garment from the company's range to be more sustainable. This study was a continuation of Study 3a, which was conducted with the same brand. This study focused on the redesign of two specific products: a pair of swimming goggles and a standard women's swimsuit. These two products had previously (in study 3a) been identified as particularly unsustainable, and thus relevant products to redesign for sustainability, from the company's current range.

The designer was tasked with developing these products to an early prototype stage, as this was seen as sufficient for the purpose of testing the GLM tool and method. Further development would require a longer time frame than this project allowed for. This study consisted of three sessions, spread over three months to allow time for the designer to work on the concepts between sessions.

Participants

This study only had one participant: an Apparel Designer/Design Engineer from the swimwear brand's innovation team. This participant had also taken part in Study 3a (Chapter 7) and was therefore familiar with the GLM and the 'Stay or Go' method and using it as support for diagnosing sustainability and discovering opportunities to improve this. This participant is anonymised and referred to as P1 in findings.

Methods of data collection and analysis

Due to the ongoing Covid-19 pandemic, all phases of this study were conducted as 'Zoom' calls, which were audio and video recorded. This study was intentionally more "hands off", compared to the previous ones, to test the GLM tool's usability without the constant presence of the researcher. The designer was briefed to record her process by simply plotting it into the GLM, recording movements across the matrix (or decisions to 'stay') and the reasoning for these decisions. During the study's sessions, the designer-participant produced a large number of hand-drawn and digital sketches, mood boards and physical prototypes, which were collected, analysed and reported in the findings. All

sessions were transcribed using ‘Panopto’, an online storage platform. This data was, once again, subjected to a mix of Thematic Analysis (Braun & Clarke, 2006) and visual mapping exercises to support and communicate the extraction of themes.

Study 3b activities

This study consisted of three sessions, as described below:

Project kick-off

The purpose of this session was to brief the designer and equip her to use the GLM tool to design for sustainability on her own. She was given access to the digital GLM tool via a hyperlink, and the set of worksheets (Figure 52-53) to support her process of working on her own. After an introduction of the worksheets and refreshing the designer’s memory of the GLM tool’s principles, the designer was briefed: To come up with at least ten early-stage ideas for redesigning the selected garments (goggles and swimsuit identified as particularly “unsustainable” in Study 3a). She was encouraged to utilise the ‘Stay or Go’ method and the GLM tool as support for her decision-making process, and to record this process by mapping it in the GLM.

Session 1: Presentation of initial DfS ideas

In this session, the participating designer presented the DfS-ideas she had generated. Next, the two of the most promising ideas were selected for further development. At the end of this session, she was invited to give feedback, responding to a few prompting questions, on her experience thus far with using the GLM tool and method, in order to assess whether these had served as useful DfS support.

Session 2: Presentation of final DfS concepts and prototypes

In this session, the designer presented her further developed concepts and prototypes, building on to the ideas from Session 1. At the end of this session, she was once again invited to provide feedback, responding to the same questions as in Session 1, on her experience of using the GLM tool and method.

8.2.2. Findings Study 3b

Project kick-off

As this session was a kick-off session, there are no outcomes to report, other than the designer’s initial reaction to the brief. She described feeling well-equipped for the design experiment. She said she expected the GLM tool to be *“super useful to control my thoughts and keep it organised”* (P1). Furthermore, she expressed understanding of the ‘Stay or Go’ method, describing how she would “*take one at the time, starting with ‘Stay’ and then ‘Go’”* (P1).

Session 1: First round of DfS concept-ideas

One month after project kick-off, the designer presented her first early-stage ideas. These were inspired by concepts developed during Study 3a, which presented ideas for redesigning a standard women’s swimsuit and swimming goggles to be sustainable. Due to time constraints, the participant chose to focus on redesigning the goggles. To present her ideas and process, she had made a slideshow. The images shown in this section are adapted from these slides. A few specific details have been omitted in accordance with intellectual property rights of the swimwear company.

The participant had kept the GLM tool at hand, and as per instruction recorded her process. She had marked the ‘fast/shallow’ position of the existing goggles (as first identified in Study 3a) in the GLM framework. This can be seen on the left in Figure 55 below.

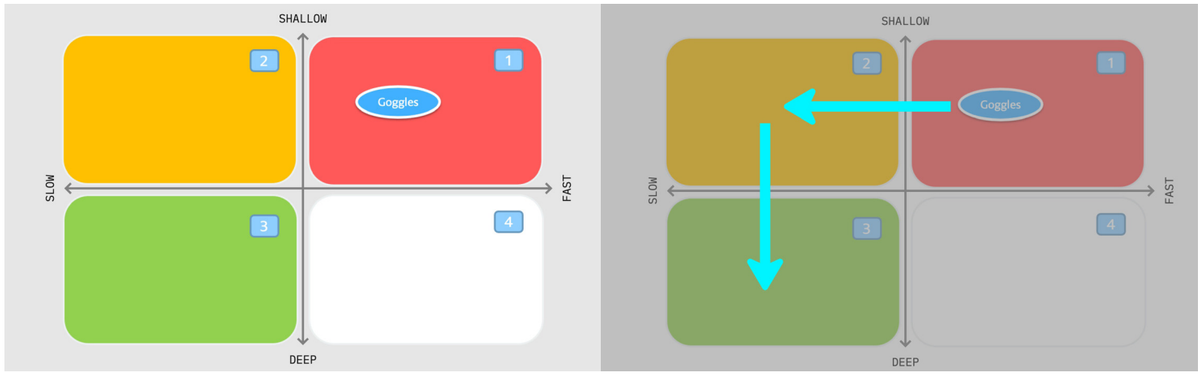
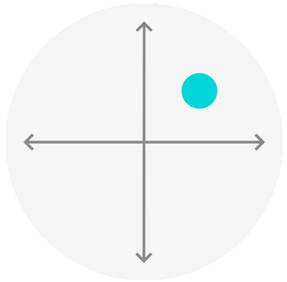


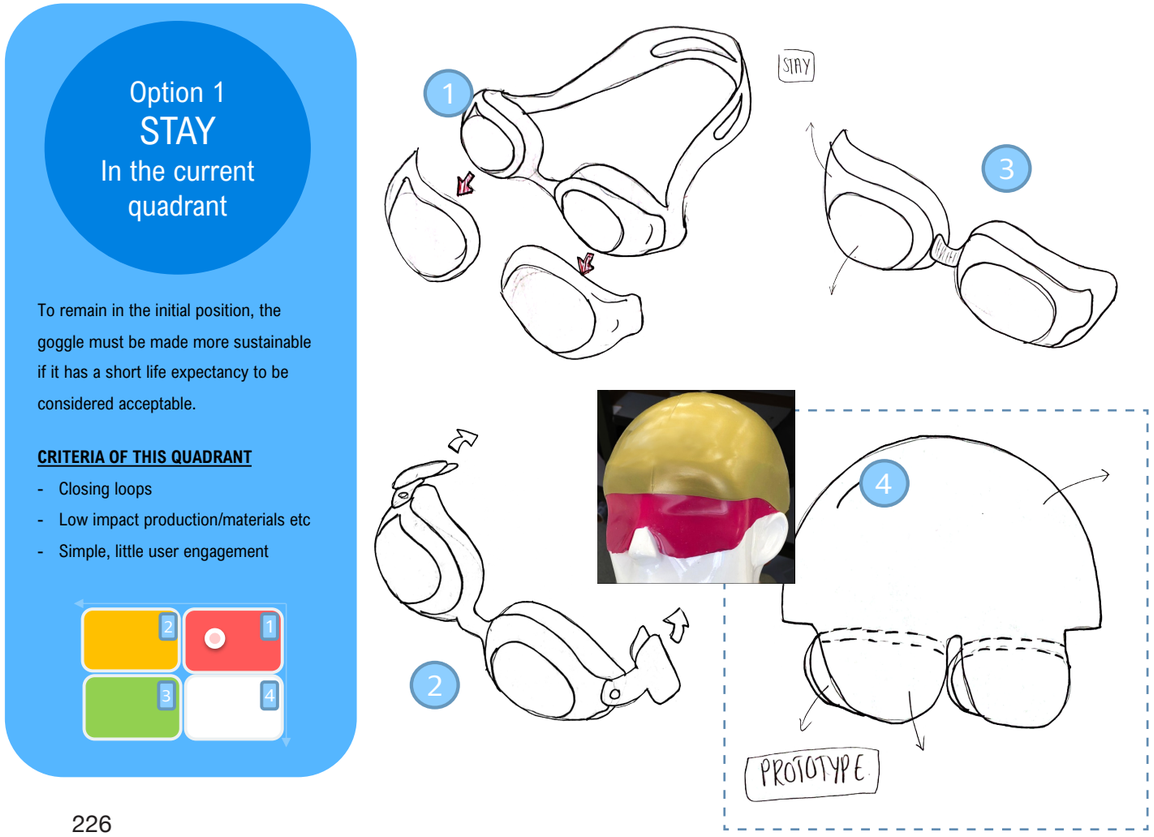
Figure 55. Left: Participants’ adaptation of the GLM framework, marked with goggles’ original placement in the ‘fast/shallow’ quadrant. Right: Participants’ usage of the ‘Stay or Go’ method



Ideas for a ‘Stay’ approach

First, the designer presented concept ideas that followed the ‘Stay’ approach, for which she had been following the GLM *recipe* in the ‘fast/shallow’ quadrant. Here, she had followed the guidance to use the DfS method of ‘Design for narrowing loops’. This meant she had focused on “*simplifying it, making it with less components and with simpler connections”* (P1). Essentially, stripping the goggles back to their basic functionality. About her process she explained: *“I started off with breaking the goggles into two parts [...] the gasket and strap, and I looked at the lenses”* (P1).

Figure 56. Images from participant’s presentation of ‘fast/shallow’ concepts

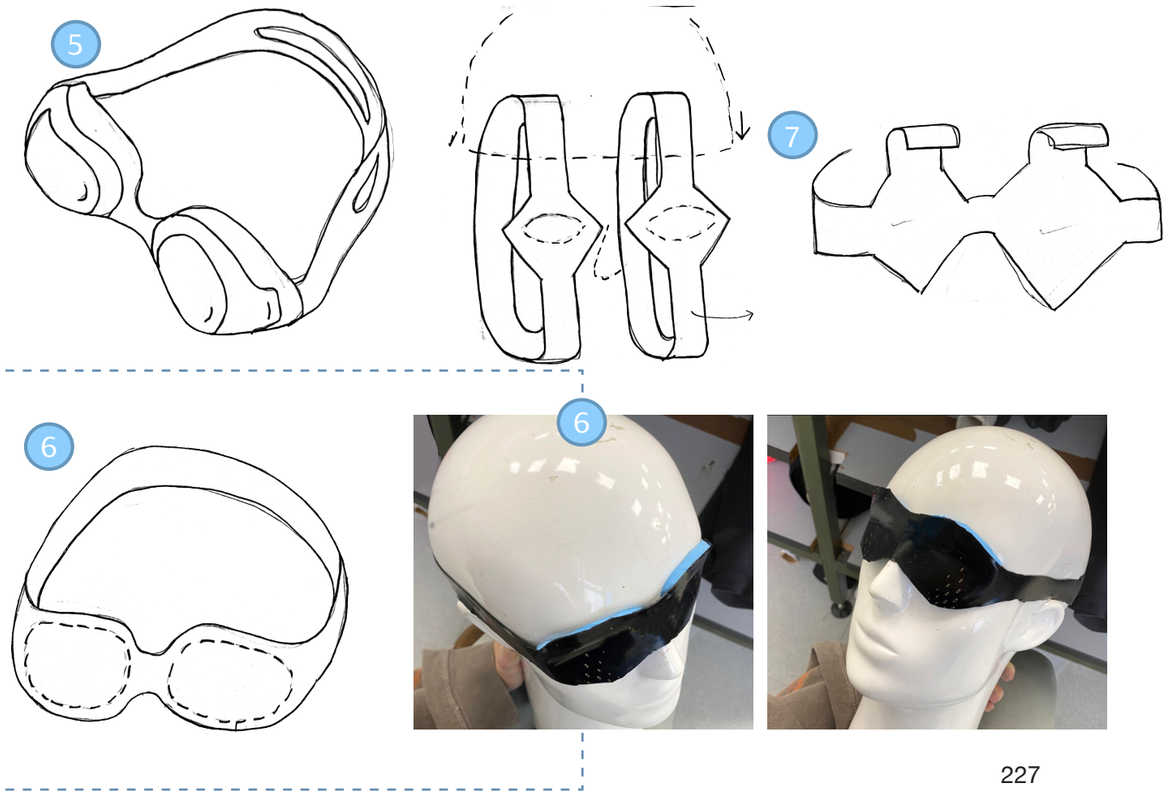


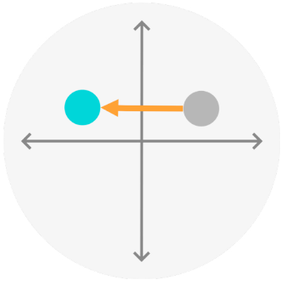
This resulted in ‘the Invisible Goggle’; a mono-material goggle, consisting of just two components. Sketches and simple prototypes of this google can be seen in Figure 56, no.5 and 6. She explained how this concept had sprung from wondering: “*is there a way that I could make this into just one part, which you can then pull over your head?”* (P1).

She came up with further iterations of this concept by considering the goggles’ structure and material in connection to the system in which the goggles sit. For example, she explained: *“if it was actually made from this material, it would make it really, really small for transportation, it would fold up tiny for the whole system of the goggle to work”* (P1).

She extended this idea to propose a multifunctional google, by considering “*how you could have the hat and the goggles all in one”* (P1). This, she thought, would reduce the total amount of products the consumer would need to buy. This idea can be seen as a sketch and prototype in Figure 56 marked as no.4.

Next, the participant switched from using the ‘Stay’ to using the ‘Go’ approach. This meant moving left across the GLM to the ‘slow/shallow’ quadrant.





Ideas for a ‘Go’ approach

Following the *recipe* in the ‘slow/shallow’ quadrant, the participant had focused on creating goggles that would last longer, simply because of their physical durability. Regarding durability, she described how the lenses easily get scratched, which often will cause the goggles to get discarded despite the other components still functioning perfectly. To address this issue, she looked at ways to protect the lenses. Once again, she decided to use the thin, stretchy material, which she imagined stretching over the lenses *“like a little cover [...] so they would be protected when they sit in the bag”* (P1). This idea is visualised in Figure 57, no.1.

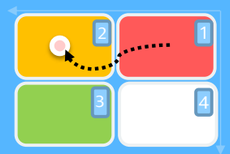
Figure 57. Images from participant’s presentation of ‘slow/shallow’ concepts

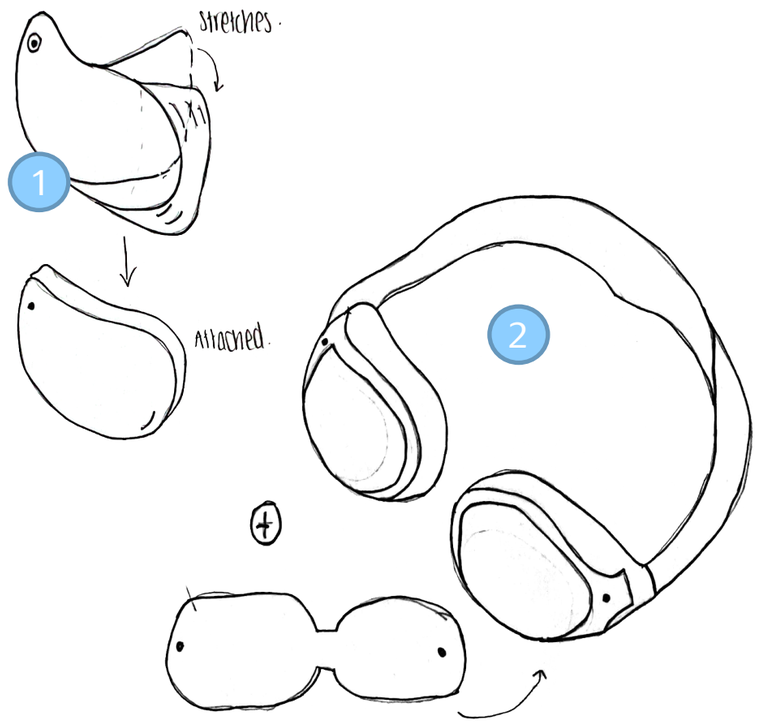
Option 2
MOVE LEFT
To the Orange quadrant

To move to this quadrant the goggle must be made to last longer. This could be through more durable products or subscriptions/sharing models etc.

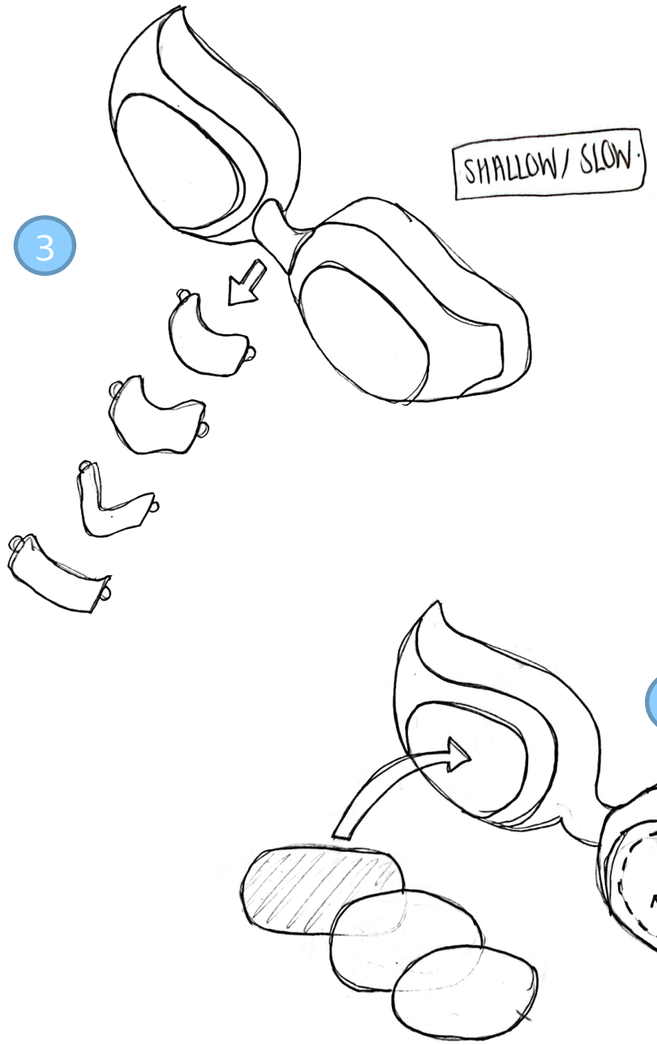
CRITERIA OF THIS QUADRANT

- Slow down the material loop
- Products have a long life expectancy
- Slow life cycle pace
- Durable products





She also thought more generally about designing replaceable parts *“looking at the bits that break, so the nosepiece and the lenses could be removable”* (P1). To enable replacements, she imagined a form of *“universal slot on the goggles for the nosepieces”,* as *“all of the goggles currently have completely different connectors”* (P1). Another issue which she focused on, was the tendency for goggles to quickly lose their anti-fog properties, which often leads to users discarding them. To make the goggles last longer, she suggested*: “You could have an anti-fog strip that you could put on the inside of the goggles, and when they run out, you could replace them at home”* (P1). The participants’ presentation of these ideas can be seen in Figure 57 below:

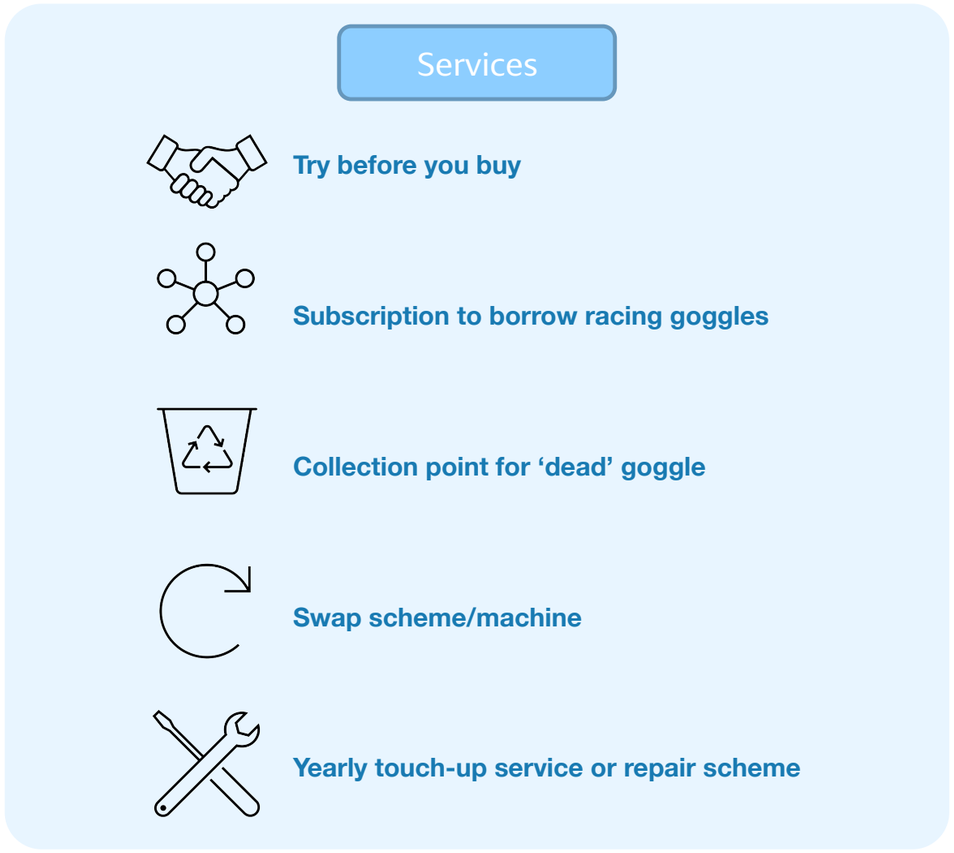


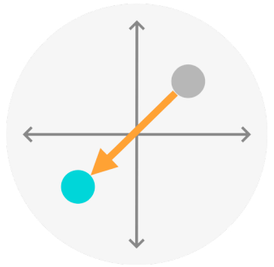
Furthermore, the ‘slow/shallow’ quadrant’s *recipe* had prompted the participant to explore new business models such as rental, swapping and subscription models (cf. Figure 58).

She thought about how profits could be generated from repeated sales of consumables for long-life goggles: “*you get a strip of six other anti-fog, peel stickers that you could use to replace the anti-fog when it runs out”* (P1). She proposed that this could be “*a subscription model where you would get sent another strip every month”* (P1).

She also thought about an access-based model, where users could rent high-quality, purpose-built goggles for races: *“instead of having to buy a whole other pair of racing goggles, you could pay a subscription for the year, and when you go to races, you could borrow a pair of goggles”* (P1). Finally, she thought of ways to have a take-back and/or swapping system for unwanted or broken goggles to be collected for reuse in new products. She imagined this take-back system would be enabled by her previous idea of the goggles having standardised, modular components.

Figure 58. Slide from participant’s presentation with sketches of ideas for ‘slow/shallow’ concepts





Next, still following the approach of ‘Go’, the participant moved downwards in the GLM to generate ideas for the ‘slow/deep’ quadrant.

The participant presented many loose ideas for this ‘slow/deep’ quadrant, but she was particularly fond of one idea: A modular, customisable goggle entitled the ‘Build Your Own Goggle’ (shown in Figure 59). Following the DfS strategy of ‘Design for emotional durability’, she suggested how a modular google-structure could be used to enhance user engagement and extend the use phase.

Specifically, she imagined that *“on the website or in the shop [...] people could select the shape and the colour of the nose bridge, the gasket, and the strap” (P1).* She expected that inviting users to configure their own goggles could create *“a massive connection between the person and the product [...] and that might make you want to keep it for longer”* (P1).

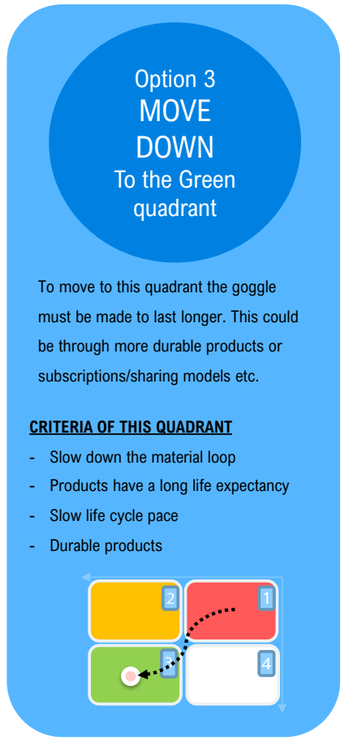
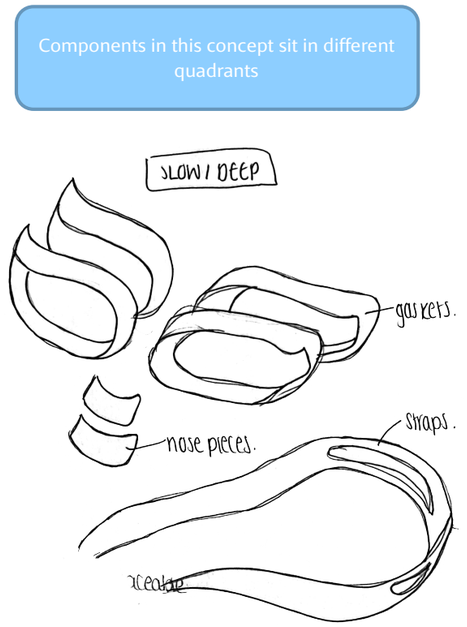


Figure 59. Participant’s presentation of ‘slow/deep’ concept: ‘Build Your Own Goggle’



Regarding personalisation, she also thought about custom-fitted parts to engage users in the customisation of their own goggles [* details omitted due to intellectual property agreement].

After the presentation, the participant and the researcher selected two concepts to develop further in the next session. Selection was partly based on the participant's motivation to work with these concepts, and on the estimated potential of each concept to impact on sustainability. I.e., concepts which had included consideration of multiple *ingredients* (*enabling factors*) and used a combination of approaches to develop potentially higher-level solutions were prioritised. The chosen concepts were the one-piece 'Invisible Goggle', and the modular 'Build Your Own Goggle'. An overview of *ingredients* used in each concept can be seen in Figure 65, p.244.

Session 1 concluded with a brief feedback-session in which the participant was invited to describe her experience of using the GLM tool and 'Stay or Go' method. Data from this session is combined with data from the Session 2 of this study and reported below on p.238.

Session 2: Final presentation of DfS concepts and prototypes

One month later, the last engagement of this study, Session 2, was conducted. In this session, the participant presented further developments of the selected ideas from Session 1, the 'Invisible Goggle' and the modular 'Build Your Own Goggle'. Once again, she had produced several sketches and prototypes, which she showed as a slideshow to present her ideas. The designer used the GLM *recipes* to structure her presentation of these concepts, going through the ideas *ingredient* by *ingredient*. This session is summarised below.

The One-piece Goggle

First, the designer presented a new iteration of the 'Invisible Goggle' from Session 1 (p.227), which she had re-named 'the One-piece Goggle'. For this design she had used the approach of 'Stay', to remain in the same 'fast/shallow' GLM quadrant as the existing swimming goggles. To navigate her process, she had once again marked sketches with a small graphic showing the concept's position in the GLM as seen in Figure 60:

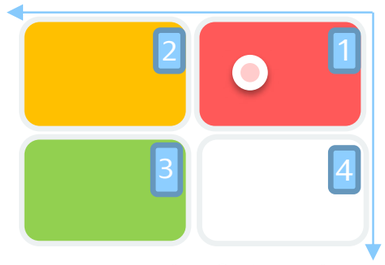


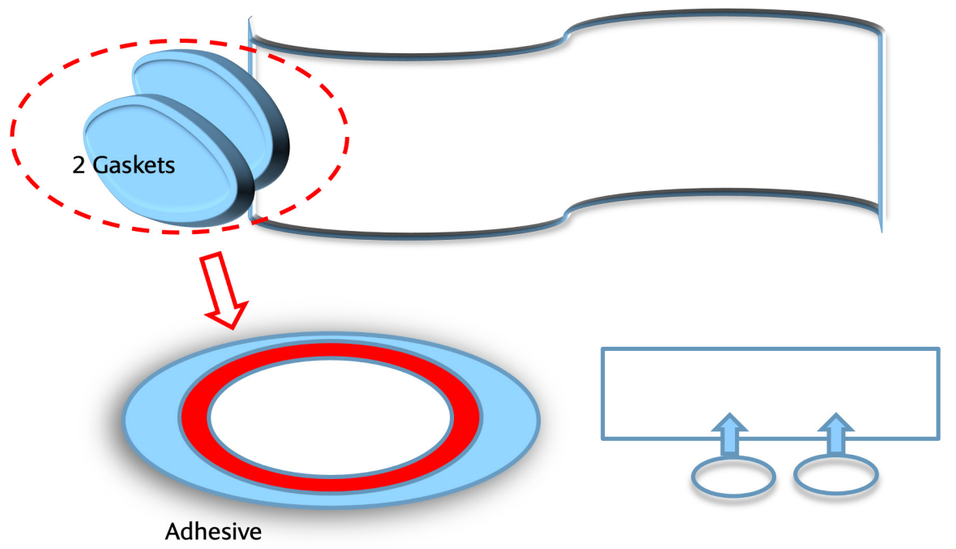
Figure 60. Participants' own sketch of the GLM, used for navigating her process

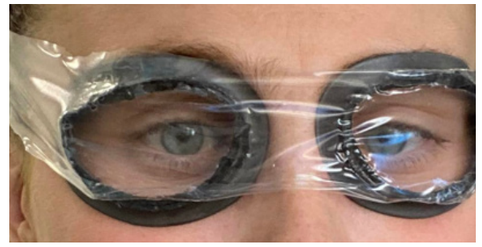
The designer's presentation-slide with sketches and prototypes of this idea can be seen in Figure 61 below.

As the name suggests, the design structure of 'the One-piece Goggle' indeed consisted almost entirely of a single sheet of thin, stretchy material. As seen in the photo x in Figure 61, the sheet material would be stretched over two eye-gaskets, and function simultaneously as lenses and strap. The only additional component was the eye-gaskets, which needed more structure and hardness to function. She imagined the gaskets would be *"mass produced, and made from a biodegradable material"*, and stuck on with *"a really small layer of adhesive"* (P1). The two-component prototype is visible in photo x, in Figure 61. She expected that the strap would be the component to break first, and thus speculated how the gaskets could be removable or replaceable to be stuck onto a new strap.

The main material used in the goggles [*omitted due to protection of intellectual property] can, according to the participant, be melted down for recycling. However, she was not sure about this.

Figure 61. Participant's sketches and prototypes of the 'One-piece Goggle'





Prompted by the DfS strategies suggested in the GLM tool, she chose the strategy of zero-waste design to propose that the goggles would *“come in a rectangle, and the sheet could be cut up in three pieces, to create zero waste”* (P1). The gaskets would be attached to the flat rectangular “strap” by simply pressing them on in the suitable place, depending on the size/shape of the customer’s face.

This mono-material structure allowed for an extremely simple production method: In its raw form, the chosen material comes in rectangular sheets from the manufacturer. These sheets would be sent directly to retail stores with no further processing. The designer imagined that *“when someone buys it, they just stamp out one of the goggles for them”* (P1). In this way, staff or consumers could produce the goggles on demand. She believed this method of *“having them almost in their raw-material form and then only creating the product once people buy them”* (P1) might help reduce waste from overproduction.

Reflecting on this production method, she explained that *“there is a reduction in production steps”* as *“at the moment they are made with multiple materials and multiple manufacturing methods”*. Thus, her idea was to *“remove all those steps and all the energy that normally is required”* (P1). She had also thought about how this sheet-based concept could save resources on transportation: *“because it’s smaller and super lightweight, it means you can transport so many more of them for less cost of energy”* (P1).

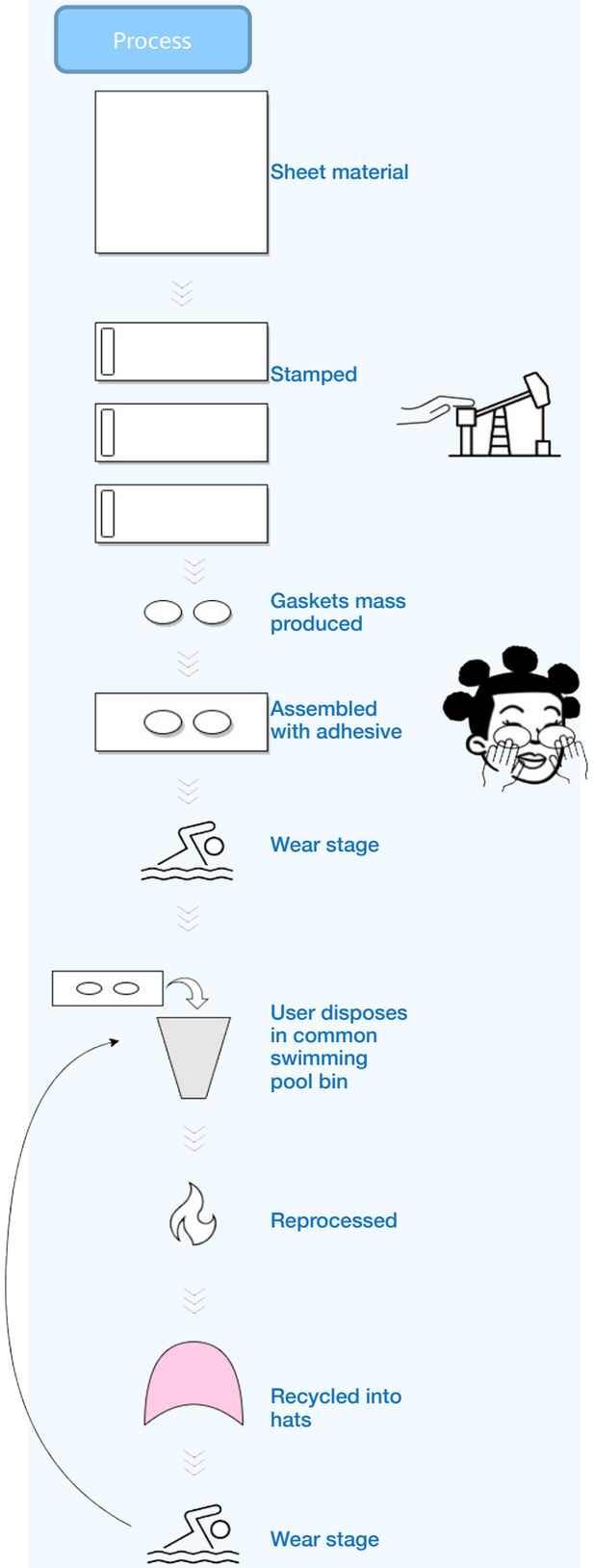


Figure 61b. ‘One-piece Goggle’ lifecycle. Adapted from participant’s presentation

She described how the goggles’ structure and material had resulted in an almost invisible, skin-like aesthetic: *“there is almost no aesthetic to them, it’s not like they are going to go out of trend”* (P1). Furthermore, she mentioned that competitive swimmers usually aim to be “streamline”, to glide through the water with as little friction as possible, and that *“these are more streamlined than normal goggles […] they are like your skin”* (P1).

Regarding user engagement, she had focused on convenience as this product sat in the ‘shallow’ half of the GLM. The stamping-activity, at the beginning of the product’s use-phase, was the only point of planned active user engagement until the end of use. She expected that after 10-15 swims, consumers would *“dispose of them at the swimming pool”,* where they would be returned for recycling.

In terms of business model, the participant imagined that these goggles would be sold at a low price point through a traditional buying model, since they would be *“extremely low-cost to make”* (P1). For this concept be sustainable, she imagined how profit would be generated from *“bio based- or fully recyclable input material”* (P1). She explained that the model only would work *“under the terms that the material can easily be recovered”* (P1), for its materials to be reused. The designer was aware that especially this part of the concept would need testing and development, and that with existing materials, these goggles would have to be downcycled into products such as swimming caps with fewer quality requirements.

Figure 61c. ‘One-piece Goggle’ prototype

Build Your Own Goggle

For the second and final concept, the designer presented the ‘Build Your Own Goggle’ concept. For this concept, she had used the approach of ‘Go’ to move from the ‘fast/ shallow’ quadrant to the ‘slow’ GLM half. For this concept, she had split up the product, so that its components were designed by following *recipes* in different GLM quadrants. The components in these goggles were a mix of personalised (‘deep’*)* and standard (‘shallow’) parts, bound together in a modular design structure as can be seen in Figure 62a.

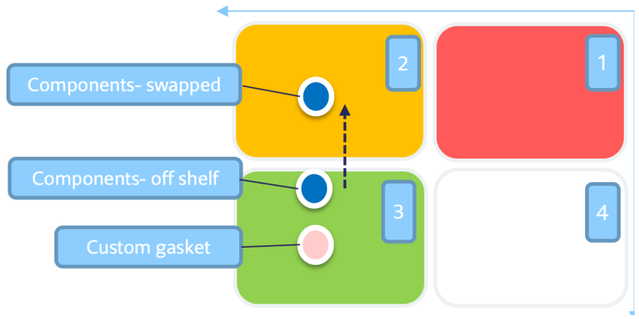


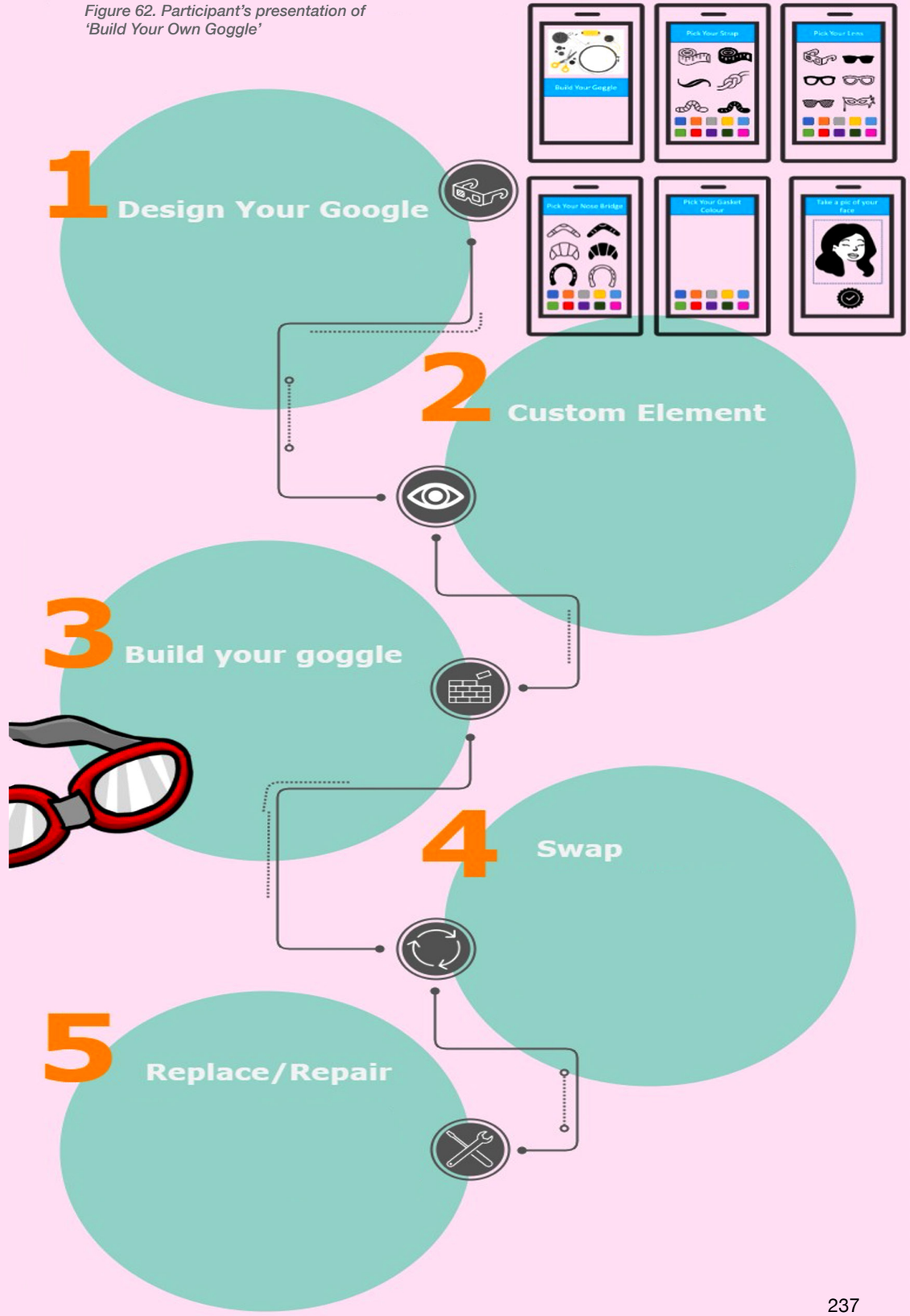
Figure 62a. ‘Build Your Own Goggle’ concept components mapped in the GLM

To introduce this concept, the participant said it was *“inspired by other products that used design for modularity and personalisation [...] Like LEGO blocks that have simple connections and stick together”* (P1).

As shown in Figure 62, she had visualised the goggles’ journey through five steps. For Step 1, users would build their own goggles. Through a web shop, they would select mass-produced parts offered in different colours and shapes. For Step 2, users would configure certain parts that *“really need to fit the person”* (P1) to be custom-made at a small scale, possibly through digital manufacturing. Once “built” by the user, the goggles would be shipped to them for self-assembly (see Step 3, Figure 62). In Step 4, the designer envisioned a swapping system where customers could swap with each other to customise or upgrade their goggles. The designer explained that this would be possible since *“all of the connections are very simple and universal*” (P1). For Step 5, she presented how users could return broken or unwanted goggles or components to the company for reuse or recycling.

She distinguished clearly between two types of components in these goggles; the standard parts designed for the ‘slow/shallow’ GLM quadrant, and the custom parts for the ‘slow/deep’ quadrant, which would be *“personal and completely yours”,* offering *“a unique solution for individual fit”* (P1). She thought this option of personalisation *“would create a deeper connection to the goggles”* (P1), and thus a slower use phase pace. In this way, the two types of components would move at completely different speeds: The ‘shallow’ parts would be cycled between users, who “*would be swapping out everything except the custom parts”,* which would stay with users for longer.

Figure 62. Participant’s presentation of ‘Build Your Own Goggle’



Regarding aesthetics, she imagined that the mass-manufactured, 'slow/shallow' components would be *"pretty simple* […] *block colours, that would make people want to swap more*". But added that "*you can pick the colours and parts, so it does become personalised"* (P1).

In the same way that the components' design varied depending on what GLM quadrant's *recipe* they were following, she also envisioned that the business would vary depending on component-type. For the 'slow/deep' bespoke parts, the company would "*profit from selling high-quality products with a long lifespan"* (P1). The 'slow/shallow' parts, which users could swap between them, would be sold through a traditional buying model, but the company would gain additional profit from *"enabling shared use and access"* (P1).

Finally, she imagined that in the case components would break, the "*resources would come back to the company"* (P1) so that they could be recycled and profited from again. She explained that this would be enabled by using "*super durable"* and preferably recyclable materials, so that the company could keep making goggle-components from them. Here she put emphasis on the goggles' modular structure, which ensured *"that the parts are easily removable"* (P1).

At the end of this session, the designer was once again invited to give feedback on her experience of using the GLM and the 'Stay or Go' method during this phase of the project. Data from the two interviews (Sessions 1 & 2) is reported below.

Feedback-session, Study 3b, (Session 1 & Session 2)

Sessions 1 and 2 of this study were both concluded with a short feedback session in which the participant was invited to give feedback on her experience of using the GLM tool and the 'Stay or Go' method. The aim of this part of the study was to assess if/how the GLM tool had provided useful support for the designer to take a holistic approach, to design efficiently with DfS strategies. Both feedback-sessions were structured around two prompting questions on the participant's process of using the GLM, and whether she had found it useful as support for DfS.

Question 1: ***Can you please explain your process of using the GLM and the 'Stay or Go' method for this stage of the design project?***

For the first design phase leading up to Session 1, the participant described mainly using the GLM tool for generating ideas for new sustainable concepts. During this phase, she described frequently returning to the *recipes* to inspire and guide her thinking: *"When I had some ideas that I liked, I would read through each of the little points again [...] Once the initial spark of ideas had been explored, I would use it to home in on more specific things"* (P1, Session 1). In the feedback-session following Session 2 the participant reported using the GLM differently: she described going from using the GLM to spark ideas in the early phase, to following the *recipes* more closely to guide her design decisions in the second phase: *"this time I had the ideas, and I would use the tool through and through, looking at every part"* (P1, Session 2). She described how, the tool allowed her to go into details of a products' *ingredients,* using the *recip*es almost like a *"checklist"*, continuously returning to them: *"I definitely went back to it during the process, it was kind of alongside* [...] *It was always there"* (P1, Session 2). On the other hand, she also described how it allowed her to see the bigger picture *"to see if you could shift it in different directions"* (P1).

Generally, the participant expressed finding the tool easy to use and *"really obvious in the way that it was laid out"* and added; *"I don't think there was anything in the matrix I didn't understand"* (P1, Session 2). She described that she thought "*it would be really good to have the matrix even without you* [the researcher]*, it's really good and you can understand it because it's intuitive"* (P1, Session 2).

Regarding using the 'Stay or Go' method, she described using it and finding it helpful for guiding her process, mainly during the early design phase. She described how she had started with the approach of 'Stay', and then moved to 'Go', moving counter clockwise around the matrix to the other quadrants (visualised in Figure 55, p.225 above). She felt that this was the most logical way to progress as she believed that *fast/shallow's* recipe could be used as a "base" for the other quadrants, whose *ingredients* could then be added "on top". Furthermore, she described how, the further she got into the process of working with the GLM, the more able she felt to use it fluidly, to the point where she would "*think about it as points sliding along scales, rather than just the section"* (P1, Session 2).

She described that using the 'Stay or Go' method in combination with the GLM tool, had enabled her to take a systematic approach: "*It made me really organised, in the way I structured my concepts"* (P1, Session 2). Furthermore she felt that together, the GLM tool and method provided useful support for her to comprehend the task of designing for sustainability which she thought otherwise could be complex: *"If someone just said to you: 'make goggles more sustainable', that is such a blank, high-level term that you would think: 'Oh no, where to start' "* (P1, Session 1).

Question 2: ***Did you feel like the GLM helped you to design for sustainability? If yes, in what ways?***

In response to this question, the participant described that using the GLM had given her *"a really thorough understanding of the whole sustainability side of things"* (P1, Session 1). She described that using the GLM had expanded her perspective on DfS: *"I knew about sustainable materials and things like that, but I have never considered it with things like the business model or user engagement [...] so it was adding to my knowledge"* (P1, Session 2).

She described how using the GLM had prompted her to consider the further system of the product: *"I looked through all the ingredients and I tried to consider the start of the lifecycle, the end of the lifecycle, like, you really think about it in a holistic way"* (P1, Session 2). She pointed to the GLM's structure and the 'Stay or Go' method as particularly helpful for these systems-wide considerations: *"this breaks up the whole concept of sustainability into these little categories that helps you think about all of it, so that in the end you get way more out of it"* (P1, Session 1). She described how the 'Stay or Go' approach and the had GLM helped her reason and organise ideas: *"My brain is a bit chaotic [...] I think that the tool almost forced me to sit down and consider everything"* (P1, Session 2).

8.2.3. Discussion of findings Study 3b

The purpose of this study was to test and validate the GLM and the 'Stay or Go' method as support for garment designers to take a holistic approach, to design efficiently with DfS strategies.

Using the 'Stay or Go' method

The 'Stay or Go' method was designed to enable the participant to use the GLM tool systematically, breaking design activities into smaller, manageable parts. The findings from this study confirmed that the participant had understood and used the 'Stay or Go' method as intended. This is demonstrated through how she continuously marked ideas with their position within the GLM and noted how she had moved between GLM quadrants to help navigate her process, as illustrated in Figure 63 below.

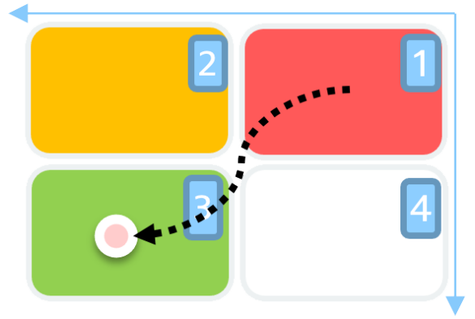


Figure 63. Participant's indication of concept taking the approach of 'Go' to move to the 'slow/deep' GLM quadrant.

Additionally, the study showed that the participant had been able to use both approaches of 'Stay' and 'Go'. This was demonstrated in the presentations of her concepts, where she showed ideas in all the GLM quadrants; starting with 'Stay', and then 'Go', moving counter clockwise through the matrix.

According to the participant, the 'Stay or Go' method had been useful for supporting her to take a systematic approach to DfS in two ways: firstly, by supporting her to organise and focus her thinking during the early phase of ideation, specifically, by providing a way for her to break down and focus on smaller parts during the early phase of ideation and ensure that she had covered relevant areas of investigation; secondly, to structure communication of DfS ideas. When presenting, she chose, on her own volition, to split concepts according to whether the 'Stay', or 'Go' approach had been used.

Taking a holistic approach

The findings from this study also confirmed the GLM tool as support for the designer to take a holistic approach to DfS. This was particularly evident in the way the participant had included consideration of factors outside of the product itself such as 'business model' and 'user engagement, which, according to her, usually would be outside of her main remit.

To understand more concretely how she had implemented the various GLM *ingredients*, another set of visual mapping exercises were conducted. To start, the initial pool of concepts generated for Session 1, were placed in the GLM, as seen in Figure 64, based on the participants' presentation.

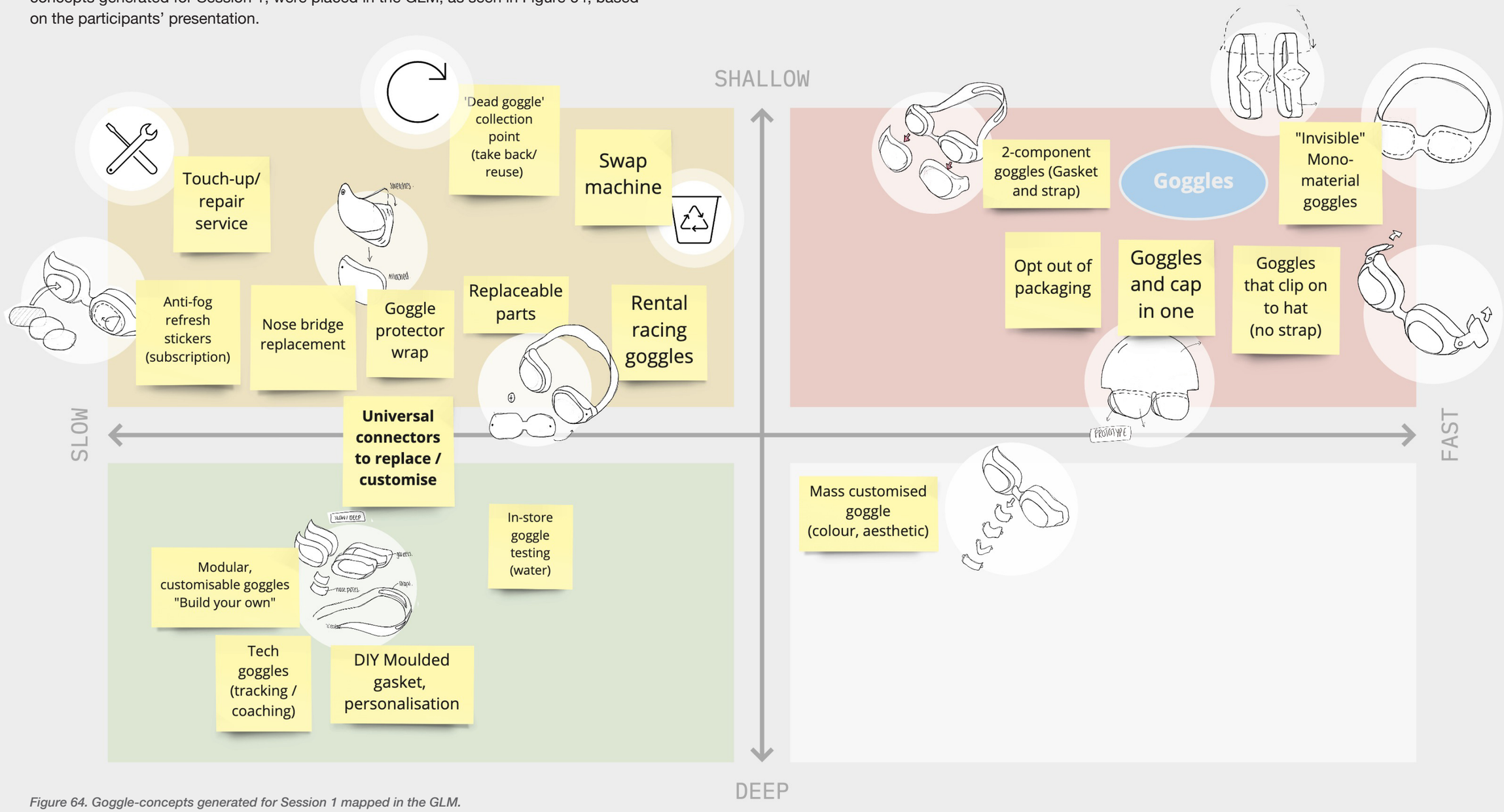
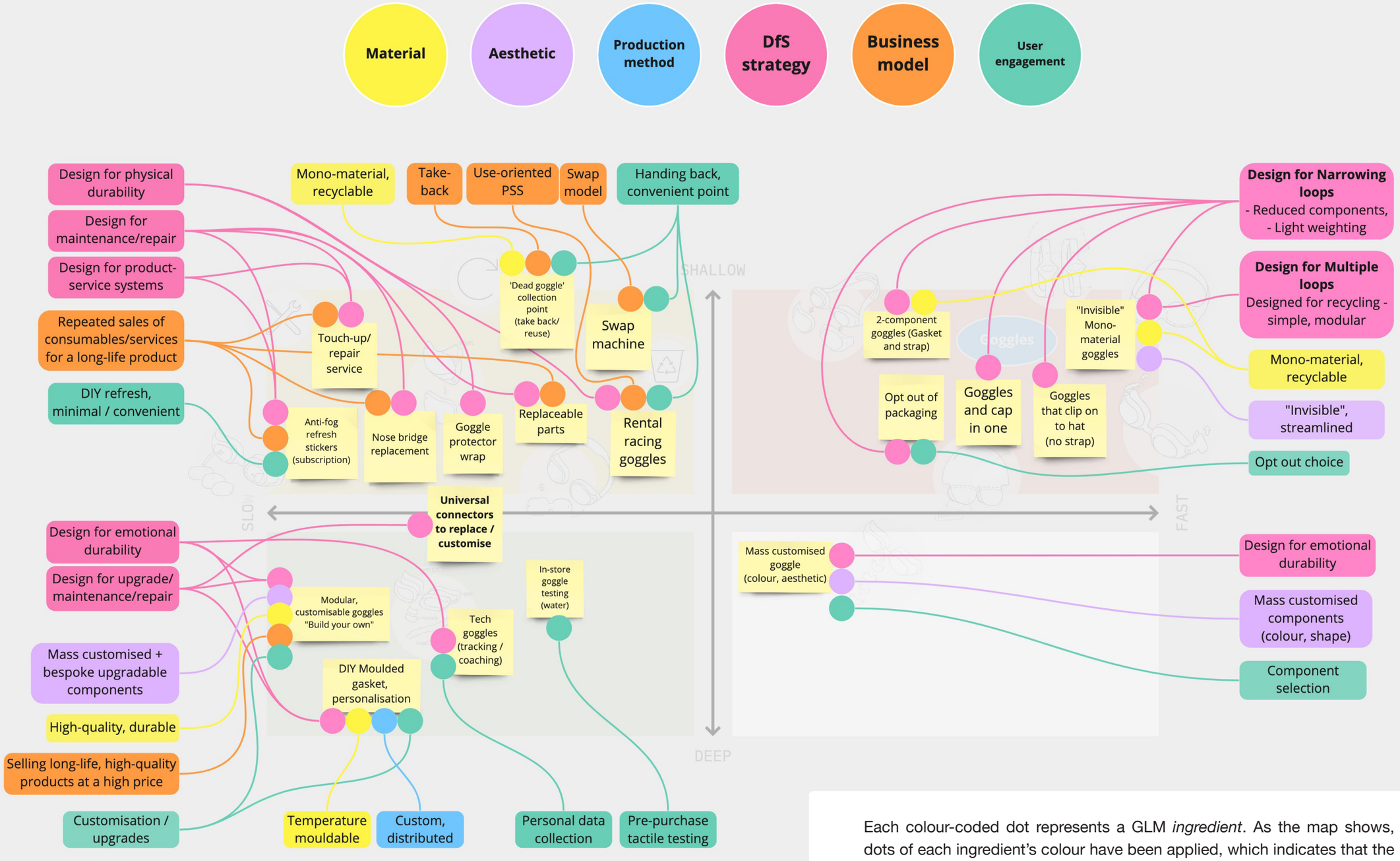


Figure 64. Goggle-concepts generated for Session 1 mapped in the GLM.

This process gave an overview of the generated concepts and illustrated that the participant had managed to follow the tools' *recipes* to come up with concepts in each quadrant. Furthermore, Figure 64 demonstrates that most concepts were generated for the 'slow' half of the GLM, and almost none were generated for the 'fast/deep' - in line with the expectations set out in section 8.1.: that designers using the 'Stay or Go' method in combination with the GLM, generally will steer towards the 'slow' GLM half.

Next, each of the concepts from Session 1 were annotated with the *ingredients,* which, according to study data, had been considered in each of these concepts. This can be seen in Figure 65 (next page).



Each colour-coded dot represents a GLM *ingredient*. As the map shows, dots of each ingredient's colour have been applied, which indicates that the participant had managed to use *ingredients* related to the entire spectrum of *enabling factors* for this first session. There is a clear overrepresentation of the pink dots, which indicate the *ingredient* of 'DfS strategy', which makes sense, as this is the participant's immediate area of expertise. The *ingredient* of 'business model' (orange) had also been used frequently, but mostly in the 'slow/shallow' quadrant, indicating that the designer saw more opportunities for testing new business models in this quadrant.

To understand how she used the GLM *ingredients* in the second and final design phase, the same mapping exercise was carried out, for the two final concepts presented in Session 2. The resulting map can be seen here, in Figure 66.

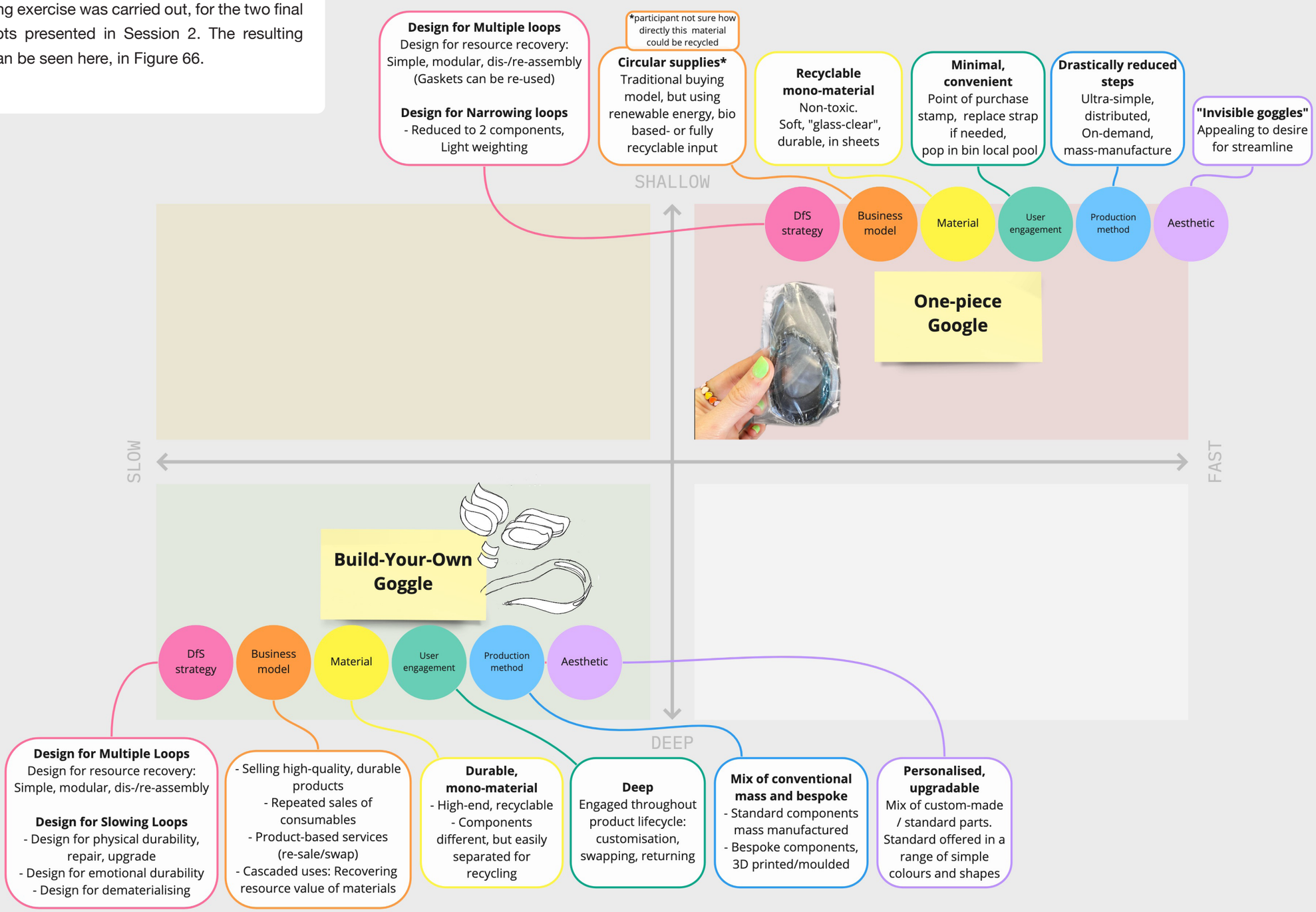


Figure 66. Two final goggle concepts from Session 2 mapped in the GLM. Annotated with GLM ingredients

Figure 66 demonstrates that the designer had managed to include consideration of all the GLM *ingredients* in her final concepts. This is in line with the participants' own description of her process in the feedback-sessions where she explained how, especially in the second design-phase, she had looked closely at the *recipes* to let them guide her decision-making, using them as a "checklist". In this way, the final concepts and prototypes demonstrate how the designer was able to think beyond the individual product and its components, to consider the entire lifecycle, and set of *enabling factors*.

Selecting and applying appropriate DfS strategies for each garment and use-context

Finally, this study confirmed the GLM and the 'Stay or Go' method as support for designers to select and apply DfS strategies which were suitable for each garment case. By following the *recipes*, the designer had been enabled to focus consideration of the various *enabling factors*, on approaches which were particularly relevant for each garment case.

For example, in the case of the 'One-Piece Goggle'-concept, the designer had gone through systematic consideration of each of the *ingredients* in the *recipe* for 'fast/shallow' to select strategies that were particularly relevant for this quadrant. This led her to select a zero-waste design strategy, combined with a material choice of mono-material sheets, and an ultra-simple, distributed, on-demand production model. All of which are particularly appropriate DfS approaches for the google-product at hand, since it was expected to have a fast use phase pace and low level of user engagement.

8.3. Study 4b: Testing the Garment Life Matrix as DfS support - Rohan

The purpose of this study was to further test and validate the GLM framework and the 'Stay or Go' method as support for designers to select and implement appropriate DfS strategies, for their efforts to have efficient impact. The purpose of this study was the same as the previous Study (3b), and its activities were almost identical. The only noticeable difference in the setup of these studies was the change in participants who, in this study, were recruited from outdoor brand Rohan.

8.3.1. Study design

To test the GLM tool and method, the participants were tasked with redesigning garments from their current range to be more sustainable, while using the GLM tool and the 'Stay or Go' method to support their process. This study was a continuation of Study 4a (Chapter 7) which meant that participants already were familiar with the GLM tool, and to some degree, the 'Stay or Go' method. This study was based on a small selection of products from Rohan's range (a fleece jacket and a rain jacket) which the team, in the previous study (4a), had identified as particularly "unsustainable" and thus relevant to redesign for sustainability.

This study was conducted alongside the company's usual practice, and therefore had to slot into existing projects. This was an interesting limiting factor for testing the GLM tool's relevance for garment companies, as it gave a sense of how industry works outside of academia; at a fast pace and with demanding targets to meet. The study consisted of two engagements spread over three months, between which the designers worked on developing the concepts. Like study 3b, this study took an action research approach.

Study 4b activities

Kick-off

The purpose of this session was to brief the participants and equip them to use the GLM tool independently of the researcher. This was not an in-person session but a video-call and email correspondence. The participants were given access to the digital GLM tool via a hyperlink, and a set of worksheets (shown in Section 8.1.) to support their process. The participants were invited to respond to the GLM tool's strategies by generating early-stage ideas for redesigning the selected garments. They were encouraged to utilise the 'Stay or Go' method and the GLM tool to support their process, and to record this process by mapping it into the GLM.

Session 1: First concept ideas

The aim of this session was for Rohan's team to present and discuss the first developed ideas for sustainable redesigns of the selected jackets, the fleece, and the rain jacket, to establish a route for the next steps in their process.

Session 2: Final design presentations

In this session, the participants presented the more developed prototypes. At the end of this session, the designers were invited to give feedback and discuss, guided by prompting questions, their experience of using the GLM tool and method. The aim of the feedback-session was to understand their process while using the tool and method, and if/how these had been helpful for the participants to design efficiently with DfS strategies.

Participants

The participants in this study had all participated in the previous study (4a) and were all recruited from the design team at Rohan. It was primarily one participant, 'D1', who undertook the design work during this project. However, as all participants listed in Table 11 below had been involved, to a varying degree, during this process, they were invited to take part in both engagements with the researcher. All participants were garment designers by profession, but one participant held the position of Manager.

Table 11. Study 4b Participant ID

ID	Field of experience
M1	Design Manager
D1	Apparel Designer
D2	Apparel Designer
D3	Apparel Designer

Method of data collection and analysis

This study took place in person at Rohan's UK headquarters. The sessions were video, and audio recorded. Photos, presentations, and sketches produced by the participants were collected to document their process. Once again, the data from study sessions underwent Thematic Analysis, following the six steps as suggested by Braun & Clarke (2006) (cf. Section 3.1.1.). The data from the Thematic Analysis was visually mapped into the GLM framework, to further analyse how the GLM tool and 'Stay or Go' method had been used during design processes.

8.3.2. Findings Study 4b

Findings Session 1

For this session, the designers showed the garment-concepts they had been working on since the kick-off session. Due to time constraints, the team had focused on ideas for just one garment: a fleece jacket. In the previous study (4a), the fleece jacket was placed in a relatively 'fast' and 'shallow' position in the GLM. To redesign it to be more environmentally sustainable, the team had chosen the approach of 'Go' to design the garment for the 'slow/deep' GLM quadrant. The participants' made this choice because they felt it was most in line with the brands' core values of designing high quality, durable garments.

The generated concepts were presented as a slideshow by the designer, 'D1', who had been the main designer involved in this study. As pictured in Figure 67 below, she had mapped the original placement (red dot), and the new desired placement (green dot), of the fleece jacket in the GLM, to help her record, navigate and communicate her design process of moving across the GLM.

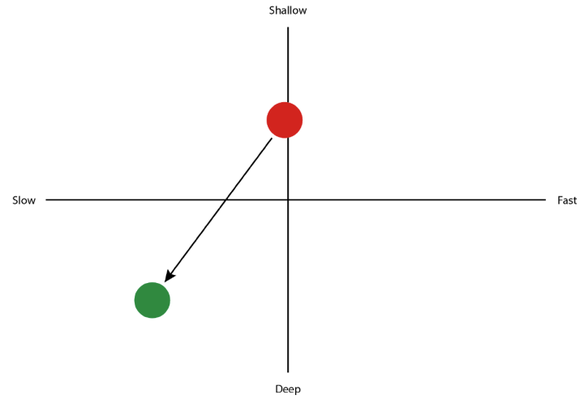


Figure 67. Original placement of fleece jacket in the GLM (red dot), and new, ideal placement (green dot). Fom participants' presentation

Some factors in the design of this fleece were determined beforehand; the team had already been briefed to develop a “high loft” (thick and fluffy) fleece garment. They had been instructed to use a specific fabric; an ultra-warm fleece fabric called ‘High Loft’ from supplier Polar Tec. According to Polar Tec’s website, this fabric has at least 50% recycled P.E.T plastic. The team had decided to use this High Loft material in conjunction with another fleece-material made from recycled polyester called ‘Tellus’, which is thinner and more hard-wearing *“to enhance the performance and the benefits”* (M1). A series of ideas were presented which aimed for achieving a slower use phase pace and deeper levels of user engagement:

High abrasion panels

This fleece was designed to be *“really high performance”* (D1). Therefore, the designer had been paying particular attention to areas on the fleece which she thought would be vulnerable to wear and tear: *“under the arm is a big one, especially because we are aiming at people who are active”* (D1). Therefore, she had “*started to think about which fabric goes where”* (D1). In line with guidance in the ‘slow/deep’ GLM *recipes,* she had placed the more durable, thinner ‘Tellus’ fabric in areas such as *“under the arms where it’s high wear”.* She described trying to “*double-whammy, making it functional and hard-wearing by placing this grid-fleece in key-abrasion areas, and then placing the high loft fleece where the user would have more benefit from it being warm”* (D1). Figure 68 shows the participant’s idea for the panelled fleece jacket.

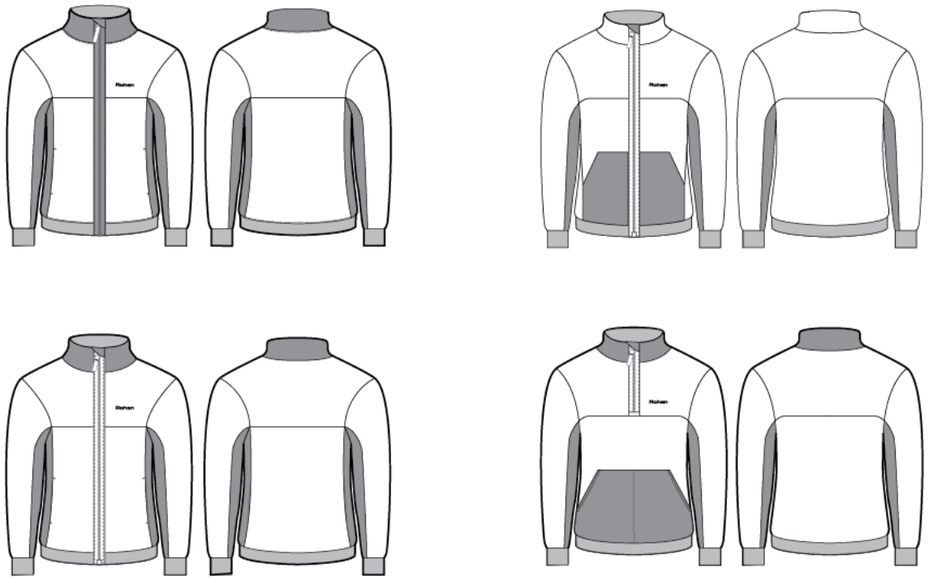


Figure 68. Participants’ presentation of for fleece jacket with high abrasion panels

Replaceable zipper

While thinking about the life expectancy of the jacket’s various components, it had occurred to her that besides the issue of fabric losing its insulating capabilities, a frequent risk for shortening the use phase is the zipper. One of the other participants explained: *“a lot of the ones we get sent back, is where the zip has actually burst”* (M1). Therefore, the team had explored ways to design the fleece’s zipper to be replaceable and/or repairable. The brand currently offers repairs for a modest fee but inspired by the GLM’s ‘slow/deep’ *recipe,* they instead aimed for engaging consumers in repairs, to elicit deeper levels of engagement.

Most zippers on Rohan’s garments are currently sewn on with multiple seams to ensure durability, however, according to participants, it’s usually the zipper mechanism itself that breaks, not the seams around it. Therefore, the team had been working on ideas for making replaceable zippers, to allow the rest of the garment to stay in use for as long as possible, as well as to enhance user engagement. These decisions were based on the desire to move the fleece jacket, using the ‘Go’ approach’, from the ‘faster’, more ‘shallow’ part of the GLM towards the ‘slow/deep’.

One participant suggested an idea for putting the zip-tape [strip of fabric that attaches a zipper on a garment, usually placed on the inside] on the outside of the garment: “*because the fabric is so fluffy that it might get stuck in the zipper”* (D1), but also to enhance user engagement by making the consumer feel *“like they can take the zipper off and replace it”* (D1). The designer explained that the usual placement of the zip-tape on the inside of a garment, hides the option of replacement and makes it look complicated, but that if “*you can see the zip-tape* [on the outside] *It looks like you could just unpick it and put another one on top”* (D1). To make it even easier for users, she proposed contrast-coloured stitching for visibility. In relation to explaining this idea, the main designer spontaneously came up with a new idea for a different type of modular zipper fastening (Figure 69) with no stitching, which she thought would be even simpler for users to replace.

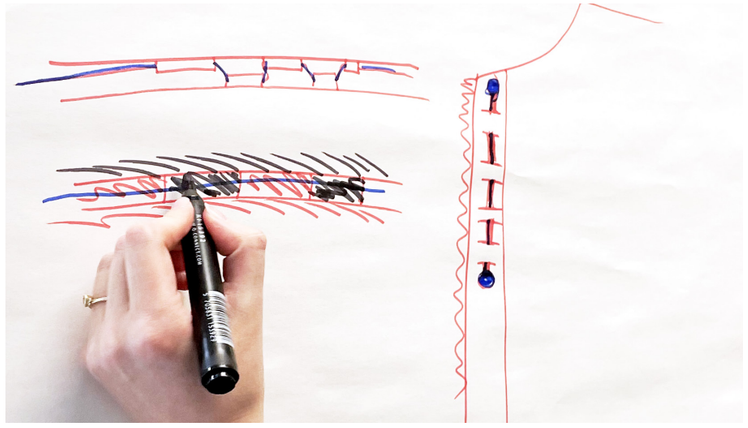


Figure 69. Participant’s sketch of easily replaceable zipper mechanism

Findings Session 2

In the final session of this study, the main designer presented the outcomes from her process of redesigning a selection of garments from Rohan's existing range for sustainability. This task had mainly been undertaken by the main designer 'D1'; however, the rest of the design team had been following her process and been involved, through discussions. Throughout the design process, the designer had been using the digital GLM tool and the worksheets with descriptions of the 'Stay or Go' method (described on p.254), as support. The designer presented her final ideas in a slideshow, which is summarised in the following sections.

Removable zip

The idea of the removable zip, conceived during Session 1 of this study, had been developed further in this session. As zippers can sit on pretty much any garment, this idea was not limited to the fleece jacket, which the idea started with, but responded to the teams' general wish to create 'slow/deep' garments. To illustrate her process of using the 'Go' approach, the participant had mapped the original placement of the fleece jacket (from Study 4a, described xx), as can be seen in Figure 70, with a red dot, and the ideal, 'deeper' position of the redesigned garment with a green dot.

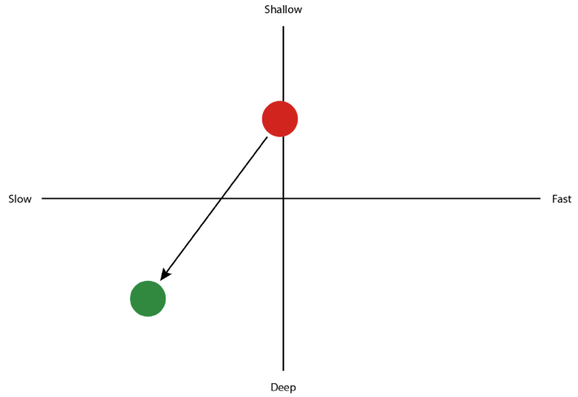


Figure 70. Fleece jacket mapped in the GLM.
Red dot: Original placement. Green dot: Ideal placement

The purpose of this new zip-mechanism was to make it 'slower'; solving a current functional problem of zippers breaking and being almost impossible to replace, by making it replaceable and thus extending the life of the garment. But also, to make it 'deeper' by engaging users in repairs and potentially customisation. Since Session 1, the designer had been looking at different ways of attaching the zipper to the garment and developed a series of paper mock-ups (shown in Figure 71).

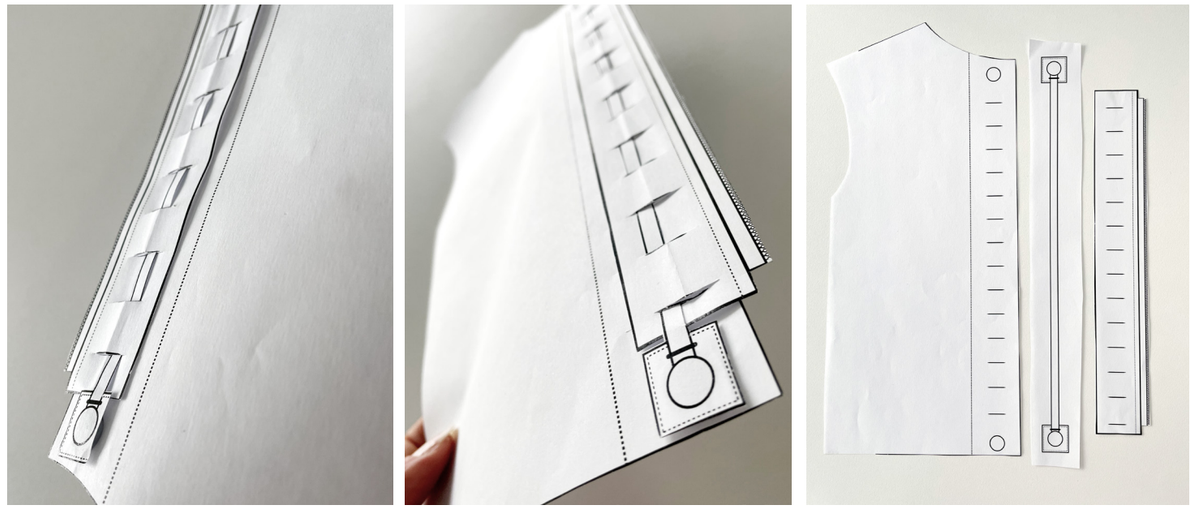


Figure 71. Removable zip-construction paper mock-up

Modular & multipurpose 'Ventus' jacket

Next, the designer presented her idea for redesigning one of the brand's most expensive rain jackets, the 'Ventus', to be more sustainable. This jacket, which is produced in two colours, orange and black, was particularly debated in the previous study (4a reported in Chapter 7), where, despite their identical construction, the two versions of the jacket were positioned in entirely different parts of the GLM: The orange version was placed in the 'fast/deep' GLM quadrant, because of the "on-trend colour", which was seen as causing the garment to be discarded before being worn out. In contrast, the black version which *"would be a much slower garment"* (D1) was placed in the 'slow/shallow' quadrant. The orange 'Ventus' jacket was seen as particularly unsustainable because of the discrepancy between the large amounts of resources required to produce it, and its relatively fast use phase.

As shown in Figure 72, the designer aimed to make the orange jacket more sustainable by using the method of 'Go' to move towards the 'slow/deep' GLM quadrant. The existing orange 'Ventus' was mapped in the GLM, in the 'fast' GLM half. The green dot in the 'slow/deep' quadrant marks the position the designer aimed to move to.

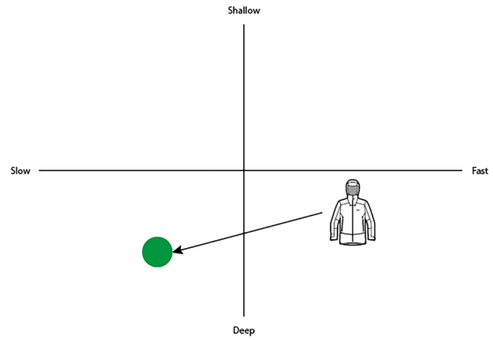


Figure 72. 'Ventus' jacket's current GLM position (jacket) and desired placement (green dot). From participant's presentation

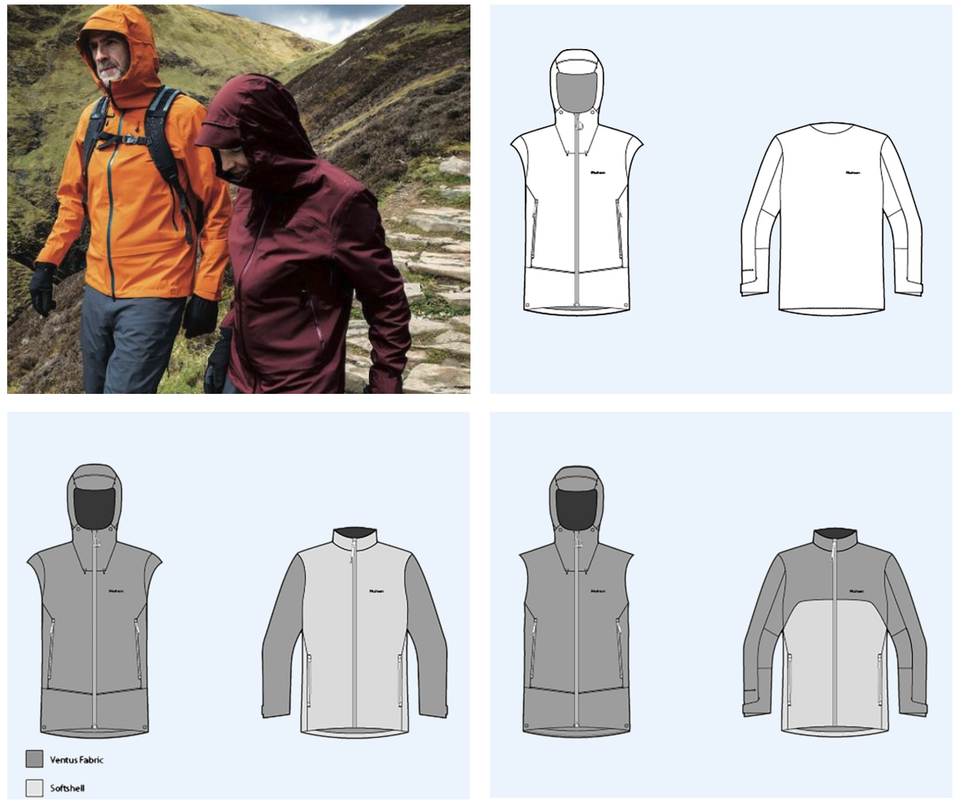


Figure 73. Modular 'Ventus' rain jacket concept

To do this, the designer developed a modular jacket/vest hybrid (pictured in Figure 73), which explored *"ways of creating seasonal colour with smaller garments, or modular garments, so you could have different colours and pieces that you could put together"* (D1). The idea was to provide a more versatile product so people would buy less.

The designer explained that the two components of the jacket would have vastly different life expectancies, *"the vest that's over the top would be replaced more often"* (D1), for two reasons: Firstly, because it would get exposed to more wear, and secondly, because the vest would be the most *"visually prominent part"*, which would follow and depend on fashion. In comparison, the jacket worn under the vest would last much longer. The vest-part would be produced in bright on-trend colours, with *"more muted sleeves and body on the jacket"* (D1). This was an aesthetic choice of "*mixing seasonal and more trend-based colours with more stable colours* (M1), to both extend the physical and psychological durability.

The designers in the team agreed that strategies related to 'Design for narrowing loops', i.e., minimising the number of components in the vest, would be the most sustainable option because it was expected to be *"a faster garment layer"* (D1). They thought about *"doing less pockets or different types of pockets, mono-material pockets rather than having trims on it"* (D1). The mono-materials for the vest were also chosen to make the garment easier to recycle. Finally, one participant proposed that minimising resource use also should be reflected in choice of manufacturing methods: "*we could think about what's the minimum amount of work that can go into that to reduce wastage"*, and suggested reducing the number of adhesives and seems used, to also *"reduce potential points of failure"* (M1).

Zip puller ideas

Next, the designer presented ideas for redesigning zip pullers; a very small component, which despite its modest size, holds great importance for the brand, as it sits on garments across the range. The designer believed that redesigning the pullers for a deeper level of user engagement by "*adding more value to all of it"*, could extend the use phase of the garments they sit on. To do this, she had taken the approach of 'Go' to move the pullers from the 'slow/shallow' to the 'slow/deep' GLM quadrant. To illustrate this, she had mapped her process in the GLM as can be seen in Figure 74.

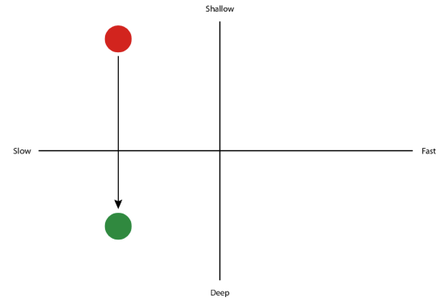


Figure 74. Zip puller's previous GLM position (red dot) and desired placement (green). From participant's presentation

Each of the puller concepts offered different levels of customisation for customers: From choosing between a selection of standard zip pullers, to having a unique puller made especially for them to *"increase the emotional engagement with the jacket or trousers"* (D1), as it would enable people to express their identity. The full description of the various puller-ideas can be found in the appendix, Section I1, p.95.

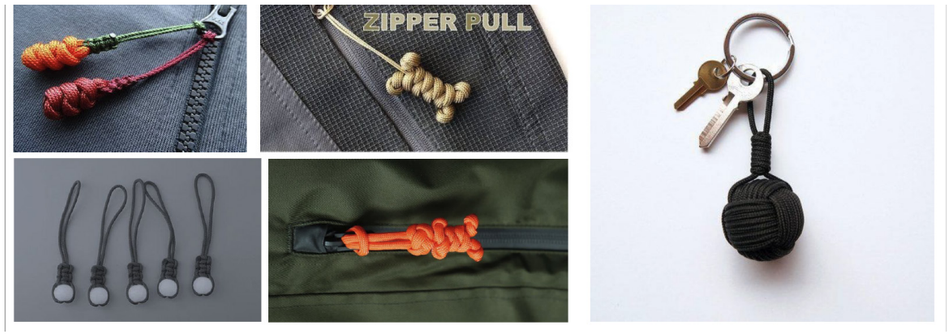


Figure 75. Zip puller ideas from participants' presentation

Fleece jacket - Design for disassembly

The final presented idea was a further iteration of the fleece jacket discussed in Session 1. Once again, the designer had followed the method of ‘Go’ to move from the ‘shallow’ and rather ‘fast’ part of the GLM to the ‘slow/deep’ quadrant, as seen in Figure 76 below.

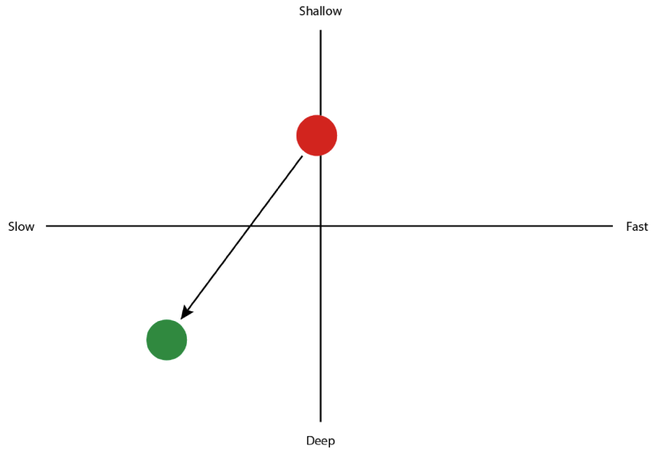


Figure 76. Fleece jacket mapped in the GLM by participant. Red dot: Original placement. Green dot: Ideal placement

For this second iteration of the fleece jacket, the main designer had continued to think about how to best place the different material-panels to enhance longevity, but the focus had been on developing the idea of an easily replaceable zipper. The intention was to enhance both durability of the garment and the depth of user engagement by designing the zipper, so that it could be replaced by users. Specifically, by placing it on the outside of the garment, using highly visible, contrast-colour stitching.

After discussing this idea with managers, and a garment technician, she had realised some significant issues with the contrast-stitching idea and had to go *“back to the drawing board”*. During this process, she had worked with a garment technician. Together, they had been *“looking at the Garment Life Matrix and discussing what options on there would be feasible”* which had led them to discuss the option of using heat-dissolvable thread, which is one of the provided examples of ‘Design for disassembly’ in the GLM *recipes*. Based on this discussion, the garment technician had been open to exploring this solution and said that *“if it was a dissolvable thread then yes 100%, to aid removal of the zip”* (D1).

Regardless, the designer ended up changing her idea. Mainly due to one realisation regarding the life expectancy of the different components: The zip will likely outlast the fabric of the garment. Instead of focusing on the replaceability of the zipper, the designer shifted her to focusing on ***“****not catching the fibres of the fleece into the zip”* (D1). This meant they went back to a traditional zipper construction, but still kept the zip tape exposed to keep the fluffy fabric from getting stuck in it. As one participant remarked: *“It’s funny, it feels like we've gone from worrying about the zip being the thing to focus on, to actually protecting the fleece from the zip* (M1).

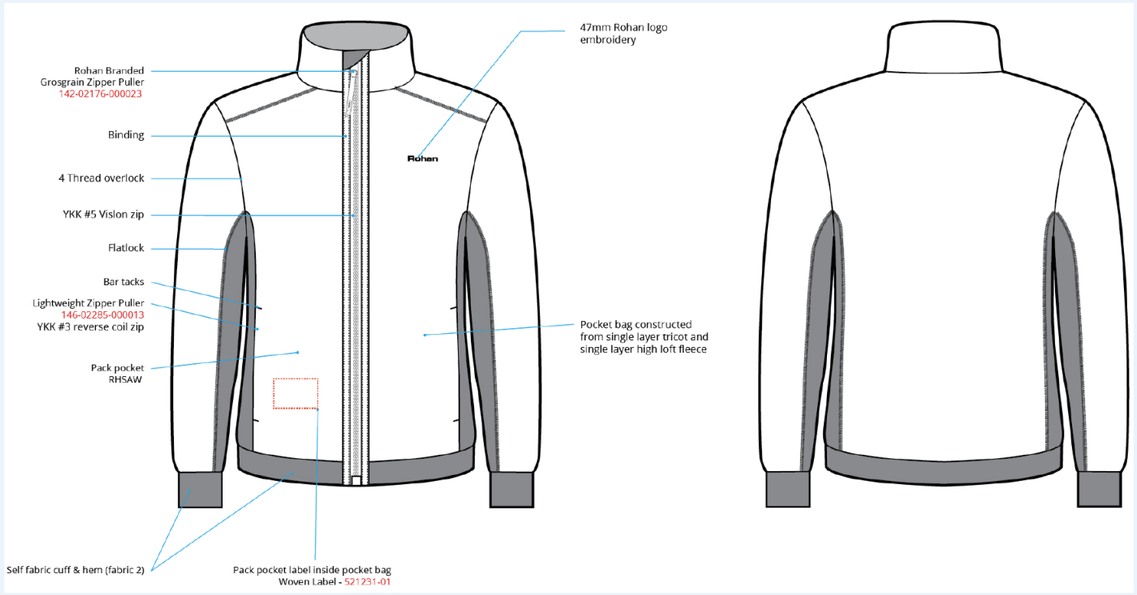


Figure 77. Fleece jacket with high-abrasion panels and extra grosgrain binding around the zipper to protect surrounding fabric.

Feedback-session, Study 4b

Like Study 3b, this study was concluded with a short feedback session in which the participants were invited to give feedback on their experience of using the GLM tool and the 'Stay or Go' method. The aim of this part of the study was to assess if/how the GLM tool had provided useful support for designers to take a holistic approach, to design efficiently with DfS strategies. This feedback-session was centred around two questions posed by the researcher but otherwise kept open for participants' inputs.

Q1: *Can you please explain your process of using the GLM and the 'Stay or Go' method for this design project?*

First, the garment designer who had been working most with the GLM explained that she mainly had been using the 'Stay or Go' for sparking ideas and finding direction: *"I think it's very useful when we start on a new product and using it to think about where it sits at the moment where we want to get it to* [in the GLM]*"*. She found it particularly useful for "grounding" her thinking, *"especially when you are starting and thinking about how to approach it"* (D1). She described her further process of using the GLM as *"a dip-in and dip-out"*; continuously coming back to the digital tool throughout the project. She had taken inspiration from the practice-examples embedded in the GLM *recipes* and said: *"I enjoyed your Pinterest boards"*.

She described how she would *"go away and research to see what's on the market, what's going on with other industries and come up with other ideas. And then [...] go back to the matrix to spark more ideas"* (D1). She also described how coming back to the GLM tool throughout her process had helped her navigate through design choices as they emerged: *"I would go back to it* [the GLM tool] *and expand it [...]and I would think: How can I take that spark of an idea and develop it into something more defined?"* (D1). Due to this iterative process, the designer expressed wanting a physical version of the GLM tool on her desk. She even imagined a tactile version with "*magnetic dots to keep track of… 'we're going from here to here'* [pointing to GLM quadrants]*"* (D1). She imagined this could be a useful reference for her during team meetings to communicate and maintain the focus of DfS discussions.

She also described how the GLM had enabled her to build reasoning for design choices and discuss these with colleagues (i.e., other designers and a garment technician). She described how proposing new design ideas often can be "*a little bit of a seesaw, push and pull, where you want to do one thing with it, but actually the demands of the business are another thing"*. However, she said that the GLM had been "*helpful for reasoning",* because *"it's not just, 'well, it's recycled plastic bottles', it's like, 'no, this is more sustainable because of this, this, this'"* [D1, pointing to the GLM *recipes*].

Question 2*: Did you feel like the GLM tool helped you to design for sustainability? If yes, in what ways?*

In response to this question, all present team-members exclaimed "*YES"* (D1, D3, M1). The Design Manager added that the GLM had affected their thinking *"and now it's going to have an effect on our products"* (M1).

The main designer said: *"Sometimes with sustainability it means losing other parts and having to make a compromise"*, but *"this leads you to a better garment overall, not just a sustainable garment"* (D1).

One participant was particularly fond of how the GLM framework had allowed for initially mapping the company's range in the GLM framework and said: "*the fact that you made us apply things that we already knew to it, I think that was really helpful* [...] *I was able to take something I was familiar with and apply it"* (D3).

Furthermore, the participants thought the tool had been particularly helpful for enabling them to think holistically about DfS: *"the awareness that everything has to be considered and everything affects everything else in a way"* (M1). Specifically, he described that working with the GLM had provided a new understanding of how user engagement and garment life expectancy affect each other. He explained that, before seeing the GLM, he was *"aware of the lifecycle of the product from slow to slow, fast, and the emotional connection"*, but that he had thought about those factors ('Depth of user engagement' and 'Use phase pace') as "*two separate things"* (M1). He added that this ability, to comprehend the various factors presented in the GLM tool, had helped the team to identify relevant areas to focus the company's efforts, to avoid a situation where: *"we spend all this time looking at the material, then all the focus goes into that* [...] *Then you kind of lose what you were trying to do to begin with"* (M1).

The main designer on the project described that the GLM tool and 'Stay or Go' method had helped her to work systematically, *"putting in buffers when you might be veering off, to keep steering in the right direction"* (D1). In connection to this, she explained that designing for sustainability is "*a creative process, and it can be hard to articulate why it makes sense or where that has come from"* (D1). She saw the GLM as a "*map to communicating and making it a more logical reasoning [...] both for communication and for putting a process into things"* (D1). With this comment, she touched on a common barrier for the design team to design for sustainability: communicating ideas and getting buy-in from stakeholders in the wider company, such as technicians and managers. The designers described feeling *"kind of stuck in the 'Rohan' way of thinking'"* (M1) and finding it difficult to persuade these stakeholders from the wider company to take risks and try new innovative ideas in relation to sustainability.

To solve this issue, they believed the GLM could be *“a really good way of explaining why a product could be improved”* (M1). The Design Manager thought the tool could enable the team to challenge the status quo and ask: *“Why do we do that? What's the purpose of that?”* (M1). Specifically, he thought that the GLM was helpful for communicating and making discussions around DfS concrete because: *“you can actually visualise it, you can see it, and you can plot things into it. And that means you talk about it”* (M1). He was particularly fond of how, in the first workshop (Study 4a) *“we had the Tech Manager in there, and we had the Communications Manager in there”,* he felt the tool had enabled them to find a common language to discuss DfS which might otherwise have been difficult: “*I think if we had tried to communicate this, just us in the design team to the Garment Tech, I think she would have been like: ‘I don’t get it’”* (M1).To this, the designer, who had been working with the tool the most, added: *“From my experience, when you’re sharing design work, it usually gets more buy-in if you tell a story [...] And I think it would be a really useful tool to help tell the story”* (D1). She added: *“If we were doing a presentation to our directors, and they understood the matrix [...] It’s a very instant visual to understand why we have done like this instead of spending half an hour trying to go through the reasoning”* (D1).

8.3.3. Discussion of findings Study 4b

This study built on findings from Study 3b to further test and validate the GLM framework and the ‘Stay or Go’ method as support for designers to select and implement appropriate DfS strategies, for their efforts to have efficient impact.

Taking a systematic approach - the ‘Stay or Go’ method

The findings from this study confirmed the ‘Stay or Go’ method, used in combination with the GLM tool, as support for participants to take a systematic approach to DfS. This was demonstrated through the participant’s descriptions and depictions of how she had used the method: for each concept, she had marked the original position (red dot) and desired position of each of the garments in the GLM, as shown in Figure 78. She described how these maps had supported her to track her movements during the design process and to *“keep steering in the right direction”* and “*putting a process into things”* (D1).

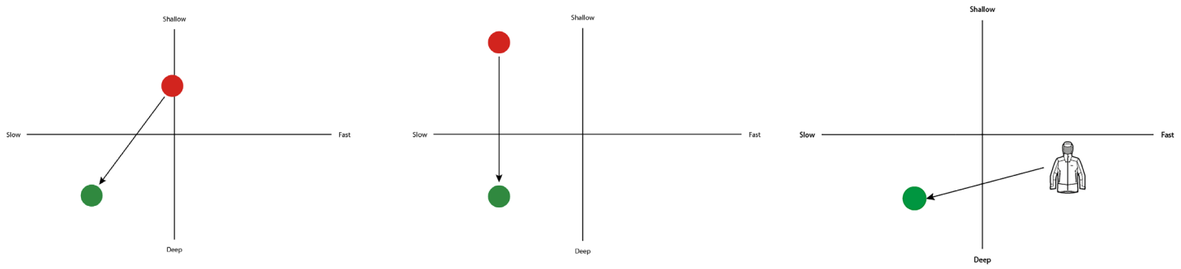


Figure 78. Participant’s visual maps to indicate of how the ‘Go’ approach had been used

She found that the ‘Stay or Go’ method had been particularly useful in the beginning of the design process; *“using it to think about where it sits at the moment and where we want to get it to [...] and thinking about how you can approach it”* (D1).

To further evidence and analyse how the ‘Stay or Go’ method had been applied in this study, the position of the original garments and the position of the various generated outcomes were mapped in the GLM in Figure 79 below by the researcher. Each garment was annotated according to whether the process had been a result of either the ‘Stay’ or ‘Go’ approach. Each garment’s placement was based on the main designer’s own visual maps and descriptions.

Besides documenting the usage of the ‘Stay or Go’ method, this visual map (Figure 79 below) also demonstrates a general tendency for the designer to choose the approach of ‘Go’ to move towards the ‘slow/deep’ half of the GLM. This confirmed the assumption made in Section 8.1., that ‘Stay’ or ‘Go’ method, likely will urge designers to ‘Go’ towards the ‘slow’ GLM half. In this case because this quadrant was particularly relevant as its *recipe* is most in line with Rohan’s core brand-value of selling durable garments.

Taking a holistic approach to selecting and applying appropriate DfS strategies

The findings from this study confirmed the GLM tool and the ‘Stay or Go’ method as useful support for designers to take a holistic approach to DfS. The participants described how working with the GLM had provided them with an understanding of how “*everything has to be considered and everything affects everything else in a way”* (D1). This was evident through the many concept ideas which were generated through this study: these concepts demonstrated how participants had incorporated consideration of the various *enabling factors* for DfS (represented as *ingredients* in the GLM *recipes*). This is evident both in the design outcomes and recordings of participants’ presentations.

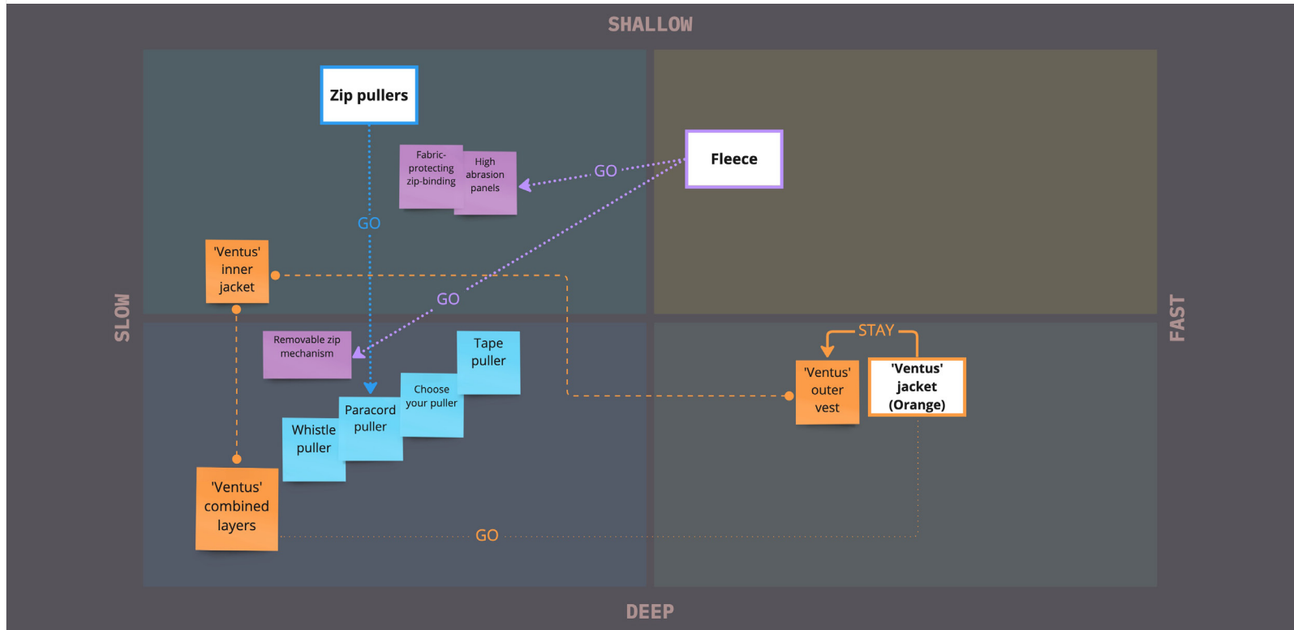
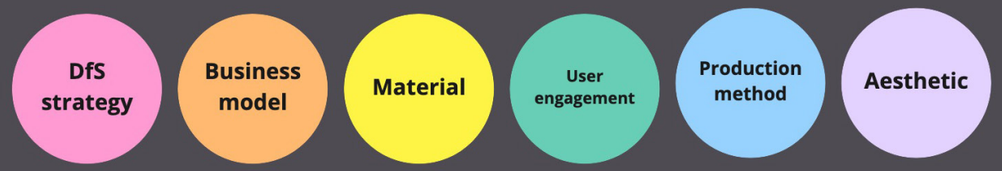


Figure 79. Garment concepts generated during Study 4b mapped in the GLM. Annotated according to use of ‘Stay’ or ‘Go’ method

To illustrate how each concept had incorporated the GLM *ingredients*, the map in Figure 79 above, was further annotated with the *ingredients* that had been incorporated in each case, here in Figure 80. The generated concepts were placed in the GLM by the researcher, but their positions and the quotes indicating how the *ingredients* had been implemented, were based on the main designers' presentation, and participants' discussions during Session 2.



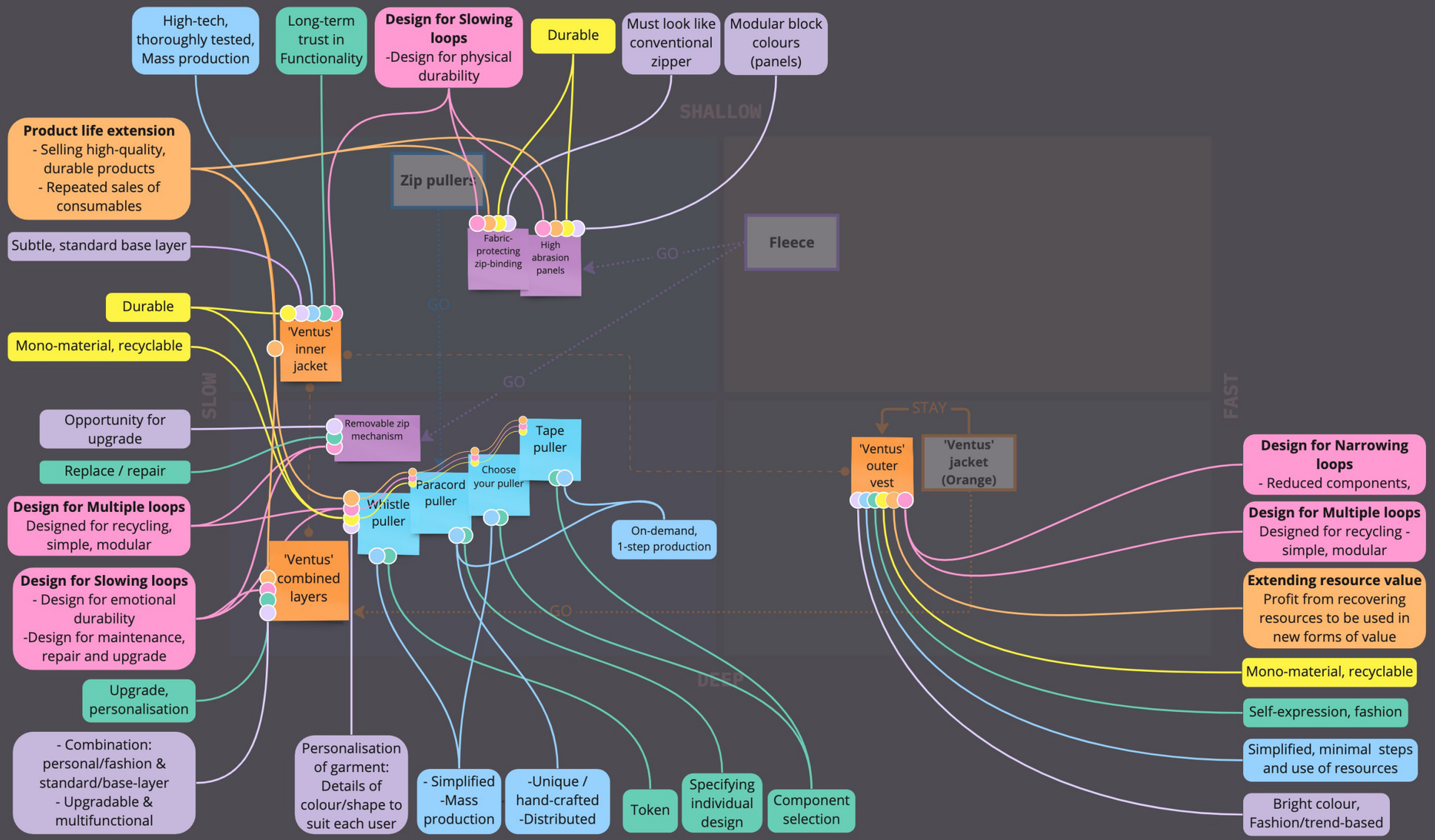


Figure 80. *Garment concepts generated during Study 4b mapped in the GLM, annotated with GLM ingredients*

Figure 80 indicates that the participants had included consideration of all the GLM *ingredients* in most of the developed garment concepts. One example is the 'Ventus' vest , the modular, layered jacket concept, the two components of which are placed in different parts of the GLM (the 'fast/deep' and 'slow/shallow') since each component's design had followed a separate GLM *recipe*. Essentially, the designer had followed a separate design brief for the inner jacket component to the one used for the outer vest-part. This jacket's components had entirely different proposed business models: for the vest-part, profit was to be generated from sales, as well as from recovering and reusing its materials once discarded after a short use phase. In contrast, the 'slow/shallow' inner-jacket component's business model was to rely on selling high-quality, durable products, accompanied by repeated sales of consumables (i.e., the vest-component). The designers used DfS strategies of design for 'narrowing' and 'multiple loops', by choosing a minimal, mono-material garment-structure for the 'fast/deep' vest-component, to make it as resource efficient and recyclable as possible. In contrast, the 'slow/shallow' jacket-component had been designed using the strategy of 'Design for slowing loops'; specifically focused on physical durability. As Figure 80 shows, the two 'Ventus' components also followed different strategies in terms of the remaining GLM *ingredients* of 'material', 'aesthetics', 'points of user engagement', and 'production method'.

A suitable tool for the way designers communicate and work

The above abilities of the GLM were especially attributed to the tool's matrix structure and concise prompts given in the *recipes*. In the feedback-session, the main designer described how these features had enabled her to work iteratively, "dipping in and out", between design experiments, then coming back to the GLM for information and inspiration. As seen above, the *recipes* enabled the designer to combine considerations around the various *ingredients* in such a way that these complemented each other to form sustainable solutions. The interactive format of the GLM tool was seen as particularly helpful for this; initially she used it to gain an overview of DfS aspects, and then during the design process, the designer would return to "expand it" to reveal layers of information when needed. Furthermore, participants described the practice-examples provided as Pinterest boards as particularly useful for inspiration and understanding how strategies can be implemented.

Cross-disciplinary, cross-level communication and collaboration around DfS

Finally, this study showed potential for GLM to support communication, and potentially collaboration, with stakeholders from other disciplines around DfS. In the feedback-session, participants described how the GLM's visual framework-format had supported communication and discussions around DfS ideas with other stakeholders (i.e., a Technical Manager and a Communications Manager). Furthermore, the design team believed that the GLM could be a powerful tool for them to challenge existing practice and get buy-in from directors and managers to impact change at a bigger scale.

Specifically, because they saw the GLM as a way to quickly and systematically visualise important areas to focus sustainability efforts and provide effective reasoning for DfS decisions in new proposed concepts.

8.4 Chapter summary

The studies described in this chapter, Study 3b and 4b, were conducted to conclusively respond to RQ4: *how might considerations of the most important design factors be structured to guide decision-making processes to enable efficient, systems-aware Design for Sustainability?*

These studies each comprised a design experiment where designers from a global swimwear brand (Study 3b) and an outdoor garment brand (Study 4b) redesigned products from their range to be more sustainable. In these studies, the designers tested the GLM tool in combination with the 'Stay or Go' method as support for them to design efficiently with DfS strategies. The studies showed a significant difference between the product-types offered by the two involved brands with the swimwear brand's garments representing a much faster use phase pace, and generally lower levels of user engagement than Rohan's products. This difference enabled these studies to validate the GLM tool's efficiency across a broad spectrum of garments, spanning across both axes of the GLM. The key ways in which these studies validated the GLM tool and the 'Stay or Go' method as support for DfS are summarised below:

Working creatively

Both studies (3b and 4b) demonstrated that the GLM *recipes* and the embedded practice examples (Pinterest boards), provided support for the designers to spark new ideas and work creatively with DfS strategies. The designers found the GLM *recipes* to be useful, concrete guidance, which at the same time was open enough to experiment and be creative. In some cases, designers described using the GLM *recipes* as a form of "checklist" to make sure they had taken aspects from the system surrounding the product into consideration. Others used the *recipes* more sporadically, returning to them as needed.

Working systematically

For the designers, the GLM's structure provided a comprehensible, concrete starting point for entering the complicated task of DfS, which, as established in Chapter 4-6, requires consideration of multiple factors to be efficient. Both studies showed how the GLM tool and 'Stay or Go' method supported designers to structure ideas and work systematically.

Taking a holistic approach

The studies in this chapter also demonstrated how the GLM tool supported designers to take a holistic, systems-aware approach to DfS. The design-concepts generated as outcomes from designers applying the GLM's principles in practice all contained elements that evidenced how they had considered most/all the GLM *ingredients* (which represent the set of *enabling factors*).

Selecting, combining, and applying *appropriate* DfS strategies

As established in Chapter 2, taking a holistic approach is a necessary but complex challenge for designers who aim to design efficiently for sustainability. The designers who participated in Study 3b and 4b described that the GLM tool had helped them to organise such considerations: The findings from these studies showed how the GLM tool's *recipes* and 'Stay or Go' method had enabled designers to gain an overview of the key forces at play in the case of each garment, and an understanding how these affect each other (diagnosis), and then, to instrumentalize this knowledge in practice (design experiments) to select and implement appropriate DfS strategies for the particular garment and use-context.

Communicating and collaborating around DfS

The two studies in this chapter both demonstrated that the visual, framework-format of the GLM had enabled designers to communicate and discuss DfS decisions, both with other designers and colleagues from other disciplines. Finally, the studies indicated potential for the GLM to serve as support for designers to collaborate efficiently with stakeholders from other parts of a company around DfS.

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Chapter 9

Concluding summary

This thesis has presented new understanding on the most important factors at play when designing garments to be sustainable, and how these factors correlate to impact garments' lifecycles. The specific emphasis has been on enabling designers to negotiate these many interrelated factors in their design process, for their efforts to have efficient, positive impact on garment sustainability.

A successful shift to a sustainable, circular model of fashion consumption requires a significantly different approach to garment design, and to empower the designer to make informed and qualified decisions about which DfS strategies will constitute the best practice within the specific context of their brief.

Whilst there are a variety of strategies and tools for DfS available, these fail to provide support for designers to design efficiently with DfS strategies for two main reasons: firstly, they fail to enable holistic consideration of DfS factors, which includes a spectrum from mechanistic to human-related, intangible factors. Secondly, they fail to provide clear, actionable guidance which enables designers to negotiate these factors, to competently select and implement appropriate DfS strategies for the particular garment, user and context they are designing.

This thesis has aimed to redress this issue, with particular attention to the garment industry, an industry that requires urgent attention to curtail its current enormous contribution to climate change and pollution of our planet.

As developed in Chapter 2, designing for a circular economy encourages a systems thinking approach, both in terms of understanding the various properties of the components that comprise a product (as opposed to understanding a product as a singular and cohesive object), and also in terms of the various actors, factors and elements that make up the whole system within which the product exists. Two crucial aspects for designing in a circular economy were identified through a literature review in Chapter 2: (i) a consideration of the pace at which a product moves through its lifecycle; (ii) and the increased importance of the role of the consumer both in the design process, but more importantly, in determining the nature and length of the product's lifecycle, and the reintroduction of its components into a circular system. Understanding levels of user engagement will affect the sort of DfS strategies that a designer will be able to implement. Building upon theories of emotional durability and product attachment by Chapman (2005), Fletcher & Tham (2004), this thesis argues that an understanding of the willingness and the emotional investment of a user affects the way a product's lifecycle will develop, and accordingly the correct approach to DfS that the designer should endeavour to implement.

Paying attention to these two key aspects help decide what the most crucial factors for garment sustainability are and provide actionable support for designers. The studies in this thesis build upon this understanding and implement them in best practices guidance. Through a combination of comparative case studies and consumer interviews, relevant factors that affect garments' lifecycles and determine their environmental sustainability were identified. Whilst a set of key *enabling factor*s for sustainable design ('DfS strategy', 'Business model', 'Production method', 'Points of user engagement', 'Materials', and 'Aesthetics') were identified as important considerations, two *primary factors* were established as being categorically fundamental to guide decisions in enabling efficient DfS: 'Use phase pace' and 'Depth of user engagement'.

This is particularly relevant in regard to designing garments as both of these *primary factors* are exceptionally variable and influential for this product-type: Garments have notoriously fast lifecycles, but in some cases, they actually last a lifetime; they generally serve as a means of self-expression, often leading to a strong emotional user-product bond, compared to, for instance, a toothbrush. However, many cheap fast fashion garments are also seen almost as a disposable commodity. Furthermore, the correlation between these two *primary factors* is exceptionally strong for garments; their life expectancy varies significantly depending on users' engagement (i.e., a user will rarely maintain or keep using a garment which they feel no connection to), and vice versa: users' engagement will often be affected by the expected length of the use phase.

The primary and enabling factors, and the relationships between them, were articulated in the Garment Life Matrix (GLM) framework, which was proposed as support for DfS. The GLM illustrates that the conditions for a garment to be sustainable varies significantly depending on the two *primary factors* of 'Use phase pace' and 'Depth of user engagement'. Thus, the GLM prescribes that all other decisions on enabling factors cascade from a clear definition of the *primary factors*.

The GLM's structure, in which the *primary factors* are pictured on two axes in a coordinate plane, defines a possibility space within each of the GLM's quadrants where the certain DfS strategies will be more appropriate than others. Each quadrant contains a different *recipe*, which further supports designers by specifying how the characteristics of each *enabling factor* (represented as *ingredients)* can be adjusted and combined to form a sustainable solution.

The GLM's ability to support DfS was tested and validated through a series of studies with garment designers who used the GLM tool and the complimentary 'Stay or Go' method as support for DfS: first, to diagnose the sustainability of their current practice and pin-point relevant opportunities to improve this, and then as support for redesigning a selection of garments for sustainability. The data collected during these studies, as well as the garment concepts and prototypes which resulted from the design experiments, confirmed the GLM tool and the 'Stay or Go' method as useful for garment designers to design efficiently with DfS strategies.

These contributions have improved existing support for DfS by providing guidance that:

- Is suitable for the way designers communicate and work, by providing the visual, interactive GLM tool, which clearly communicates information on different aspects of DfS, articulates how they correlate, and lets designers map their own practice in relation to these aspects.

- Enables designers to engage in cross-disciplinary collaboration around DfS, by providing a central framework where stakeholders can map and discuss their practice in relation to DfS aspects.

- Enables holistic consideration of DfS factors, by providing the GLM *recipes,* which prompt consideration of the full set of *primary* and *enabling* factors, which includes a broad spectrum of factors from product-scale to systems-scale aspects, as well as human-related, intangible factors.

- Enables designers to select and combine appropriate DfS strategies, by putting DfS factors into a relationship and a hierarchy and articulating this in the GLM framework. By communicating how these aspects correlate, in the GLM *recipes*, the GLM enables designers to competently negotiate them in a DfS process.

9.1. Meeting the research objectives & contributions to knowledge

This thesis has been developed in response to a discernible lack of straightforward and actionable support for garment designers to take a holistic approach to Design for Sustainability -specifically, the developed support should enable them to:
i) negotiate the multiple factors that affect garment sustainability, and
ii) instrumentalise this knowledge to select, combine and employ appropriate DfS strategies for the particular garment and its use-context.

Thus, it was important to first identify the most influential factors for garment sustainability and generate an understanding of how these factors correlate to impact on garments' lifecycles. This understanding was necessary for developing new support for garment designers which enables them to negotiate these key factors, to design efficiently with Design for Sustainability strategies. In the following sections I shall describe how this research has addressed these research objectives, and how this has contributed to previous knowledge.

To begin, the research objectives were clarified through a phase of qualitative exploratory research focused on the following research question:

9.1.1. Responding to RQ1. *What support do garment designers currently have to design for sustainability?*

To address this question, a review of literature on DfS (reported in Chapter 2) was conducted. This enabled an understanding of the requirements for design to be able to contribute to a shift from a linear to a circular fashion system, and an understanding of how designers currently are supported to contribute to this.

Such a shift relies on the collaboration of a network of actors participating in different parts of the fashion system, and this fundamentally changes the role of users and designers:
- Users become important actors who determine the speed of garment lifecycles and the closing of material loops.
- Designers necessarily take on the role of systems thinkers and facilitators of collaboration between network actors.

The literature revealed that designers currently aren't sufficiently equipped to take on this new role. The increased complexity of the design process makes it challenging

for designers to identify where best to focus their efforts to design sustainable outcomes. Despite a substantial amount of existing DfS strategies and tools, there is still no evidence of their tangible impact on the fashion industry. The review of literature identified two main shortcomings of current DfS support, preventing impactful implementation within the fashion industry.

On the one hand, DfS support (a) can tend towards a narrow focus on functional, mechanistic aspects of design, neglecting important broader factors such as human-related aspects (e.g., user behaviours, emotional attachment, aesthetics, norms, and trends), business models and supply chain infrastructure. This ultimately leads to support that only offers guidance for incremental product-level innovations, rather than holistic approaches that encompass more complex system-level innovations (e.g.) Byggeth and Hochschorner (2006) describe how *"important aspects, from a sustainability perspective, are often missing in the tools (for example social and economic aspects together with ecological aspects), which can lead to incremental changes without the long term in mind"* (p.1429), and, focusing specifically on tools for DfS in fashion, Kozlowski et al. (2019) also demonstrate a clear lack of tools that can support higher levels of innovation in their analysis.

There is a need for tools to support designers to consider and negotiate the many factors at play in DfS in their practice. This holistic level of support is particularly important for garment designers working in fashion who wish to adopt DfS approaches, in an industry in which the intangible and immaterial aspects of the product are inextricable from the material product itself. As discussed in Chapter 2, Payne explores at length the immaterial aspects of fashion, focusing on what she terms "weightless design objects" (2021, pp.123 -140). Payne details how aspects of fashion design such as brand story, trends and styles determine the material product and its lifecycle. Current DfS support, in its narrow and granular focus on design processes, overlooks these crucial elements, and does not provide adequate support, such as a tool, which enables designers to negotiate these factors.

On the other hand, (b) where DfS support does aim to address a broader range of DfS factors, the result is often overly complex and difficult to both understand and implement as a designer. As Kozlowski et al. puts it, such approaches *"fail to fully take the complex idea of sustainability and simplify it into clear digestible resources and actions"* (2019, p.4). Kozlowski et al. goes on to observe how this typical approach *"entails providing descriptions, definitions, examples, and further readings but lacks the "how-to" component to integrate these strategies into a fashion business and design practice" (*p. 15). Numerous factors are specified for the designer to consider, but too rarely is intelligible guidance provided for how to implement the consideration of these factors into the design practice. The result is that the designer is often left feeling overwhelmed, "*unsure as to where best to start, and how to be most effective"* (Stevenson et al., 2011, p.4).

This problem is fundamentally one of communication, in which the information is there, but is not effectively presented. These approaches fail to efficiently convey information for the designer to implement; as Kozlowski et al. (2019) puts it, these approaches need to "speak the language" of design by providing, as Lofthouse (2006) suggests: a combination of information, inspiration, education, and guidance. This is particularly critical for fashion designers who move iteratively between stages of 'idea', 'concept' and 'design' (Dieffenbacher, 2013), rather than following a strictly linear design process from concept to production.

Furthermore, as broadly agreed in literature (Coley & Lemon, 2009; Wever & Vogtlander, 2014; Ceschin & Gaziulusoy, 2020; Brown et al., 2021) the implementation of higher innovation level approaches cannot be reached by designers working in isolation but requires them to collaborate across disciplines and organisation-layers. However, as outlined by Brown et al., (2021), there is a lack of support that facilitates collaboration which, again, can be linked to the complexity and lack of practical guidance in existing tools.

The understanding of the two main-shortcomings of existing DfS tools (a & b), generated in the literature review, led to the specification of four criteria which DfS tools ideally should fulfil to provide efficient guidance for garment designers. Namely, that DfS tools should:

1. Be suitable for the way designers communicate and work (i.e., be visually appealing and suitable for use in iterative processes)

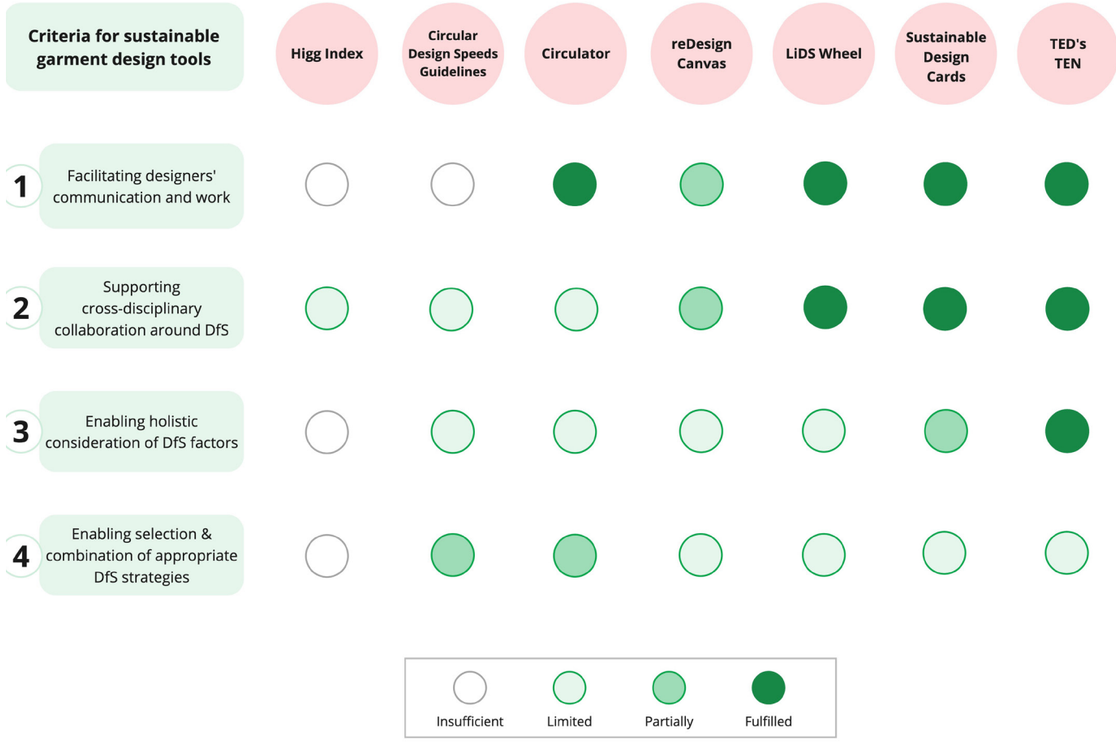
2. Enable designers to engage in cross-disciplinary collaboration around DfS

3. Enable holistic consideration of DfS factors (i.e., mechanistic and tangible as well as human-related and intangible; at the scale of the product as well as the business models and supply chain infrastructure)

4. Enable designers to select and combine appropriate DfS strategies.

The review of existing tools for sustainable garment design (Section 2.5.3.) revealed that many existing tools partially fulfil these criteria. A few of them fulfil almost all of them. However, as visible in Figure 81. no previous tools fully fulfil the fourth criterion; even the most advanced previous tools fail to enable designers to select and combine appropriate DfS strategies.

Figure 81. Heatmap of Reviewed DfS tools according to the four DfS tool criteria



The discrepancy between existing DfS strategies and tools, and their effect on change in the fashion industry, is the primary point of interest of this thesis. Accordingly, the following research questions were proposed:

RQ2. How have existing DfS strategies been applied in practice?

RQ3. What are the most important design factors for garment sustainability?
RQ3a. How might these factors be related?

RQ4. How might considerations of the primary design factors be structured to guide decision-making processes to enable efficient, systems-aware Design for Sustainability?

In the following, I shall summarise the findings developed in response to these research questions and describe how they contribute to existing knowledge in the field of sustainable garment design.

9.1.2. Responding to RQ2:
How have existing DfS strategies been applied in practice?

This research question was addressed in Chapter 4 through a review of state-of-the-art examples of businesses which have applied DfS strategies in their practice to understand which strategies have been used and how. Furthermore, this chapter investigated the characteristics of successful models.

Thematic Analysis of these cases revealed that they have all applied a combination of different DfS strategies, across innovation levels and in widely different ways. Importantly, it also revealed that the sustainability of each model can be attributed to a series of factors that lie outside of the design of the physical product in itself.

Further analysis of the characteristics of these cases' models and products revealed a pattern in the types of overarching factors which these characteristics relate to. The "factor-themes" which resulted from this process were proposed as a set of the most important *enabling factors* for DfS, comprising: 'DfS strategy', 'Business model', 'Production method', 'Points of user engagement', 'Materials', and 'Aesthetics'. Thus, this chapter also contributed towards responding to RQ3.

9.1.3. Responding to RQ3:
What are the most important design factors for garment sustainability?

To begin to address the identified gap in knowledge (and respond to RQ3), a series of studies were conducted, which enabled the establishment of the enabling *factors*: the most influential factors for the environmental impact created throughout a garment's lifecycle, that are crucial for garment designers to consider in DfS.

The *enabling factors* were discovered through a funnelling process:
First, as reported in Chapter 4, the comparative study of business cases revealed the first iteration of the *enabling factors.* This set of *enabling factors* were tested, validated, and developed through Studies 1 and 2 (Chapter 5). Study 1, which consisted of a series of consumer interviews, confirmed, and enriched the understanding of the *enabling factors'* influence on the lifecycles of garments informed by consumers' perspectives. Then, in Study 2, the *enabling factors* were further validated and refined by drawing in the experience and perspectives of garment industry professionals through a focus group-session. Finally, the supplementary review of literature, described in Chapter 6, enabled more refined understanding and definition of each *enabling factor*.

By establishing the set of *enabling factors* for DfS, this research has contributed to previous comparable collections of factors proposed in support for DfS, such as: the eight "steps" in the LIDS Wheel-tool (van Hemel & Brezet, 1998), or the "building blocks" in the ReDesign canvas tool by Kozlowski et al. (2018), or the factors included in the Circular Design Guidelines by Goldsworthy et al. (2019). Despite representing the most sophisticated amongst the DfS reviewed tools in Chapter 2 (literature review), these all lack consideration of users' emotional and physical engagement with garments. Instead, they focus on the functional and mechanistic aspects of DfS. The *enabling factors* identified in this thesis add to existing knowledge by including a nuanced consideration of user engagement as one of the most important factors for DfS. This factor has been described as essential for enabling sustainable consumption of garments by scholars such as Chapman (2005), Fletcher and Grose (2012), and Payne (2021), but it has never been included as a key factor in a DfS tool.

Thus, the establishment of this set of *enabling factors*' contribution to knowledge lies not in the identification of each *enabling factor*, but in the curation of these specific factors to form a set which covers both mechanistic and human-related aspects of DfS, and proposing these as the most important factors which garment designers should consider in order to achieve sustainable outcomes. Importantly, as we shall see in the following section, this research contributes further to knowledge by generating an understanding of how these factors correlate to affect garment lifecycles.

9.1.4. Responding to RQ3a:
How might these factors be related?

The studies reported in Chapter 4 and 5 first revealed the relationships between the six *enabling factors*. From these studies it emerged that the *enabling factors* affect each other, and that they concurrently affect garments' lifecycles. Furthermore, the findings from these studies led to the identification of two of these factors as supremely influential *primary factors,* which have decisive impact on the other *enabling factors*, namely, 'Product life expectancy' and 'User engagement'.

The identification of the two *primary* factors for DfS builds on and extends previous knowledge by scholars such as Fletcher and Tham (2004), Armstrong et al. (2016), and Goldsworthy et al. (2019), whom each have proposed that garments' lifecycle "speed"/ "metabolism" and users' emotional attachment are important factors for designing "appropriately durable", sustainable garments. However, these sources have not specified these two factors as *primary factors* for DfS.

The iterative Research Through Design processes described in Sections 5.1.3. and 5.4. confirmed and developed the understanding of the relationship between the *enabling* and *primary factors*.

Furthermore, these experiments led to the establishment of a framework which articulates the correlation between these factors, the Garment Life Matrix. The first, simple version of the GLM, developed in section 5.1.3., showed only the correlation between the *primary factors* by placing them on two axes in a coordinate plane.

The generated understanding, and articulation of the correlation between the *primary factors* also builds on and extends previous knowledge by scholars such as Alistair Fuad-Luke (2010), Kate Fletcher (2012) and Jonathan Chapman (2005) who each advocate and draw a link between enhancing users' emotional attachment to extend a product's use phase. However, no previous work has articulated this relationship through a visual framework as this thesis has in the GLM.

The further visual mapping experiments, described in Section 5.4, in which garment types from Studies 1 and 2 were mapped into the GLM framework, developed further understanding of the relationship between the *primary* and *enabling factors*. The visual maps which emerged from these experiments revealed how the *enabling factors'* characteristics vary depending on the *primary factors*, and how these characteristics should be configured, for the garment they constitute to be suitable for a sustainable, circular consumption. Crucially, these mapping experiments revealed that the conditions for designing a garment to be sustainable in each of the four quadrants of the GLM, which represent different segments of the garment market, vary considerably. The final visual map, described in Section 5.4., enabled the proposal of the GLM *recipes,* which specify *how* garments' characteristics should vary depending on these changing conditions. Each *recipe* provides a particular set of characteristics *(ingredients)* that designers should strive to follow, to design efficiently for sustainability in each of the GLM's quadrants.

The supplementary review of literature in Chapter 6 situated the empirical findings from Chapters 4 & 5 within a review of DfS literature, to further refine the understanding of how the *ingredients* (*enabling factors)* in each *recipe* should be configured to ensure their guidance will lead to a sustainable outcome. Furthermore, this chapter finalised the names of the *primary factors*: 'Use phase pace' and 'Depth of user engagement'.

The understanding of the correlation between the *enabling* and *primary factors* generated through these studies complements, rather than replaces existing knowledge: plenty of sources in literature describe similar factor-relationships: Fletcher & Tham (2004), link certain aesthetic characteristics to specific lifecycle speeds of garments, Belk (2014) links certain forms of user engagement to specific business models, and Chapman (2021) links certain levels of user engagement to specific production methods. However, no previous sources have described the relationship between multiple factors at the time, like this work, which develops an understanding how the many *enabling* and *primary factors* concurrently influence garments' lifecycles.

The most important contribution to knowledge developed from the studies and experiments reported in Chapter 5, is the GLM tool which, with its *recipes* and *ingredients*, articulates the relationship between the *primary* and *enabling factors*. No previous research has clearly and visually articulated the relationship between such a range of factors as the framework produced in this work, and no previous research has instrumentalized this in a framework to support DfS. Specifically, how the framework was tested and developed to support designers, is summarised in the following.

9.1.5. Responding to RQ4:
How might considerations of the most important design factors be structured to guide decision-making processes to enable efficient, systems-aware Design for Sustainability?

A subsequent question that emerges from RQ3 (What are the most important design factors for garment sustainability?) and RQ3a (how might these factors be related?) concerns how these factors are ordered and implemented into the design process. An important component of this thesis is an investigation of how the various factors of DfS approaches to garment design inter-relate and affect one another holistically, and how the designer can determine not only which is the most important, but how these factors can be arranged and structured to guide decision-making processes. How current DfS approaches consider this question was examined in the literature review (Chapter 2), which, in summary, made the following observations on current trends in DfS support (detailed above in RQ1 discussion, p.274):

Two main problems confront the designer who wishes to utilise current DfS approaches, to identify and structure considerations of design factors and implement them into their design process. The first is an insufficient consideration of factors and an overly granular approach, focused on functional and mechanistic, and overlooking the equally important intangible aspects of design. The second is an overly complex understanding and presentation of design factors that does not effectively communicate 'theoretical knowledge' to designers and does not support collaboration.

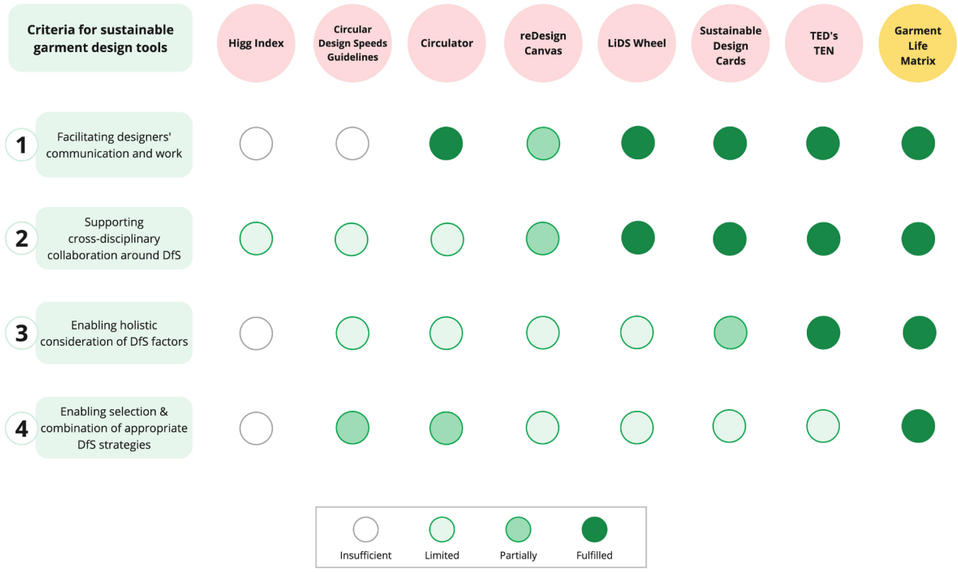
In response to these identified shortcomings, this thesis proposed new support for sustainable garment design: the Garment Life Matrix tool, and the supplementary 'Stay or Go' method. These were specifically designed to offer applicable guidance for garment designers to conduct efficient, systems aware DfS. The proposed tool and method emerged as the result of a series of Research through Design (RtD) experiments (described in Section 7.1.2), which used the findings from Chapters 4-6 (the *primary* and *enabling factors*, the understanding how they correlate, and their articulation in the GLM) as input.

The tool consists of a digital, interactive matrix framework (the GLM), constructed from two axes (representing the *primary factors* of 'Use phase pace' and 'Depth of user engagement'), which split the framework into four quadrants. Within each of these quadrants, DfS guidance is provided as *recipes;* collections of *ingredients,* prompts for consideration of a holistic set of factors (i.e., the *enabling factors*). The 'Stay or Go' method provides designers with a systematic approach. The method encourages them to focus on one of GLM quadrant's (following one *recipe*) at the time; guiding them to either *stay* in one GLM quadrant, or if the *recipe* doesn't seem like a good fit (for the garment at hand, the user, or the company), explore what *going* to other quadrants might entail and enable.

The GLM tool and method were tested and developed in two phases: first, through study 3a & 4a (Chapter 7) where garment designers and industry professionals used the tool and method to diagnose the sustainability of their current practice and discover relevant opportunities to improve. Then, in study 3b & 4b (Chapter 8) where designers utilised this knowledge from the previous diagnosis-studies in conjunction with the GLM tool and method to *select and implement DfS strategies in practice.*

The understanding of the two main-shortcomings of existing DfS tools, generated in the literature review, informed the specification of the four DfS tool criteria (described in relation to RQ1, p.274). The review of existing DfS tools (Section 2.5.3.) revealed that many existing tools partially fulfil these criteria. A few of them (i.e., The LiDS Wheel, the Sustainable Design Cards, and TED's TEN) fulfil almost all of them. However, no previous tools fully fulfil the fourth criterion; even the most advanced previous tools fail to enable designers to select and combine appropriate DfS strategies. In comparison, as demonstrated in Figure 82, the GLM tool (marked in yellow) proposed in this thesis, surpasses previous DfS support by living up to all four of the criteria.

Figure 82. Previous DfS tools and the GLM tool rated according to ability to fulfil DfS tool criteria



The GLM tool and the 'Stay or Go' method were designed with the goal of providing DfS support which lives up to these criteria, and thus address the two main shortcomings (a & b) of existing DfS support, described above. As visible in Figure 82, existing tools certainly do live up to a lot of the criteria, and many of them indeed have a track record of providing useful DfS support for designers in practice. The following sections will discuss the ways in which the GLM tool and 'Stay or Go' method live up to the four criteria, and compare these abilities to previous DfS tools, to demonstrate this thesis' practical contribution to knowledge.

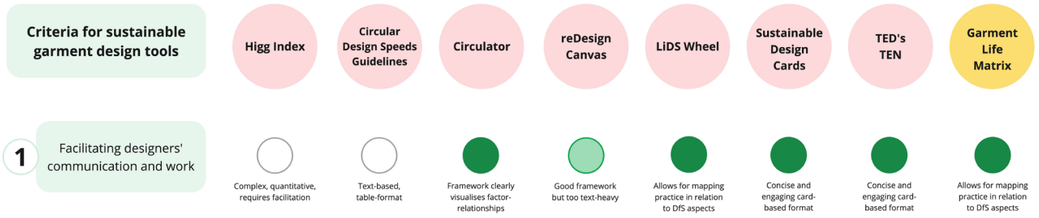
1. Facilitating designers' communication and work

This criterion is based on a broadly accepted viewpoint in DfS literature (Baumann et al., 2002; Eskandarypur et al., 2009; Gómez Navarro et al., 2005; Connor-Crabb, 2017), that the best way to communicate information to designers is through "visually appealing" formats, rich in graphics rather than text. Another key part of this criterion, is that tools should be able to support iterative processes where thinking occurs through cycles of experiments, which, as established in the literature review, is how garment designers usually work.

To fulfil this criterion, the GLM tool is designed to be visually comprehensible with few elements; consisting of two axes and four quadrants, and a minimum amount of written information (in the *recipes*). Furthermore, the tool is built in a digital, interactive format, which allows for layering information so that more detailed guidance only is revealed if selected. The effect of these design-choices was demonstrated in the practice-based

studies (3a, 3b, 4a and 4b), where designers tested the GLM tool as support for DfS. During workshop sessions, observations showed that designers quickly and easily were able to understand and use the GLM to analyse their current practice, identify a route to improved sustainability, and, eventually, to guide their selection and implementation of DfS approaches in practice. This was also evident in feedback-sessions where the participating designers reported finding the tool intuitive to use and *"really obvious in the way that it was laid out"* (P1, Study 3b).

Figure 83. DfS tool criterion 1: Previous DfS tools vs the GLM tool



The visually comprehensible format of the GLM tool is not, in itself, a contribution to existing DfS tools for garment designers. As Figure 83 shows, four of the tools reviewed in Section 2.5.3. were also seen as particularly fit for this criterion, namely: the Circulator, the LiDS Wheel, the Sustainable Design Cards, and TED's TEN. The two card-based tools (TED's TEN and Sustainable Design Cards), both keep written information to a minimum, and especially the Sustainable Design Cards, communicate through rich graphic content. Their real strength in relation to this criterion, however, lies in their card-based format which is particularly engaging for designers as it allows them to take an active and "playful" approach to exploring DfS approaches.

The GLM is not card-based but instead engages designers through a digital, interactive framework, which allows designers to explore and interact with DfS approaches through a layered structure, where increasingly detailed information can be revealed as needed. Furthermore, the GLM provides hyperlinks to collections (mood boards) of practical examples shown in Pinterest (online tool widely adopted by designers to find and compile inspiration [Izadpanah, 2021]). The Pinterest boards enable the GLM tool to support communication of the *recipes* with real-world examples, which as Lofthouse (2006) argues, is a preferred form of information for designers. Although the use of practical examples was seen in a few of the reviewed tools (e.g., Sustainable Design Cards and the Circulator), none of these tools, which are all analogue, provide links for designers to discover practice-examples through such an engaging mood board-format. In the studies reported in Chapter 8, designers used the Pinterest boards to discover and discuss new approaches to DfS. Designers reported finding the mood boards "enjoyable", and useful for sharing with other collaborators (e.g. garment technicians) to communicate and discuss ideas.

In regard to providing efficient communication, the review of existing DfS tools (Chapter 2), also showed that framework-based tools (e.g., The LiDS Wheel and the reDesign canvas) are particularly suitable for supporting garment designers for two reasons: Firstly, because they enable an overview of complex concepts and strategies by visually presenting these aspects in one central framework. Secondly, because such frameworks provide a way of visually "recording" a concept in relation to these DfS aspects, which can serve as an anchoring point to which designers (and other collaborators) can return as they move iteratively through their process.

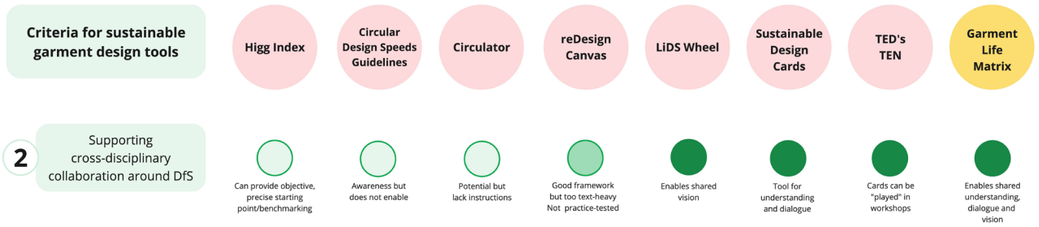
The GLM is also based on a framework-format, and thus benefits from the same attributes as these framework-tools. However, in comparison to these previous tools, the GLM was evidenced as particularly easy to comprehend and use for designers. The reviewed framework tools comprise multiple elements and (especially the reDesign Canvas) quite a lot of text connected to each element. In comparison, the GLM tools' digital format allows for limiting the number of visible components to four quadrants, where textual information is hidden until the *recipes* are opened. This comprehensible format, which represents a landscape (described by the two GLM axes), enabled designers to map garments from their practice into it, and directly relate the tools' elements of guidance to their practice. First, in the studies presented in Chapter 7, teams of garment industry professionals easily mapped their company's range into the framework. This enabled them to visually "record" and diagnose the sustainability of their current practice and discuss a shared vision for improving this. In the studies reported in Chapter 8, designers used the filled-in GLM frameworks in conjunction with the 'Stay or Go' method in DfS experiments to *"keep steering in the right direction"* (D1, Study 4b). In a feedback-session, one participant explained that the GLM tool is useful for supporting DfS decision-making processes because *"you can actually visualise it, you can see it, and you can plot things into it. And that means you talk about it"* (M1, Study 4b).

This ability of the GLM, to support collaborators to talk about DfS brings us to the discussion of the ways in which the GLM tool lives up to the second DfS tool-criterion, related to collaboration around DfS.

2. Enabling designers to engage in cross-disciplinary collaboration around DfS

The review of literature (Section 2.5.2.) revealed a lack of support for designers to collaborate with other stakeholders around DfS. However, this thesis' review of tools (Section 2.5.3.), did in fact identify a few tools that do fulfil this criterion, as depicted in Figure 84. The two card-based tools (TED's TEN, the Sustainable Design Cards) which engage users, including collaborators from other disciplines through game play, and the framework-based tools (the ReDesign Canvas, the LiDS Wheel) which provide a space for visualising, capturing, and discussing ideas, were seen as most able to fulfil this second criterion. Here, the LiDS Wheel is particularly interesting, because its "wheel"-format, in which a product can be mapped, allows the tool to serve as a central framework where collaborators from different backgrounds can visualise a product's current, desired, and achieved environmental profile. By mapping a product into the LiDS Wheel, collaborators can pinpoint aspects of a product's design that should be improved for the product to become more sustainable. This process provides collaborators with a shared vision for how they might improve sustainability.

Figure 84. DfS tool criterion 2: Previous DfS tools vs the GLM tool



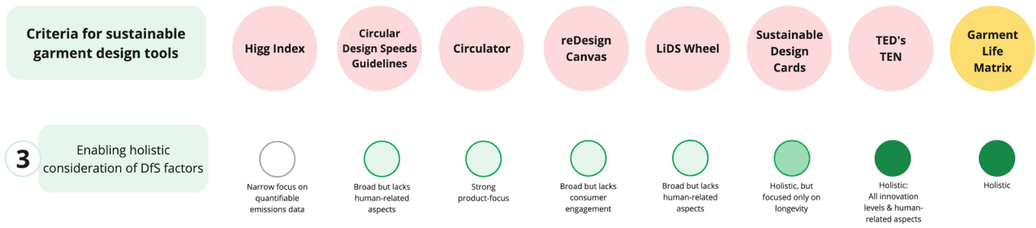
Like the LiDS Wheel, the GLM tool also provides a central framework where stakeholders can map and discuss their practice in relation to DfS aspects. The studies reported in Chapter 7 demonstrated how the GLM framework enabled participants from different backgrounds (garment technicians, designers, managers, and material experts) to collaboratively map their company's current range in relation to the *primary factors* 'Depth of user engagement' and 'Use phase pace'. This process, and the prompts provided in the GLM *recipes,* supported the participants to discuss, as a group, their current practice in relation to the *primary* and *enabling factors*. Furthermore, the *recipes* led these participants to develop a shared vision for how the company might improve the sustainability of the company's range. In the design experiments reported in Chapter 8, which were an extension of the 'diagnosis'-workshops in Chapter 7, the GLM tool supported designers to collaborate with garment technicians, managers, and other designers to implement DfS strategies in practice-based experiments. As one designer said, reflecting on her process during these experiments; designing for sustainability is "*a creative process, and it can be hard to articulate why it makes sense or where that has come from"*, but she felt that the GLM tool had served as a "*map to communicating and making it a more logical reasoning"* (D1, Study 4b). Finally, designers described seeing potential for using the GLM as support for the design team to discuss and critique existing practice, and explain new DfS concepts to obtain support from the company's management: *"when you're sharing design work, it usually gets more buy-in if you tell a story* [...] *And I think it* [the GLM] *would be a really useful tool to help tell the story"*, because *"It's a very instant visual to understand why we have done like this instead of spending half an hour trying to go through the reasoning"* (D1, Study 4b).

In theory, the LiDS Wheel tool, had it been applied in these studies, could also have enabled many of these collaborative processes. However, as we shall see in the following sections, the LiDS Wheel is significantly limited by not living up to the last two of the four DfS tool-criteria, i.e. It only enables consideration of a limited, mostly mechanistic range of DfS factors, and it does not put these factors into a relationship to allow designers (and collaborators) to negotiate them efficiently in a DfS process. Therefore, it is likely that the outcome of these endeavours, if supported by the LiDS wheel rather than the GLM, would have been limited to solutions at the lower product- or component-levels of innovation.

3. Supporting holistic consideration of DfS factors

This criterion was based on findings in the literature review (Chapter 2) which revealed that consideration of a broad set of factors when designing for sustainability is necessary if higher, systems-levels of innovation is to be reached. 'Holistic' consideration entails a full spectrum of factors from mechanistic and tangible, to human-related and intangible; at the scale of the product, as well as aspects in the surrounding system such as business models or supply chains. As described above, the literature review revealed a clear lack of tools that support such holistic consideration of DfS factors.

Figure 85. DfS tool criterion 3: Previous DfS tools vs the GLM tool



As shown in Figure 85, a few of the reviewed tools: the Sustainable Design Cards, the LiDS Wheel, and the reDesign Canvas, include a broad spectrum of factors in their guidance, but still neglect consideration of human-related aspects like aesthetics or consumers' relationship and behaviour with garments. This is critical, as established in the literature review, the sustainability of garments in a circular economy often is contingent on consumers' behaviours.

Furthermore, as pointed out by Ceschin & Gaziulusoy (2020), inclusion of human-related aspects is necessary for DfS solutions to reach higher levels of innovation.

The GLM tool addresses this shortcoming of existing DfS tools by providing the GLM *recipes,* which prompt consideration of the full set of *primary* and *enabling* factors. As described above (p.278), this set of factors includes a broad spectrum from product-scale to systems-scale aspects, such as business model and production methods, as well as human-related, intangible factors directly relevant to fashion design, such as aesthetics and depth of user engagement.

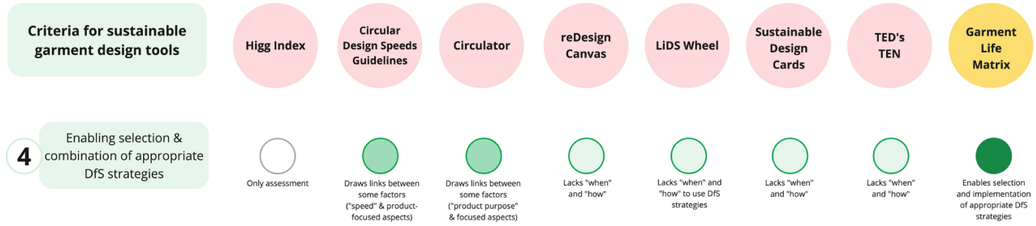
The studies in Chapters 7 and 8 demonstrated how the GLM *recipes* prompted designers to consider a broad range of DfS factors and implement these considerations in holistic solutions. This was revealed in the concept-presentations and prototype outcomes from these studies (3a, 4a, 3b & 4b). The presentations showed how consideration of the full spectrum of *primary* and *enabling* factors, including intangible, human-related aspects, and aspects related to the system surrounding the product, had been included in these solutions. For example, in Study 3b, a modular goggle-concept was generated, whose structure, business model and production method had been specifically designed to be customisable to suit the individual users' taste, emotional attachment and types of expected interactions with its lifecycle. The GLM tool's ability to support holistic consideration of DfS factors was further evident in the recordings of designers' feedback on working with the tool; for example one designer said: *"I looked through all the ingredients and I tried to consider the start of the lifecycle, the end of the lifecycle, like, you really think about it in a holistic way"* (P1, Session 2, Study 3b).

Despite the clear lack of holistic tools, this research did in fact identify one other tool in existence which does fulfil this criterion: The TED's TEN. This tool encourages consideration of factors across the full spectrum from mechanistic to human-related, and product-scale to systems-scale aspects. However, crucially, the TEN tool does not assist designers in utilising such holistic consideration of factors to assess what DfS strategies will be best suited for the particular garment-case they are working on. As unpacked below, it is exactly by closing this "missing link" between information on DfS approaches and enabling designers to competently choose between and combine these in practice, that the GLM tool contributes to and improves previous DfS support.

4. Enabling designers to select and combine appropriate DfS strategies

This final criterion also came from findings in the literature review (Chapter 2) which showed that existing tools often provide plenty of information on DfS and suggestions for approaches but lack guidance on which DfS strategies will be most suitable for applying in each case to reach the desired effect. As Kozlowski et al. (2019) phrase it, existing tools lack the *"how-to"* component to efficiently implement DfS strategies in practice. This lack is critical because, as Ceschin & Gaziulusoy (2020) describe, effectively addressing sustainability challenges requires designers to combine DfS approaches which are complementary and appropriate for each project.

Figure 86. DfS tool criterion 4: Previous DfS tools vs the GLM tool



As visible in Figure 86, none of the reviewed existing tools fulfil this criterion. None of them provide designers with sufficient means to make the leap from awareness and information about DfS strategies to determine when to use what strategy, and how these might be combined to have efficient impact. Some tools, e.g. TED's TEN, the Sustainable Design Cards, and the reDesign Canvas, do provide useful pointers to compatible approaches, but lack advice on when to apply these to optimise the sustainability of the garment being designed.

It is by closing this "missing link" between providing theoretical information on DfS approaches and enabling designers to competently select and combine these in practice, that the GLM tool contributes to and improves on previous DfS support. Rather than "just" providing an overview of DfS aspects or approaches, like most of the reviewed tools, the GLM puts these aspects into a *relationship* and a hierarchy and articulates this in the GLM framework. By communicating how these aspects correlate, the GLM enables designers to negotiate them in a DfS process. This communication is facilitated through the GLM *recipes*, whose guiding prompts vary from quadrant to quadrant, depending on the *primary factors* represented on the GLM axes. By varying the content in the *recipes*, the GLM tool illustrates what DfS approaches will be the most appropriate to combine and implement for each garment to be as sustainable as possible.

This ability of the GLM tool was tested and validated in the studies reported in Chapters 7 and 8. In Chapter 7 the GLM tool's framework and *recipes* led teams of garment industry professionals to diagnose sustainability of their current practice and pin-point areas or garment-products that were particularly relevant to improve this. By consulting the *recipes* (which sit embedded within the same framework as the one used to conduct the diagnosis), the participant-teams were able to link insights from this activity regarding *what* aspects needed to change, with *how* they might approach this in practice. These insights were brought forward to inform the practice-based experiments reported in Chapter 8. Here, the GLM tool's *recipes* supported designers to, based on insights from the 'diagnosis', select appropriate DfS strategies for each garment-case, and implement these in practice. During feedback-sessions, the designers described how the GLM had enabled them to competently decide between DfS strategies. E.g., one designer said: *"Rather than just making lots of suggestions to what you should think about, this is a tool which will really help and guide your thought-process to think about the products you have, the materials you have, the business model* [...] *and then suggest the things you can do to improve it"* (M1, Study 3a).

The prototype outcomes from these design experiments showed how the designers had selected and adjusted the various aspects of garments' designs by following the relevant *recipes* for each garment's position in the GLM, to ensure these features collaboratively contributed to a sustainable solution. A practical example of this is the layered, modular 'Ventus' jacket, generated in Study 4b: Decisions about every aspect, from the choice of materials, garment-structure, business model, production method, to aesthetic features were carefully navigated and adjusted based on the two *primary factors* of 'Level of user engagement' and 'Use phase pace', represented on the two GLM axes.

While no previous DfS tools close the link between theoretical DfS information and enabling competent selection and implementation of appropriate strategies, two of them do in fact draw connections between a small number of DfS factors, and thus partially live up to the fourth criterion: The Circulator visualises a relationship between garments' "product purpose" (how long and how often the garment will be worn), and six design strategies, and material-properties. The Circular Design Speeds Guidelines describe a relationship between garments' lifecycle speeds and certain design strategies, production methods and material-types. However, as outlined above and visible in Figure 82, these tools have significant shortcomings when it comes to fulfilling other tool criteria. E.g., they both lack consideration of human-related aspects, which will then also limit the usefulness of the links they draw between factors.

Furthermore, these previous tools do not, to the degree that the GLM does, enable designers to relate the provided guidance to their own practice. The Circulator tool does this to a small extent by basing guidance around the "product purpose" of the particular garment at hand. In comparison, the GLM creates a clearer link between guidance and practice: By allowing designers to visually map their own practice in relation to DfS aspects in the GLM, to create a visual landscape where the practice (whether a single garment or the entire range) can be observed, designers are able to understand, in a very direct way, how the various DfS aspects relate to their work. Specifically, this is achieved by varying the provided guidance between GLM *recipes*, and then embedding these *recipes* in the same framework which is used for mapping designers' practice.

A final important aspect which makes the GLM tool particularly competent to fulfil this tool-criterion, is the supplementary 'Stay or Go' method, which supports designers to take a systematic approach when using the GLM; guiding designers to focus on one of GLM quadrant's (following one *recipe*) at a time. Designers who used the 'Stay or Go' method during the studies reported in Chapters 7 and 8, described that the method was instrumental for them to manage the complexity of DfS: The method enabled them to approach DfS systematically and in manageable pieces, while still ensuring that holistic consideration of all relevant aspects of the garment's surrounding system were included. As one designer said: *"This breaks up the whole concept of sustainability into these little categories that help you think about all of it, so that in the end you get way more out of it"* (P1, Study 3b).

Amongst the two previous tools which also draw links between different DfS aspects, it is only the Circulator tool that offers a systematic approach for designers. This tool specifies a four-step process, which guides designers to start by determining the "product-purpose", then select materials and design strategies. However, the Circular does not, like the GLM, allow designers to directly map and track their process in a visual framework.

As seen in the literature review, the complexity of DfS will often be a barrier for designers to engage in DfS, which previous tools do not support them to overcome. However, DfS cannot be reduced or simplified as designing efficiently with DfS strategies necessitates holistic consideration of the many factors which play into sustainability, which naturally entails a certain degree of complexity. Rather, it is about equipping designers to understand and negotiate these factors, and a providing them with a systematic approach to sustainability which, as Kozlowski et al. state *"must be approached in manageable pieces (product-level innovation and associated strategies) but are related and moving towards the bigger systems thinking vision that a designer has established"* (2019, p.16). By fulfilling the four DfS tool criteria, the GLM enables exactly this: Supporting designers to work systematically (following the 'Stay or Go' method), to focus on specific DfS elements at the time, to combine the various aspects of a sustainable solution (following the GLM *recipes*), and yet, by locating these efforts within the greater GLM framework, always ensuring the larger-scale sustainability vision is visible, to ensure designers keep steering towards it. Thus, by putting the *primary* and *enabling factors* into a relationship, and articulating this in the Garment Life Matrix tool, this thesis has responded to RQ4

9.2. Limitations of the research

The main limitations of this PhD are related to a combination of methodological choices, limitations of the developed tool, and external factors.

Firstly, this research relied on qualitative methods of analysis, and hence another researcher presented with the same data may have interpreted them differently. However, each study followed the established method of Thematic Analysis (as described in Section 3.2.4.), supported by visual mapping methods to capture research-backed insights and ensure generated themes were grounded in data.

The next set of limitations relate to the limits to the GLM tool's capabilities:
Firstly, by including the 'fast/shallow' quadrant as an option for designers, rather than removing it all together, there is a risk of the tool "normalising" fast fashion. This can be problematic as there currently is a lack of large scale, affordable materials, production and recycling technologies which can enable rapid consumption of short-life garments to be sustainable (as detailed in Chapter 6.3.4., p.157). To prevent such a "normalisation" of design for fast fashion, the GLM recipes have been built to encourage designers to move away from the ´fast´ part of the matrix. As described in Chapter 8.1 (p.222), the recipes are much stricter and more difficult to follow than those in the 'slow' half. The effect of tightening these recipes was seen in the studies in Chapter 8, which showed a clear majority of developed ideas that moved products from 'fast' to 'slow'. Rather than omitting or blocking the 'fast' half, it was an intentional strategy to include it: In line with the purpose of the tool– providing an understanding of the key forces at play in DfS, and making DfS strategies operational in practice– the tool is designed so that designers will feel invited to gain an overview of relevant approaches, but also, so that they will meet natural obstacles in the 'fast' GLM-half as they explore and apply the tool. Regardless of these preventative steps, it would still be relevant to conduct further research and development to minimise the risk of normalising fast fashion.

Another limitation of the GLM tool, is the level of detailed information in the recipes: As the GLM ingredients represent such a broad spectrum of fields, and since the format of this thesis, and the breadth of this author's expert knowledge covers a limited area, it was a challenge to include enough detailed data in the GLM recipes. The GLM tool does therefore not offer guidance which supports designers to solve in-depth complex issues or managing detailed trade-offs, such as selection and comparison of exact amounts or combinations of materials and production methods. Rather, the GLM is designed to provide overarching strategic guidance and "a way in" for designers to conduct effective DfS. It is a solid framework which would benefit from expansion and detailing by experts who can, and should be, invited to add detail to each ingredient. Regardless of how much information is added, it remains important that the tool is organised in layers of increasing detail to ensure its usability in daily design practice.

In this thesis, the focus has mainly been on single garments, the pace at which they and their components age or become obsolete, and how consideration of this primary factor can enable effective DfS. Just as each component plays a significant role in the overall life expectancy of a garment, the garments surrounding the individual piece in a wardrobe can also play a significant role in how, and for how long, they are used. This concept, seeing the wardrobe as a system whose components affect each other's use phase pace, was not investigated in depth beyond the specification of the GLM-ingredient of 'aesthetics' in Chapter 6.3.6. which proposes that, in order to be long-lasting, garments must be versatile and able to *"match other components from a wardrobe*" (p. 164). In some instances, this limitation could mean missing out on opportunities for holistic consideration of the system within which the garment will sit. It would therefore be a particularly relevant direction for future research to investigate wardrobes and collections as systems consisting of interdependent components and exploring the potential to adjust them to each other to optimise their characteristics and their use phase pace to achieve sustainable outcomes.

Another, more practical limitation was related to working with garment industry partners: despite great willingness and effort from industry to collaborate, the challenge of negotiating collaboration agreements was a significant obstacle which prevented a few collaborations, very close to actualisation, from taking place. Finally, the coronavirus pandemic had a significant impact on this research, as it unavoidably steered the work in a less physical, more digital direction, changing the format of certain studies as well as generally delaying the research.

9.3. Contributions to knowledge

This research contributes to knowledge in two main ways: Firstly, by specifying a set of the most important factors for garment designers to consider when designing for sustainability and putting them into a relationship (conceptual contribution), through (secondly) a new tool which makes consideration of these factors and their relationship operationalizable for designers in practice (practical contribution).

The Conceptual contribution emerges through the specification of the holistic (both mechanistic and human-related) set of particularly important factors for enabling sustainable garment design, consisting of the *primary* and *enabling factors* for DfS, and putting these factors into a relationship.

Specifically, by proposing the understanding that all the *enabling factors* are correlated, and that two of these factors, the *primary factors* ('Depth of user engagement' and 'Use phase pace'), are supremely influential. Precisely, consideration of the two *primary factors* should guide designers' decisions around all the other *enabling factors,* to design efficiently with DfS strategies.

Importantly, this conceptual contribution is demonstrated through the articulation of these factors and their correlations in a comprehensible visual framework, The Garment Life Matrix framework.

The Practical contribution is demonstrated through the proposal of a new DfS tool and method: The Garment Life Matrix tool and the supplementary 'Stay or Go' method.

This tool and method support designers to design efficiently with DfS strategies by prompting them to consider DfS factors holistically and systematically and their relationship. In doing so, it allows for these considerations to be actionable, by supporting designers to select and combine appropriate DfS strategies for each product and its use-context.

Specifically, the tool enables four practical steps for garment designers:

1. Diagnosing the sustainability of their current practice
2. Identifying opportunities for intervening to improve this
3. Selecting and combining appropriate DfS strategies to create a route for improvement
4. Engaging in systematic discussion and collaboration with other stakeholders.

9.4. Future work

The research in this thesis focused on investigating the most important factors for DfS, and how garment designers can be supported to negotiate these factors, to design efficiently with DfS strategies. As described in more detail below (9.6.1.), the discussion of findings opens up questions around how these factors could be further explored in other design fields, and how the design support proposed in this thesis could be applied to support designers in other disciplines.

This thesis developed and tested the GLM tool and the 'Stay or Go' method as DfS support through action research studies run over 3-6 months, using qualitative data and prototype outcomes to validate the efficacy of this tool. To test the efficacy of the tool in more depth, further research would be required. A logical next step would be to run studies over longer periods of time; following garments designed as an outcome of using the tool through at least one cycle of use to:

i) Collect qualitative data around user's engagements with these garments to test whether these really would follow a pattern of use as expected and planned for by designers.

ii) Conduct a Life Cycle Assessment to gather quantitative data on how these garments really would perform in terms of environmental impact and comparing them to equivalent products.

The findings from this thesis' many engagements with garment industry professionals indicated a clear need in the garment industry for a tool which can support efficient cross-level, and cross-disciplinary collaboration around DfS. Findings from this thesis' studies demonstrated the ability of the GLM tool to support this need, however, further research and development is needed to fully establish the GLM as support for other disciplines than design. This could be explored through qualitative approaches, running experiments, and observing dynamics in cross-disciplinary groups collaborating on DfS projects. e.g., design workshops with participants from across an organisation, perhaps involving users, as well as running long-term studies, continuously interviewing stakeholders to follow the development and implementation of DfS ideas.

As mentioned in Section 9.5., the GLM tool has already met significant interest from industry, and it is therefore my intention to pursue the opportunity for launching the GLM as a real-world design tool, perhaps as part of consultancy services, in the coming months. Besides developing and user-testing the format of the tool, it would benefit from another iteration of user experience design, perhaps in collaboration with a digital UX Designer, to construct an app, website, or other interactive medium.

9.4.1. The Garment Life Matrix methodology as a template for DfS in other industries

It has not escaped my notice that the specific principles I have postulated immediately suggest a possible mechanism for supporting other industrial design fields.

This research has shown that garments can be seen as assemblages of components that change at different paces. The components fulfil different purposes and are used in different ways by consumers. My work has identified two *primary factors*: 'Use phase pace', and 'Depth of user engagement' which determine the longevity of the component.

There are obvious parallels to other industrial products: Although the exact factor that causes a part of a product to become obsolete or worn out varies from category to category, it is quite simple to identify components within other product categories, which age at different paces and that consumers engage with in entirely different ways.

For example, in consumer electronics, like a laptop or a phone, there are only a few parts, such as the keyboard or screen-glass, whose life-expectancy will be determined by their physical durability. But central components such as the processor, camera, and connectors are subject to rapid technological developments which can lead to these parts becoming inadequate, incompatible and - to the discerning consumer - psychologically obsolete.

For this type of product, the *primary factors* that determine obsolescence might be redefined as "physical wear and tear" and "technical adequacy and compatibility".

Similarly, buildings consist of various layers, which, as described by Brand (1994), change at different paces: The foundational structure depends almost entirely on its physical durability, whereas the non-structural parts like the services and interior design will be vulnerable to fast-changing subjective factors like shifting trends and lifestyles of the people who live there.

As my research has shown, designing for sustainability and CE requires an understanding of the factors which determine the pace at which the components in an assemblage need replacement, to avoid that the entire product is discarded even though only one part might be obsolete. Such an understanding is productive for designers to strategically select (or rule out) certain DfS strategies, materials, business models, production methods and aesthetics, to construct sustainable solutions.

One category which has very close similarities to the issues explored in this report is furniture. Prior to undertaking this research, I have in fact tested similar principles to those underlying the GLM by applying them to the design of furniture in my start-up

business 'Strata' (Tucker, 2017), a product-service system model originally developed as a Masters' project at the Royal College of Art.

The design of Strata's furniture was based on 'The logic of layers', a precursor to the GLM *recipes*, which developed separate design-briefs for each furniture-component, or "layer", based on how these would age or be replaced. This resulted in a modular furniture system whose parts were designed for three different lifecycle speeds and depths of user engagement.

The fast-ageing components (covers, "skins") were designed to be easily replaced and become part of new assemblages and slow-paced components (inner-structure, frame) were designed to be as durable as possible, which enabled more resource-efficient furniture consumption. Regarding user engagement, each of these furniture-parts were designed so that the structural, "invisible" inner parts, were simple and standard, ultra-durable and accessed through a long-term leasing model (essentially following the 'slow/shallow' GLM *recipe*). The more fashion-dependent, personal parts; the sofa covers, through which users' express identity, were designed to be customisable, easy to change, made from recyclable mono-materials, and accessed through a regular ownership model (much in line with the 'fast/deep' GLM *recipe*).

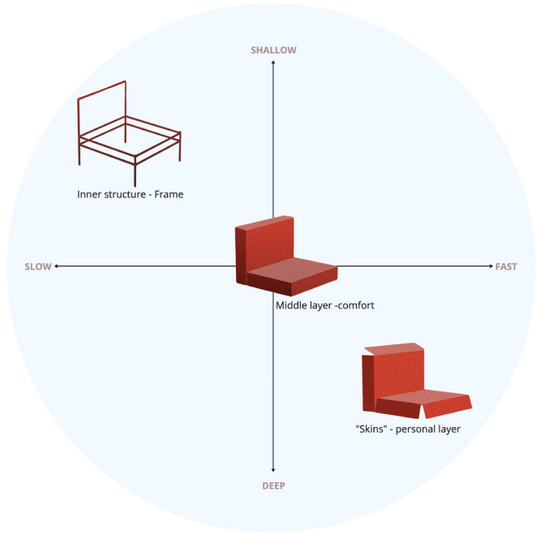


Figure 87. Components of a sofa mapped in the GLM

The three examples from very different product categories indicate that the methodology used in the GLM probably can be generalised to cover a wide range of industries - which obviously adds significantly to the value of this research.

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The Garment Life Matrix

A tool for negotiating complexity in Design for Sustainability

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