Edited by
Gianpaolo Vignali · Louise F. Reid
Daniella Ryding · Claudia E. Henninger

Technology-Driven Sustainability

Innovation in the Fashion Supply Chain

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Introduction

Gianpaolo Vignali, Louise F. Reid, Daniella Ryding, and Claudia E. Henninger

The following collection of chapters is a collaboration of academics from across Europe investigating technology within the fashion industry and its impact on creating a more sustainable way of production and manufacturing. All of the scholars are renowned independent scientists who share the same drive in creating a sustainable supply chain.

They share a communal goal in answering how can the contribution of technology interlink with sustainability and how can this be improved. These dialogues have been borne out of conference discussions, of networking in key forums and through lobbying policy makers.

Kofi Annan inspired a generation through "Freedom from want, freedom from fear, and the freedom of future generations to sustain their lives on this planet." Each chapter in turn focuses on educating

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the next generation of sustainable thinkers on development practices and, in particular, the key challenges facing technology in supply chains today.

These chapters provide an insight into the different solution-driven priorities in industry and touch upon the concepts of co-production. Fundamental research into the growth of society by means of creating cleaner production allows for incremental change. However, innovation in turn increases rate of obsolescence, and the consistent move towards new technology creates a dearth of technology. Seeing through this mist is key if we want "freedom from want and freedom from fear."

Chapter 2 provides an insight into the circular economy and how recycling technology transforms garment design, closing this loop from production to reuse. The managed use of land, with the growing demand of cotton not being able to meet demand, requires investigation into exploring textile recycling and waste sorting. Furthermore the processes of mechanical, chemical and thermal recycling are conveyed. Finally a clear message is the transparency within the industry and how this is implemented.

The next section commences with an overview of the garment industry being the second most polluting in the world and again an emphasis on circular economy. In this chapter, however, the author explores the consumer role in this arena and how designers can centre their concerns on the user. The discussion of computer numerical control (CNC) technologies and how they are leading to a trend of external assembly systems including fablabs is presented.

Researchers from Munich, Germany, discuss an exploration of the trends in digital technology and new consumption modes in Chap. 4. Particular emphasis is made on the models of exchange between customer–to-customer (C2C) and business-to-customer (B2C) interactions. C2C and B2C once established as access-based models are then contextualised in two case studies linked to short- and long-term loans. The chapter concludes with consumer preferences in the engagement and use of access-based and collaborative consumption models.

Chapter 5 addresses how to mimic certain colours that are around consumers in the natural environment. In particular, it focuses on the unique colours elicited by the *Morpho* butterfly and how the use of a dye kitchen and the technology within it allow for the reproduction of these colours.

In the next chapter, design processes are explored. From the legislative drivers associated with circular economy and the ambitions associated with it to the design for sustainable use and disassembly, this chapter provides an insight into the challenges facing the textile sector. The chapter concludes by defining a culture change for the circular economy shifting towards producer responsibility.

Researchers from Portugal seek to present an alternative approach of managing fashion business online in Chap. 7. Digital technology can assist supply chains in providing better sourcing solutions not only for existing retailers but also for start-ups. The chapter reviews and explores how designers commence the sourcing process to the satisfaction linked to this task. In particular the B2B (business-to-business) model, which was developed in Chap. 3, as well as the B2C and C2C models, are highlighted in a case study of U.MAKE.ID.

Chapter 8 explores 3D printing with a focus on the emerging Chinese market realising its potential. The origin and use of 3D printing is conveyed leading to the Chinese millennial consumption of luxury garments. The perceptions and purchase intentions of this segment cement their understanding that there are negative connotations of garments of this type. However, the model is novel and may be too early in the phase for these consumers.

Chapter 9 is conceptual in nature and focuses on more recent technological innovations that have been implemented in the fashion industry, namely augmented reality (AR) and virtual reality (VR). The technology acceptance model (TAM) further evaluates the *perceived usefulness* and the *ease of use* of AR and VR from a consumer perspective by drawing on current fashion examples. The chapter concludes by highlighting future directions for research.

Chapter 10 considers three-dimensional (3D) body scanning and its applications in the fashion industry. The focus will lend itself to how this technology can help drive a more sustainable and cleaner production process, help reduce the rate of returns in online shopping and reduce the waste attributed to the construction of clothing. After initially defining 3D body scanning, the emphasis shifts towards cleaner production and the value for supply chains. The exploration of human and computer interactions and the measurements of the data that is elicited will highlight the benefits and limitations to this method of data capture and the gaps attributed to the diverse range of retailers' measurements of apparel. The chapter culminates with areas of strength but also areas of future research growth that will lead to a more sustainable fashion supply chain.

The following chapter considers in-store technology and how the technology acceptance model (TAM) in this context relates to premium brand consumers. The conceptual framework develops the links between the traditional TAM dimensions and customer brand relationship dimensions. Researchers from the University of Manchester and the University of the Arts, London, provide practical recommendations and supported technologies for premium fashion retailers.

Chapter 12 culminates in the applications of the closing the loop (CTL) framework at the product level. Sustainability by use of toxic-free designs and zero waste encapsulates circular economy in the production and manufacturing approach.

Hopefully these insights will provide the reader with an opportunity to delve into the works of sustainability and product development within the fashion industry. These innovative ways of working will help pave the way for a more sustainable future for the next generation.

Gianpaolo Vignali is a graduate from the University of Manchester Institute of Science and Technology (UMIST) with his first degree in mathematics. Later adding a master's in Strategic Management, his career started as a part-time lecturer and researcher at Manchester Metropolitan University before moving to full-time employment in the Department of Retail at Leeds Metropolitan University. He then became Programme Leader for Fashion Buying & Merchandising at Manchester Metropolitan University until he achieved his PhD and moved to Manchester University working in the School of Materials, where he delivers lectures on both undergraduate and post graduate programmes.

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Closing the Loop: Intentional Fashion Design Defined by Recycling Technologies

Kirsi Niinimäki and Essi Karell

2.1 Introduction

Sustainable development in the fashion industry is strongly moving towards greater system understanding and a circular economy (CE) approach. Material recovery after the product use phase is an important principle of the CE system. Hence, textile waste should be seen as a valuable resource for the textile and clothing industry. For example, using recycled instead of virgin materials in manufacturing can save notable amounts of virgin materials, energy, water and chemicals. Furthermore, constant population growth and the increase in clothing manufacturing pose a risk for the fashion industry and its virgin material sources. The growth of this industrial sector is remarkable; in the last 15 years, clothing production has doubled (Cobbing and Vicaire 2016; EMF 2017). However, cotton cultivation, for example, cannot be increased to meet the rising demand for materials because arable land is needed for food

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cultivation to feed the growing population. Cotton cultivation also uses huge amounts of water, fertilisers and pesticides. Therefore, its production has a remarkable environmental impact. On the other hand, the amount of textile waste is on the rise, providing an attractive interesting material source for the fashion industry.

This chapter focuses on the current developments in textile recycling technology. These technologies open up interesting future opportunities for using recycled materials as substitutes for some of the virgin materials. However, emerging recycling technologies have limitations, such as with respect to the types of textile materials that can be identified by automatic sorting systems (robotics) and the types of fibres that can be upcycled. Information on the end of products' life determines what materials can be used in the first round of the design process to create garments that are suitable for recycling. However, selecting recyclable materials for the first lifecycle of the garment is not the only challenge. As some current materials cause problems in both mechanical and chemical recycling processes (e.g. elastane), it might not be possible to use these materials at all in fashion design in future, and this will affect the technical and sensorial properties of garments.

This chapter also focuses on the second lifecycle of garments, the quality and aesthetic aspects thereof. Through innovations, it is possible to recycle not only fibres but also chemicals and even the colour components of the fibres. When aiming to close the loop and reuse all chemicals, it is also possible to recycle these chemicals and even to modify fibre and textile attributes with certain chemicals. The chapter ends with a description of intentional fashion design that takes into account the textile recycling technologies, their limitations and possibilities. This new knowledge of recycling will transform the paradigm in fashion design with the aim of closing the material loop in the fashion and textile industry.

2.2 Textile Recycling and Waste Sorting

Nearly 100% of used clothing textiles can be reused or recycled (Hawley 2006). In spite of this, it is estimated that 73% of global post-consumer textiles end up in landfills or incineration (EMF 2017). No comprehensive data sets on clothing reuse are available due to a lack of information on how much clothing is shared and donated between private persons. In terms of recycling, however, some estimates suggest even less than 1% of clothing textiles are recycled into new high-quality textiles, that is, upcycled (Ibid.). Yet, clothing recycling is critical for success in efforts to close the material loop and transform the industry towards circular economy (CE).

Recycling of post-consumer textile waste is one of the most challenging tasks within the clothing industry (Franco 2017), but ambitious goals have been set for it. Textile waste flows have been estimated to increase, especially in Europe, because of EU-level regulations (Palm et al. 2014). The future goals at the societal level (e.g. in the Nordic region but also at the EU level) are that all textile waste will be collected back and that 90% of the total amount of collected textiles will be reused or recycled by 2025 (Fråne et al. 2017; EC 2018). The textile recycling process is, however, not economically viable in its current state for multiple reasons: lack of recycling infrastructure, high costs of logistics, manual sorting requiring human labour, low prices of virgin fibres and lack of demand for recycled fibres (Elander and Ljungkvist 2016). At the level of textile collection and sorting, it is especially challenging to operate profitably due to increasing competition in collection, lower prices of reuse grades (but higher collection costs), uncertainties in many second-hand markets, lower quality of textiles and the lack of demand for recycled materials (Ljungkvist et al. 2018; Niinimäki 2017). Furthermore, the sorting phase includes numerous stages starting from separating unwearables (non-textiles, damp and dirty textiles) from the recyclables and reusables, of which the latter can be further separated into around 400 different grades according to, for instance, specific market needs, season, product type and gender (Hawley 2006; Thompson et al. 2012; Soex 2018). In addition, sorting is done manually. This means that the sorters go through each piece of textile by hand to evaluate its condition, look and feel.

In order to improve the recycling rates of textiles, it is important to ensure the profitability of the entire process (Ljungkvist et al. 2018). This calls for rapid improvements in the efficiency of textile collection and sorting (Ibid.). The development of new sorting technologies based on automation plays a crucial role here in contrast to manual sorting.

Automation enables handling high volumes of low-quality textiles (Ibid.) and hence reduces the costs of textile recycling (Palm et al. 2014).

Along with the growing interest towards circular economy principles in the fashion and textile sector, automated sorting systems for textiles have been investigated in recent years. For example, the commercial availability and cost-effectiveness of possible technologies were studied by Humpston et al. (2014). They compared the following: (1) manual sorting (the current method), (2) Fourier transform infrared spectroscopy (FTIR) that enables identification of colour and fibre content, (3) radio frequency identification (RFID) tags that provide a low-cost method but face challenges in tag readability and durability during laundry, and (4) 2D barcodes (for use on care labels, for instance) with similar benefits as RFID (however, the labels must be manually presented to a reader) (Humpston et al., 2014). According to the comparison, the 2D barcodes showed potential when aiming for a circular economy in textiles. This was due to advantages such as their modest cost in production, sorting accuracy and their ability to be integrated into existing manual sorting processes (Ibid.).

In addition to the aforementioned sorting technologies, research projects involving near-infrared spectroscopy (NIR) (based on FTIR) also show great potential, especially when targeting chemical recycling of textiles. NIR is normally used in plastics recycling (e.g. polyester fibre). An EU-funded Textiles4Textiles (T4T) project (2009–2012) introduced NIR for use in the sorting of non-wearable post-consumer textile waste (Palm et al. 2014). The method enables identification of materials based on their chemical composition and colour, which makes it suitable to be paired especially with chemical recycling technologies. Since T4T, more research on automated NIR technologies for textile sorting has followed. Fibersort technology (funded by Interred NWE, 2016–2019) shows commercial potential, even though it is still under development: the technology is already in operation (currently able to detect 60% of materials, with a target of 80%) and enables the sorting of materials on a commercial scale (Circular Economy 2018). Fibersort is programmed for 14 different material types of pure and blended fibres, which require further research in terms of machine accuracy. Machine productivity and features related to colour sorting are under study as well (Ibid.). In Finland, the

Lahti University of Applied Sciences (UAS) has also been developing analytics for identifying textile fibres based on NIR (Cura and Heikinheimo 2017; Zitting 2017). The research has been conducted as part of the multidisciplinary Telaketju project (2017–2018), which aims to develop a nationwide textile recycling network in Finland. The identification and sorting unit functions on the basis of textile material libraries, grounded (and constantly expanded) on reliable textile samples with various knit and weave structures. The ability of NIR to detect harmful and hazardous chemicals is also on the research agenda at Lahti UAS (Cura and Heikinheimo 2017). Swedish Innovation Platform for Textile sorting (SIPTex) (2015–2018) is another Nordic research project that, like Fibersort, aims to demonstrate non-wearable textile sorting on a larger scale. Even though the sorting methods based on NIR need further development, the research projects described above provide a clear future direction invested in at the European, regional and national levels.

In addition to improved efficiency, sorting accuracy is a critical point in automated sorting methods. Hence, it can best support chemical recycling (Thompson et al. 2012). Chemical recycling methods require high-quality sorted fractions, meaning that the chemical and structural composition of textiles needs to be accurately identified (e.g. Wedin et al. 2017; Zitting 2017). Unknown fibres or chemicals can disturb the processes or even waste the whole material batch. After the sorting phase, the waste material must undergo pre-processing before the actual chemical (or mechanical) recycling process can take place (Heikkilä et al. 2018). For recycling, detailed information on the fibre content and its history is needed to decide on the right recycling path and accordingly a pre-processing method. Here digitalisation can help. For example, fibre traceability could be done through an RFID code that uses electromagnetic fields to automatically identify and track tags attached to objects (Amed et al. 2016) or 2D bar labels could be used for the same purpose. RFID technology can also be integrated into a yarn that can be woven into a fabric (Global Fashion Agenda and The Boston Consulting Group 2018). Information technology, IT, provides us with new ways to track the origin and flow of materials (Webster 2017), which enables closing the material loops in a controlled way; therefore, new technology can help increase transparency.

Moreover, technology enables optimising the use time of clothing and informing the user or company when the clothing's use time is over, that is, when it is worn out and should be returned for fibre recycling. For example, some leasing companies use this information already. In Denmark, the children's wear leasing company Vigga has used RFID tagging to investigate the average use of their clothing: the company noted that their baby clothing products can be used by five families before they are visibly worn out and end up in recycling (EMF 2017). RFID tags could also include information on the fibre content and knowledge of the suitable recycling path to follow.

2.3 Mechanical Recycling

Mechanical fibre recycling is an old technology that is still in use. In mechanical recycling, fibres can be recycled according to one fibre type (e.g. wool recycling is an old technology) or fibres can be mixed. Pre-consumer textile waste (offcuts from the fashion industry) works better than post-consumer textiles with this technology as the material quality is better and the material content is well known (Fontell and Heikkilä 2017). The following example comes from Finland: "Pure Waste recycles the offcuts and spinning waste from clothing and textile industries. The raw material is collected, sorted by colour and quality, and mechanically opened back into the fibre. Then we mix it with recycled polyester or viscose and spin it into new yarns. After that, the process is the same as with virgin materials except that our yarns and fabrics don't need to be dyed as their colour comes from the textile waste" (Niinimäki 2018, 226). This example shows how the colour can also be recycled in the mechanical fibre recycling process and can therefore prevent the impact of fibre bleaching and re-colouring.

As mechanical recycling is a harsh treatment for fibres and the process lowers their quality (the fibre length is shortened), it is better to use pre-consumer textile waste for this process. To keep the quality high enough, virgin material is frequently added, accounting for around 10%–30% of the fibre content (Heikkilä et al. 2018; Watson et al. 2017). If a mechanical recycling process is used, then the fibre can very often be upcycled from waste material only once after which the material content might be useful only for downcycling (resulting in lower value products that can be used for purposes such as filling).

2.4 Chemical and Thermal Recycling

Textile waste that is too low in quality for mechanical recycling is still suitable for chemical recycling. Yet, in the chemical or thermal recycling process, the fibre content must be known quite precisely and an accurate sorting technology is needed. Chemical and thermal recycling technologies have environmental benefits, as they are real upcycling processes where the quality of the fibre can be kept at quite a high level. In this way even low-value or valueless waste can be turned into valuable raw material again.

Synthetic fibres (e.g. polyester) are in most cases thermoplastics, meaning that they can be recycled at a polymer level. When these fibres are melt-spun into textile fibres in the same kind of process used to produce the original yarn, this is referred to as thermal recycling. This new technology is already in use, for example, in the workwear sector, where the fibre can be recycled as many as eight times between garment lifetimes, providing a total lifespan of as much as 40 years for these fibres (Watson et al. 2017; Heikkilä et al. 2018; Niinimäki 2018). Further chemical monomer-level recycling for synthetic fibres is also available and new technologies are under development in this sector. First, the fibre is broken into monomers, then repolymerisation is done after which the fibre is melt-spun (Heikkilä et al. 2018). These technologies have huge potential; in the future, when they can be employed successfully on an industrial scale, they will provide opportunities for clothing-to-clothing recycling. These technologies are currently in the development stage and at the lab-scale only. Current recycled polyesters available in the markets are mainly made from plastic bottles [polyethylene terephthalate (PET) material], and polyester textiles or blends including polyester are not recycled on a large scale, but soon will be.

For waste originating from natural fibres (cotton, all other cellulose type fibres, e.g. viscose, modal, lyocell), many new emerging recycling technologies are being developed. One interesting technology in this sector is Ioncell-F, a chemical recycling method for cellulose fibres (Aalto University, 27 October 2015). The process uses environmentally friendly ionic liquids, which are an alternative to the solvents currently used in man-made cellulosic processes (viscose production). Ioncell-F technology converts wood into textiles, or textile waste or paper waste into new fibres. It is an alternative to virgin cotton production or viscose production, which has a high environmental impact, and therefore Ioncell-F provides an environment-friendly way of producing high-quality virgin or recycled cellulose fibres (Sixta et al. 2015; Trash-2-Cash project n.d.).

In principle, materials can be recycled several times with these technologies, which have environmental benefits compared to the mechanical recycling processes. When aiming to achieve several lifecycles and efficiency in fibre recycling, transparency and especially information on the fibre content are a necessity.

2.5 Colours and Chemicals in Waste

In order to close the material loop, new technical and system innovations are required to use the textile waste as a valuable resource within manufacturing. New material testing methods are also needed as more and more waste is being remanufactured into new fibres, yarns, textiles and clothing. Safety issues are critical in this effort as the chemicals in textiles will also be recycled if they are not removed before the fibre recycling process. Textile waste material contains different kinds of chemicals, some of which are quite harmful, and therefore, transparency regarding all ingredients in the garment is necessary. Technology can support this aim by providing information not only on the fibre content but also on the chemical content of the textile materials (Webster 2017).

In addition, new inventions are needed to totally close the loop and to recycle not only materials but also the chemicals and even the colour in the textile materials. As the aim of the circular economy is to recycle all materials, it would be worthwhile to study how to best reuse chemicals in textile waste. With these recycled chemicals, it could be possible to create totally new functional attributes in textile fibres, and this aspect could be used as a competitive advantage in the development of recycled textiles. Carrying out waste recycling and processing at small-scale units will enable this kind of selective recycling of chemicals and therefore also the development of unique functional attributes for fibres through the reuse of certain chemicals (e.g. retaining metal content in recycled fibres to develop conductive fibres).

As discussed above in the section on mechanical recycling, this technology is already employed for colour recycling, at least for basic colours. This kind of colour recycling is also possible in the chemical recycling process. In the chemical recycling process, some colour types stay quite well in the fibre recycling process while some colours fade. This phenomenon has been investigated by researchers such as Smirnova (2017), who studied Ioncell-F technology. She identified the best colour types to be used when the aim is to recycle the colour as well (vat colours). On the other hand, those fading colours could be used if the aim is to change the colour of the fibre in the following industrial processes (bleaching and dyeing, or just overdyeing a darker colour on the recycled fibre). Smirnova (2017) developed a colour library system in which these colour properties could be taken into account while designing the next and third lifecycle for garments and while mixing different coloured waste in the recycling process (Smirnova et al. 2016; Smirnova 2017; Niinimäki et al. 2017).

It can be summarised that in the closed loop system there are three different approaches to design re-colouring:

1. Continue as today (first bleaching and then dyeing).
2. Keeping the colour but focusing on black, grey and mélange colours (easier to control the result).
3. Keeping the colour in the recycling process while aiming for a multicoloured end result (waste can be sorted according to colours). The result no longer represents a unitrend (as is the case today in mass manufacturing) but rather industrial fashion design involving many different shades of one colour, even in mass manufacturing processes. Therefore, it enables more creative ways of designing industrially manufactured clothing, although the exact colour result is hard to control.

2.6 Intentional Fashion Design Defined by Recycling Technologies

Intentional design refers to sustainable development where the aim of the design is to transform the current unsustainable situation. "The role of the designer in developing a sustainable society is not simply to create 'sustainable products,' but rather to envision products, processes, and services that encourage widespread sustainable behaviour. This goal of designing for sustainability can be accomplished through the practice of what I refer to as 'intentional design' and the development of a new philosophy to help guide design decisions" (Stegall 2006, 57). Even if Stegall (2006) is writing about intentional design and its aim of influencing consumers' behaviour, we extend the definition to mean design that aims to influence the paradigm in the current fashion industry. The paradigm change concerns moving from a linear system to a circular one. Grounding previous intentional fashion design in the context of CE means design that enables recycling and even makes the recycling process more efficient. Therefore, fashion design needs to renew its knowledge base and practices and harness new information on recycling technologies. As Stegall (2006) points out "[a]pplying intentional design to promote sustainability requires a redefinition, or more precisely an expansion, of current environmental design principles." According to Stegall (2006), intentional design has different philosophical approaches, including the philosophy of purpose, which facilitates guiding the practice of intentional design to ensure that new products will promote sustainability. In our case, intentional design needs to promote the circular economy and enable textile waste recycling. Therefore, to change the paradigm and practices in fashion design, knowledge on recycling technology must be incorporated into fashion design and its practices. In this way, intentional fashion design can be said to take a backwards approach (from recycling technology to original design).

The main questions in intentional fashion design are as follows: what needs to be taken into account at the level of design when aiming for improved clothing recyclability rates? More precisely, what kinds of materials (ideally after multiple reuse phases) can be recognised reliably in the sorting process? Once that phase has been successfully passed, what kinds of materials are suitable for chemical recycling and upcycling into other high-quality textile applications? Considering the rapid pace of development in automated sorting technologies, designers are likely to face a range of unexpected limitations if they aim to close the material loop and design for recycling. Even though the emerging technologies (like NIR) need further research with respect to their sorting accuracy, for instance, some rough limitations in the fibre identification phase can be already given to guide designers. As part of the EU-funded project Trash-2-Cash (which focuses on upcycling post-consumer polyester and cotton), four different NIR units across Europe were tested to investigate the feasibility of NIR to improve the sorting quality of textile waste (Wedin et al. 2017). Preliminary observations showed that NIR was able to recognise pure cotton, polyester, acrylic, wool, polyamide, silk and man-made cellulosic fibres (viscose, modal and lyocell), as well as cotton-polyester blends. However, none of the tested NIR units was able to identify a low elastane content in cotton-elastane blends. Furthermore, textile blends where different fibres are shown on the different sides of the textile could not be recognised as blends (Wedin et al. 2017). This is the case for example with plated knits or denim. As the NIR unit samples only a small part of the textile, products that have big transfer prints may also be identified as plastics if the so-called measurement point hits the print (Wedin, 22 February 2017; Zitting, 6 June 2018).

Moreover, it might not be possible to use some currently popular fibres at all if the future system aims to close the material loop. Elastane (spandex, Lycra), which is commonly used in different garment types and blended textiles, causes problems in both mechanical and chemical recycling processes, and therefore, its use needs to be limited in garments aimed for recycling. On the other hand, in the closed loop system, it might be possible to design fibre properties and quality levels more individually in accordance with the needs of the fashion industry. If the production of recycled fibres is carried out at small-scale production units and if we have technologies to also recycle chemicals and colours, then this provides opportunities to produce more unique types of attributes in the fibres, for instance by keeping some chemicals in the recycled fibres in order to provide specific fibre attributes (e.g. conductivity through metals).

To overcome obstacles in textile sorting, products need to be designed in such a way that they can be identified correctly in automated sorting processes (Wedin et al. 2017). This gives some design guidelines on what fibres and even textile structures to use in intentional fashion design. Moreover, the textile industry must limit or even cease the use of fibres or blends that prevent recycling if society wants to move towards circular economy.

While designing and manufacturing garments, their construction must be designed in a manner that makes them easy to take apart and separate all the parts and materials and then guide them into a suitable recycling system. The easiest way to do this is to design garments using only a single material (i.e. monomaterial design), which means that the whole garment and all its details can be placed in the same recycling system. Several recycling technologies can tolerate small amounts of impurities (like polyester yarn in a cotton t-shirt); these impurities go through the process and remain in the recycled batch. However, monomaterial design is the safest option when targeting a successful recycling process. Another solution is to use new technologies to destroy the sewing yarn—such as with heat or microwaves—so that all parts/materials can be separated. Design based on modular pieces could also be useful in separating all materials.

We argue that designers can affect the efficiency of emerging technologies through intentional fashion design and hence help close the material loop if they understand the limitations and possibilities of the techniques and technologies used in textile sorting and recycling processes. This means that designers need to understand the basic requirements of the current and emerging technologies: first, what kind of textile structures, compositions and colours, as well as non-textile components can be identified at the level of sorting (and how this is done) so that the materials can be reliably directed to certain material streams. Second, it is important to roughly understand into what different grades textiles are generally sorted and which material streams they may enter—incineration/landfill, reuse (charity, resale), textile-to-textile recycling (mechanical, chemical or thermal) or recycling in other industries (usually mechanical). Third, the designers need information about the general limitations and possibilities of textile-to-textile recycling technologies—more precisely, what can and cannot generally be recycled through them, and what elements in a textile product may disrupt the recycling processes. Table 2.1 presents some principles for intentional fashion design for recycling.

Table 2.1 Intentional fashion design for recycling (authors' own)

Intentional fashion design	Mechanical recycling	Chemical recycling
Waste resources	Pre-consumer textiles	Pre- or post-consumer textiles
Quality	Low quality of waste prevents mechanical recycling. Some quality is always lost in the process. Some virgin material is often used to guarantee the quality.	Low-quality textile waste can be recycled. High-quality yarn can be produced without virgin materials (upcycling).
Fibre content	Different kinds of fibres and blends can be used. Elastane disturbs the process.	Fibres that can be identified by an automatic sorting system can be used. Blends are problematic. Exact fibre content needs to be known.
Textile structures	No effect	Only textile structures that enable fibre identification in an automatic sorting system can be used.
Garment structures	Garment shredding is quite a rough process, which enables different kinds of garments to be used.	No effect if monomaterial. If not monomaterial, then modular design or easily disassembled materials.
Prints, finishings	Might prevent recycling	Might prevent recycling
Colours	Can either be taken into account or not. Colour recycling enables a new colour design system for recycled textiles. More colour variations in mass manufacturing.	Can either be taken into account or not. Colour recycling enables a new colour design system for recycled textiles. More colour variations in mass manufacturing.
Chemicals	Stay in the fibre in the recycling process. Harmful chemicals might cause some harm to the end user.	Can either be recycled or removed. Can be reused to design certain unique attributes into recycled fibres.
Lifetime	Should be optimised and information provided on when and how the garment should be returned for mechanical recycling (second lifecycle).	Should be optimised and information provided on when and how the garment should be returned for chemical recycling (second, third or fourth lifecycle).

Garments should be designed with a certain use context and defined lifespan in mind so that their functionality and lifecycle can be optimised and this information can be provided to the user. In addition, quality should be optimised for a defined lifetime so that the garments last the planned time after which they will be returned to recycling (e.g. in the case of Vigga). Therefore, it is not always necessary to aim for the best quality and long-lasting durability. Transparent information will give recycling guidelines when processing a garment containing certain fibres, chemicals and colours.

2.7 Conclusion

According to Ellen MacArthur Foundation's (2017) detailed vision of a new textile economy, transforming clothing design, collection and reprocessing of textiles plays a crucial role when aiming to improve textile recycling. "Coordinated action is required to capture the opportunity to introduce clothing recycling at scale, involving designers, buyers, textile collectors (including cities and municipalities), recyclers, as well as innovators" (Ibid., 99). As Ljungkvist et al. (2018, 37) highlight: "The ideal scenario for all actors would be that the increasing share of non-reusable textile begins to raise real income for the collection and processing industry and not be the economic deadweight it is today. This requires both technological advancements through research and development in new sorting and recycling technologies in Europe and increased demand for recycled fibres from the fashion industry in particular." It is also important to highlight that the closing the loop approach provides opportunities for boosting the local economy, as pointed out by Ljungkvist et al. (2018, 34): "Automated sorting would probably need to be regional in order to get sufficient volumes and economies of scale." This local aspect could be included into design; it is possible to design and manufacture smaller amounts of recycled yarns with specific attributes and specific colour shades to revamp the aesthetics of recycled fibres and thereby challenge current mass manufactured fashion and its aesthetics.

Intentional fashion design processes will have two main outcomes in the closed loop system. First, only limited material choices can be used in the closed loop system, materials with a fibre content that can be identified through automatic waste sorting technology and which can be upcycled. This might cause some limitations in the sensorial properties of garments if the fibre choices are limited in the first lifecycle. It is likely that some materials that prevent the recycling process cannot be used in the future. For example, the use of elastane needs to be critically evaluated in textile manufacturing or it needs to be replaced with some other material suitable for recycling. This might change textile qualities in garments. Elastane provides comfort in use through its stretch properties and it is largely used in blends. In intentional design, certain woven or knit structures may be considered to provide mechanical stretch. Alternatively, new materials need to be developed to enable stretch in textiles without elastane. Second, there will be a new colouring system based on recycled colours in recycled fibres. The aforementioned knowledge will change the aesthetics of mass manufactured clothing, providing more shades and variations and less even and stable colour throughout the clothing collections. This might lead to fashions designed and made in smaller collections, providing more variation in fashion.

Technology can help close the material loop and is also necessary for building a functional circular system for textiles and garments. The following aspects are critical in closing the textile material loop:

- Transparency: providing information on the end of a garment's life, fibre content and suitable recycling system
- Automatic sorting system (according to fibre content, chemicals, colour)
- Recycling systems (mechanical, chemical, thermal)
- Transparency in the second lifecycle (all this information should follow the product)

Technology enables the whole supply chain to be included in the circular system. Transparency at all levels of the supply chain is important and it also enables the designers to make the right choices in the first and second lifecycles of the garments. Intentional fashion design needs transparency and information on recycling technologies to successfully create recyclable garments.

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3

A Designer Contribution to the Use of CNC Machines Within the Supply Chain in Order to Extend Clothing Life Span

Elisabeth Jayot

3.1 Introduction

Unbridled overconsumption fueled by the fast fashion business model has largely contributed to making clothing the second most polluting industry in the world.

Within the context of the 2017 Copenhagen Fashion Summit call by clothing industry professionals to initiate a transition toward a circular economy (CE), we are exploring, through practice-based perspective, to what extent a transposition onto clothing of the open object theory of philosopher Gilbert Simondon could give rise to a modular clothing design conciliating extended clothing life span and fashion renewal pleasure.

We have imagined replacing the fabless system of fast fashion by a relocation of production through an overall network of micro-manufactures inspired by fablabs. By updating the pattern-making business in light of computer numerical control (CNC) technologies, it would become

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possible to produce locally and on-demand customizable modular clothing made of combinable spare parts.

As a first proof of concept, we have created a first collection of eight seamless and modular garments, based entirely on a unique pattern consisting of ten different spare parts and produced by one single person in only two and a half days of laser cutting and manual assembly.

3.2 Clothing Industry: A Needed Transition to a Circular Economy

In 2011, the *Carbon Trust* report ranked the clothing industry second most environmentally damaging industry. Two years later, the deadly collapse of the Rana Plaza in Bangladesh, where more than 5000 workers were employed in sweatshops acting for international firms like Mango and Primark, marked the beginning of a collective awareness of the devastating effects of the fashion industry.

Hence, the business model of fast fashion ends up being questioned. Such model, called after fast-food chains, combines creative team responsiveness, off-the-shelf manufacturing in low-wage countries, tense logistical flows and a globalized distribution network, and enables these brands to offer new trendy and cheap clothing in all their boutiques on a weekly basis.

Thanks to the outsourcing of their production to developing countries, fast fashion brands have developed a so-called fabless system, that is without factories of their own and using subcontractors who manufacture the products they design. Thus, they lower production costs through competition among garment factories and orders volatility. Hence, Western brands discharge their social and environmental responsibilities onto their foreign partners who are often subject to laws much more lax than those in Europe. By refocusing their activities on creation and distribution, fast fashion companies manage to achieve high returns without assuming any responsibility for the production apparatus.

By forgoing long series with high margins and significant downside risks, fast fashion brands, with their attractive prices and non-renewal of inventories, are fueling uninhibited overconsumption. Such a shopping frenzy generates significant waste because not only do consumers buy more clothes than during the preceding century but also they wear them during a much shorter time span. Aesthetic obsolescence now takes precedence over material wear.

At the 2017 Copenhagen Fashion Summit, however, industry professionals called for a worldwide mobilization to initiate a transition toward a circular economy, a system based on a non-polluting production of objects that can be entirely reused or recycled, thus creating virtuous loops. In a context where many responsible and sustainable initiatives have already emerged but are struggling to reverse the general market trend, we wonder how could we reconcile extended clothing life spans with the pleasure of fashion renewal within the scope of a circular economy.

3.3 Redefining the Consumer's Role and the Designer's Approach

3.3.1 Centering Our Concerns Around the User

Aesthetic standardization, which results from fast fashion globalization, seems to contradict a growing desire for individualization. Consequently, it seemed essential to place the user at the heart of our concerns by developing the potential for personalization and user involvement in order to give rise to an emotional attachment which might lead to a longer life span.

Personalization is also a marketing argument likely to arouse clients' interest and to favor their voluntarily taking part in the necessary pedagogy we shall define to help change consumption habits.

In view of this ambition, we wanted to expand the strategy of sustainable development, which was initiated in the 1970s in the United States, known as the "3R", reduce, reuse and recycle, through reference to four simple terms, our "4M" concept, as follows:

- *Making-off*: refers to optimizing the manufacturing process in combining astute resources management and ingenuity.

- *Maker*: refers to the involvement of the user in the manufacturing process as well as in the reuse.
- *Re-make*: refers to the second life of the product.
- *Makeover*: refers to recycling.

3.3.2 Adopting the Reflective and Emancipated Posture of an Object Designer

The circular economy requires that environmental impacts be taken into account at each stage of a product's life cycle. However, sustainable design requires following a systemic and analytical thinking that seems to contradict the aesthetic and commercial concerns of those fashion designers who are always caught up in renewal frenzy.

Indeed, as fashion historian Emilie Hammen points out in her article *Aux frontières du design: Mode et intentionalité* that "the fashion designer stands out as a kind of herald to people and reveals to his contemporaries exactly what they want". On the other hand, "the object designer acts as an emancipated figure in a position of transgression who analyzes the social and political issues of the time and thinks his project as a more or less utopian answer to these questions". We believe, therefore, that it is more appropriate to adopt the posture of an object designer, rather than that of a fashion designer, in order to contribute to the garment's transitions to a circular economy.

3.4 Toward an "Open" Garment

3.4.1 Transposing the "Open Object" Philosophy onto Clothing

Considering the garment as an object has allowed us to see Gilbert Simondon's open object theory as a possible method for reconciling trends versatility and product sustainability. The linear capitalist model has severely impacted object conception. As pointed out by the French philosopher, objects, fully new and valid when out of the factory, can only then deteriorate, even if they do not wear out, because they are dedicated to age and to be discarded.

Gilbert Simondon calls such objects "closed objects". Their internal structures cannot be seen, even less understood, and this often prevents replacing defective parts or repairing, thus prohibiting any copy and pushing the consumer to purchasing new products. Scheduled obsolescence further increases this phenomenon by voluntarily reducing products' life spans.

3.4.2 Opening Initiatives

In response to the voluntary hermeticism of the industry, initiatives have developed advocating open access. Inspired by the Hacker movement, which fights confidential data by hacking, free softwares have allowed studying, altering, using and duplicating of their source codes. Intellectual property rights can be opened to third parties through defining conditions of exploitation thanks to Creative Commons (CC) licenses. Places combining learning by doing, exchanging knowledge among peers and sharing of prototyping machines have opened and favored the transposition of this philosophy into the material world, thanks to OpenSource projects which document and provide guidelines for manufacturing processes.

By facilitating quick, simultaneous and connected iterations, these free initiatives help accelerate the innovation process through the use of collective intelligence. The fusion of Gilbert Simondon's philosophy with these practices has been illustrated by the creation of contemporary open objects: legible and comprehensible, easily repairable and removable, all or parts of which can be transformed and reused for new creations (Fig. 3.1).

3.4.3 Sustainability Defined as the Ability to Evolve

Just as Gilbert Simondon's open object theory teaches us that an object's durability lies in its ability to evolve, costume history is full of examples of ingenious uses of removable, reversible and modular systems allowing easy replacement of used parts or changes of appearance at will.

Nevertheless, contemporary garments still seem to resist being conceived on the basis of those reusable spare parts designs common in

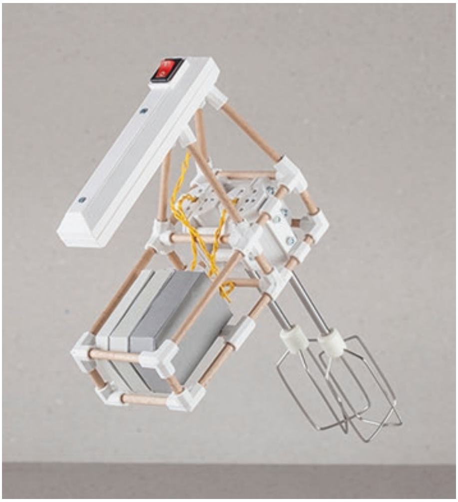

Fig. 3.1 Electric mixer, "Hacking Households", Coralie Gourguechon, Leonardo Amico, Natasa Musevic, Thibault Brevet, Jesse Howard, Jure Martinec and Tilen Sepic, presented at the Design Biennal BIO5O, Llubljana, Slovenia, 2014

sustainable objects, which leads us to question whether sewing, predominant since the Paleolithic age, would not be slowing this evolution.

3.4.4 Using CNC Technologies

The emergence of fablabs, where access is possible to computer numerical control machines (or "CNC"), seems to have largely contributed to open objects developments because these machines (laser cutting, 3D printer, digital milling) allow for a fast and on-demand creation of customized parts at a low cost and facilitate experimenting. In this context we have come to ask ourselves how could the designer, inspired by the open initiatives, imagine a local and on-demand production line of modular clothing so as to reconcile extended life spans and fashion renewal pleasure?

To achieve this, our approach is twofold. First, our practice-based prospective, following an abductive inference method, will check whether reversible and repositionable textile assemblies, opening the way to trans-

Fig. 3.2 Diagram of the 4M concept proposed in enrichment of the 3R's sustainable development strategy

formable clothes, would increase life spans in favoring repair, reuse and recycle. Second, we will study to what extent, by updating the patronage business thanks to CNC technologies, we could imagine local and on-demand production of modular clothing with a high personalization potential, co-created by their users (Fig. 3.2).

3.5 Major Elements Derived from the State of the Art

Aiming at developing garment modularity leads to an imperative standardization of measures and processes, as shown by the OpenStructures (OS) project designed in 2011 by Thomas Lommée. The French designer has imagined grids and rules from which designers can create spare parts or components in order to manufacture modular, removable and transformable objects. Plans and documentations are published in OpenSource on the website http://beta.openstructures.net/ (each author determining conditions of use with a Creative Commons license) so that they can contribute to the making of new objects produced by the community. From the start, translating these principles onto clothing looked promising.

So as to allow the user to self-transform his/her modular garment, I became interested in the *Self-Assembly* line created by Finnish designer Matti Liimatainen. His laser-cut seamless clothing is delivered flat-packed, leaving buyers to self-assemble the different parts of the kit.

Dutch designer Martijn van Strien is developing a similar approach with his collaborative *Post Couture Collective* project since 2016. However, instead of delivering the kit to be self-assembled, its digital pattern is also on sale on the website and can be adapted to the user's measurements with parametric software and parts can be then laser-cut by the user on his own in a nearby fablab.

Hence, a worthwhile perspective seemed to emerge from combining such recent approaches with OpenStructures' modularity principles in order to create modular garments produced locally and on-demand in fablabs.

For their *Don't Run project* designed in 2013, instead of opting to produce their personalized and demountable shoes in established fablabs, Eugenia Morpurgo and Juan Montero imagined a concept store where the customer attends the laser cutting of the parts composing the selected shoes, as well as the 3D printing of removable jointing parts replacing the traditional sewn and glued joint.

In view of the current state of the art and the experiments shown herein, we concluded that to think of a flexible clothing design inspired by the fablabs could lead not only to reconsidering textile assembly techniques, but also to arriving at a new fashion system based on stores transformed into micro-manufactures.

3.6 Experiments Around Different Levels of User Involvement

As summarized in the major elements derived from the state of the art, the implication of the user seeming essential to really bear an impact on modular garments life spans extensions, such concern has been the focus of our experiments. We first aimed at involving the consumer in garment assembly and then at disassembly to facilitate repair and recycling, before developing modularity. Throughout this process, we focused on replacing seams by different systems of reversible and repositionable textile assemblies, easily and quickly manipulated by the user (Fig. 3.3a, b).

"Under Construction"

This woman collection is made of 7 silhouettes of 16 clothes developed between January and June 2014. It became the starting point of the ongoing research work.

Modeling, pattern making and sewing are time-consuming practices requiring equipment and technicality no longer transmitted from generation to generation, making it more difficult to be accessed.

3.6.1 Making Clothes Assembly Accessible to the User

This design project for disassembly aimed at making clothing manufacture accessible to the user lacking any specific technical expertise by allowing to self-assemble the ordered garment, delivered in a flat-pack thanks to removable grouting pieces. Such dismountable garment allows for easy flat repairs by the amateur as well as for duplication of patronage in an open design spirit.

In this manner, assembly would be the fastest and easiest possible, we can progressively reduce the number of pieces per clothes down to more than half of them ending up made of one piece of cloth only.

Machine sewing, in view of its time-consuming and very technical nature, was replaced by copper staples, and they were constitutive, orna-

a
Experiments Overview

PROJECTS		UNDER CONSTRUCTION	BLANK PAGE	TRIBUTE TO MONDRIAN
CONDUCTING EXPERIMENTS DATES		01 - 06/2014	05 - 10/2016	06 -09/2017
CONCEPTION	NUMBER OF PIECES PER GARMENTS	MINIMUM	ONE SOLE PIECE	SPARE PARTS CONCEPT
	PATTERN MAKING	MANUAL	VECTORIAL	
	FABRICS TYPE	ALL	SYNTH. & LEATHER	SYNTHETICS
PRODUCTION	CUTTING TECHNOLOGY	MANUAL	LASER	
	USE OF SEAMS	LIMITED	NONE	
	TEXTILE ASSEMBLY SYSTEM	REMOVABLE STAPLES	6 INTERLOCKING SYSTEMS	INTERLEAVED STANDARDIZED INTERLOCKING SYSTEM

b
Supply Chain Steps

PROJECTS		UNDER CONSTRUCTION	BLANK PAGE	TRIBUTE TO MONDRIAN
CONDUCTING EXPERIMENTS DATES		01 - 06/2014	05 - 10/2016	06 -09/2017
CONCEPTION	CO-CONCEIVED			
	CUT TO MEASURE			
	CUSTOMIZED			✓
PRODUCTION	CO-PRODUCED		✓	✓
	ASSEMBLED	✓	✓	✓
USE	SELF TRANSFORMED			✓

Fig. 3.3 (**a**) Comparative table of conception and manufacture experiments developed between 2014 and 2018; (**b**) comparative table of supply chain steps of the experiments developed between 2014 and 2018

mental and maintained textiles in place thanks to their double hooks (Fig. 3.4).

3.6.2 Going Back to the Essence of Modeling

Inspired by the series *Spatial Concept, Waiting* of Lucio Fontana's "slash" paintings and Robert Morris's *Wall Hanging* felt sculptures as well as the

Fig. 3.4 Fixing the *Under Construction* blazer

quotation by Constantin Brancusi which says that "simplicity is complexity resolved", we endeavored to go back to the essential gestures of model making: cutting, turning around the body, and fixing and defined the following protocol (Fig. 3.5a, b):

- Design the garment directly in volume
- Make the garment with one only piece of fabric as much as feasible
- Restrict the number of pieces needed to a strict minimum in all cases
- Turn the fabric around the body passing either from front to back over the shoulders or from below the crotch, or it will wrap around the bust on the circumference line
- Form the volume of the garment, by cutting, notching, folding and covering one panel on top of the other
- Leave the fabrics raw edges
- Only glued liners inside the outer fabric are allowed
- Fix the volume, as much as feasible, thanks to removable fasteners
- Reduce fixing points to a strict minimum
- Add seams only when impossible to do otherwise (Fig. 3.6)

Fig. 3.5 (**a** and **b**) Examples of seamless clothes made of one sole piece of fabric, shown flat, in volume, and worn on

3.6.3 Investing Time in Conception so as to Make Production Simpler and Quicker

Mounting time and complexity were significantly reduced. This has been particularly noticeable as regards jackets and coats. For instance, a classic women's blazer consists of a minimum of 30 pieces, and its cutting and assembly by a professional mechanic requires at least a day and a half of work, whereas the manufacture of the *Under-Construction* blazer required

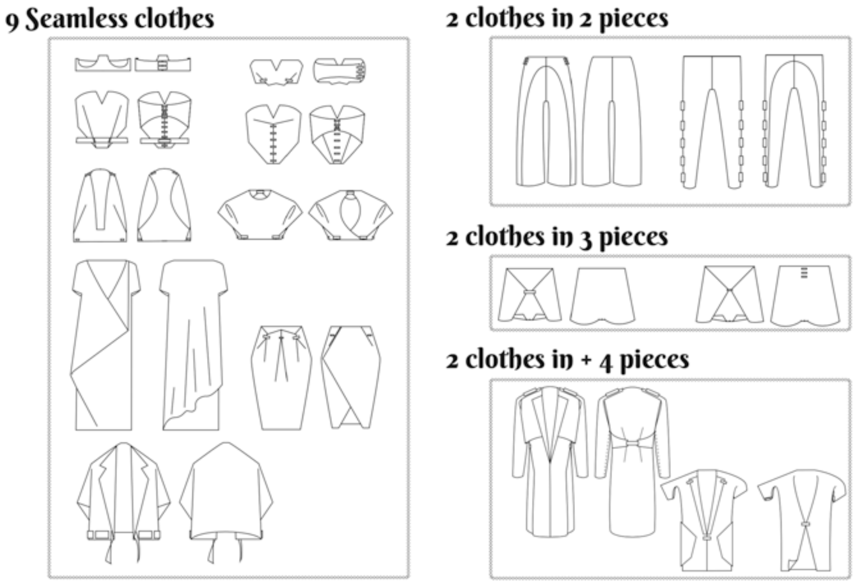

Fig. 3.6 Technical design of *Under Construction* collection, shown according to the number of constitutive pieces

only three hours of cutting, shaping, stapling and stitching for pockets. In addition, less fabric was needed for some of these garments made of one sole piece of fabric than for their cut and sewn equivalents.

Nevertheless, this garment design finds its limits when it comes to pants or shorts as their junction at the crotch is problematic, in terms of both space geometry and necessary solidity and comfort in view of the local tensions, frictions and warm-ups and no satisfying alternative has yet been found to replace the seam.

3.6.4 Toward Using CNC Machines

This collection was hand-cut with scissors in natural textiles. Hence, the edge of each piece received a Framis band through ironing in order to limiting scrolling, thus making the splitting of materials necessary for sorting. Such a long and tedious process led us to envisage using laser cutting.

"Blank Page"

3.6.5 Facilitate Recycling

"*Blank Page*" is the result of revisiting the bra, strapless, t-shirt, blazer, high waisted trousers, and jacket of the "*Under Construction*" collection with a will to add to the pre-existing design for user implication and dis-assembly a recycling aspect.

After having studied the recycling processes of the clothing industry, we arrived at the following postulate: in order to facilitate and automate the mechanical grinding of discarded clothes while improving the quality of the resulting fibers, new clothes should be created with the following principles:

- No added metal, plastic parts or other non-textile elements; clothes must be 100% textile made
- No interlining, lamination or coating as they make it difficult or impossible to separate materials
- No mix of materials in order to avoid having to separate different types of fibers
- No non-recyclable fabrics
- No seams as they create extra thicknesses and irregularities after grinding

3.6.6 Create 100% Textile Self-Locking Systems

Inspired by glue-free packaging and joinery assemblies with mortise and tenon, we developed self-locking arrow-shaped textile assembly systems that work with straps going through passers after which they widen and end up blocked. Thanks to these bindings, all clothes could be created seamless and in sole piece of fabric, except for the wide pants that needed two. In order to solve each problem, seven different self-locking fasteners were developed (Fig. 3.7).

- Applied single arrow (e.g. bra chest clip)
- Applied double arrow (e.g. t-shirt armhole)
- Applied elongated double arrow (e.g. strapless)
- Pass way belt (e.g. middle back of blazer)
- Single nested arrow (e.g. middle back of the t-shirt)

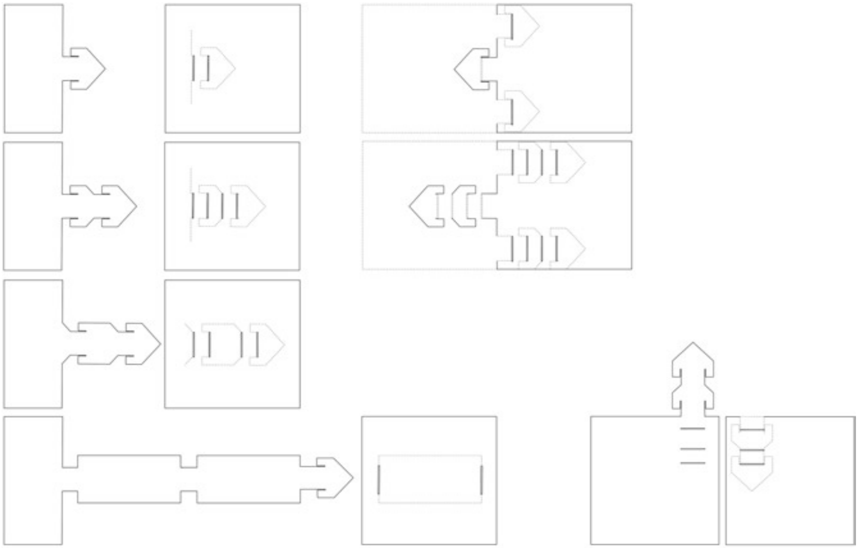

Fig. 3.7 Technical design of self-locking assembly systems; from top to bottom and from left to right

- Double nested arrow (e.g. bra frames)
- Double perpendicular arrow (e.g. blazer sleeves)

It is clear that such fasteners offer unequal strengths. Single-arrow fasteners, whether nested or not, are clearly too weak to withstand body movements without detaching. The perpendicular simple fastening, although more resistant, has the disadvantage of creating disgraceful deformations. Consequently, the most powerful types of assembly turn out to be the double arrows as well as the pass way belt.

3.6.7 Move to Digital Design

Fasteners have been duplicated numerically so as to design vector patterns for laser cutting. If fabric ironing and preparatory time is not to be ignored, the use of the CNC machine allows for a significant cutting time saving and cauterizes edges with a tracing precision needed for the type of assembly chosen (Fig. 3.8a, b).

Fig. 3.8 (**a**) The *Under Construction* blazer (three pieces, six seams, four staples); (**b**) its *Blank Page* version (one piece, no seams)

3.6.8 Toward a Modular Design

Even though our initial intention was to laser-cut the entire collection, a major problem had to be faced as some of these one-piece fabric patterns proved too large to be handled by the laser-cutting machine to which we had access (900 mm × 600 mm). Such a matter of fact led us to opt for modular concept bases on these same assembly systems.

"Tribute to Mondrian"

3.6.9 A Unique Base Pattern for Eight Different Garments

Tribute to Mondrian is a collection of eight clothes: shirt, two dresses, two blazers, perfecto, trench coat and coat, fully achieved out of a unique pattern of ten combinable spare parts. Each piece of clothing has the same

Fig. 3.9 Technical design of *Tribute to Mondrian* collection with related spare parts, shown in gray the ten-piece basic pattern

front and back, and the same sleeve (when there is one), only the length of it varies. Two sets of extension strips can be added to bring the garment to the hips or knees. Finally, patch pockets, storm flaps and belt can be installed as an option.

This collection draws its inspiration from construction games such as Lego or Mecano, known for their modularity and their saturated hues. We elected to use the colorful range dear to Mondrian: blue, yellow, red, black and white to highlight the playfulness of this clothing design (Fig. 3.9).

3.6.10 A Better Standardized Self-Locking Attachment System

We used the same kind of fastening systems as for *Blank Page*. However, we sought to standardize the fastener so as to arrive at a unique one that can be used in any circumstance and anywhere on the body.

For the sake of solidity, the most suitable form seemed to be a double-notched interlocking arrow, which can distribute forces on both sides of the assembly and are therefore stronger than with the applied method. As regards size and proportions, we relied on the measurement of the shoulder line, as it is the shortest in pattern. The fasteners must remain large enough to be handled easily and quickly by the user; this is the reason we decided that a shoulder line would have five fasteners: three on the front piece, interspersed with two on the back. The dimension thus defined allowed us to establish a metric reference for the development of the remainder of the pattern (Fig. 3.10a, b).

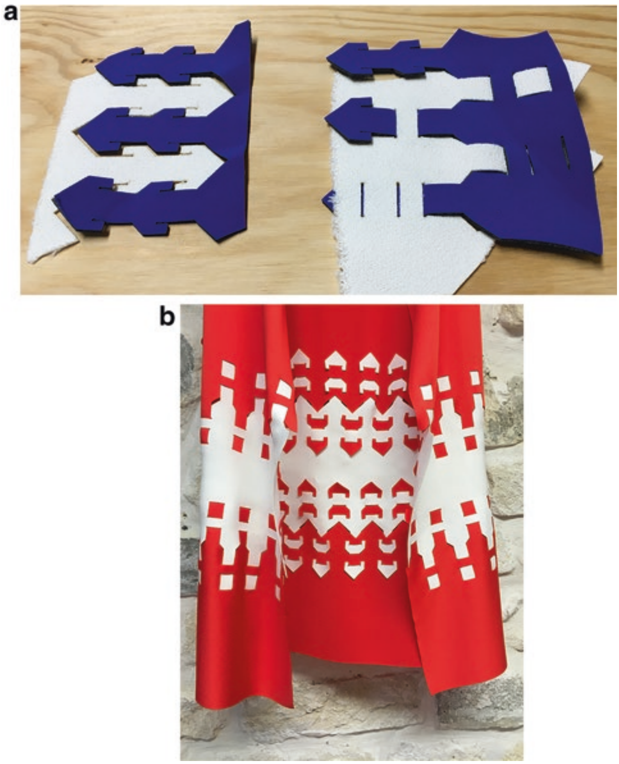

Fig. 3.10 **(a)** Two parts being assembled; below left, two parts fully flat intertwined; **(b)** inside of garment made of parts of two contrasted colors

3.6.11 Minimize Cutting Waste

We then reworked the shape so that pieces would fit not only when they are mounted but also when they are flat. Thanks to this new design, it is now possible to cut two pieces side by side by generating textile drops only on the periphery of the overall shape and not between the two pieces now perfectly interlocked. Without making it a project of zero waste design, it demonstrates the strong intention to reduce cutting waste to a minimum.

In order to express the versatility of this modular proposal, we chose materials with very different weights and holds (polyester, scraped wool and neoprene). In some instances, we played with fabrics of different colors to enhance the pattern created by nested assemblies. We also used several two-sided textiles to materialize possible future evolutions for these reversible pieces (Fig. 3.11).

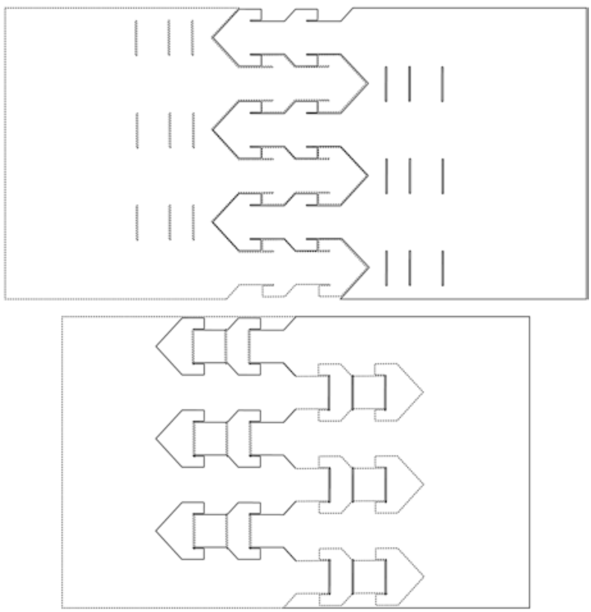

Fig. 3.11 Top, technical design of 2 intertwined fasteners, cut side by side; bottom, technical design of 2 intertwined fasteners, assembled

3.6.12 Towards Productivity Gain

The biggest success of this experiment was the productivity gain. Indeed, a person working alone was able to produce the entire collection in just two and a half days. The first day was dedicated to cutting fabric coupons, ironing, then laser-cutting each piece and the rest was dedicated to the manual assembly of parts.

However, the shape and size of the fasteners makes the joining of four pieces together problematic, and these do not seem really strong except on slightly thick fabrics with a certain hold. Moreover, laser-cut fixing arrows are visible inside the unlined garment and are not so pleasant to be worn directly on the skin. For all these reasons we believe that this clothing design is probably better suited to produce clothing worn on top of other garments, such as jackets and coats (Fig. 3.12a, b).

Fig. 3.12 (**a**) A perfecto (polyester and neoprene); (**b**) a coat (two-sided grated wool and neoprene)

3.7 Conceptual Extrapolation

"FashionTechAway"

Developed in March 2017, this concept of micro-manufactures producing and selling locally and on-demand won the second prize at the Zero Waste Design Contest 2017 organized by the Paris Region Waste Agency.

3.7.1 Fabless Versus Fablab

In response to the fabless system of fast fashion, we propose a relocation through a network of micro-manufactures scattered throughout the territory to better control the environmental and social impacts of production. Inspired by fablabs, we imagine a production line based on the digitalization of patterns and the use of CNC machines to propose a local and on-demand production of tailor-made, customizable and modular garments, able to be transformed by the users without specific skill or machine according to their needs, style or season (Fig. 3.13).

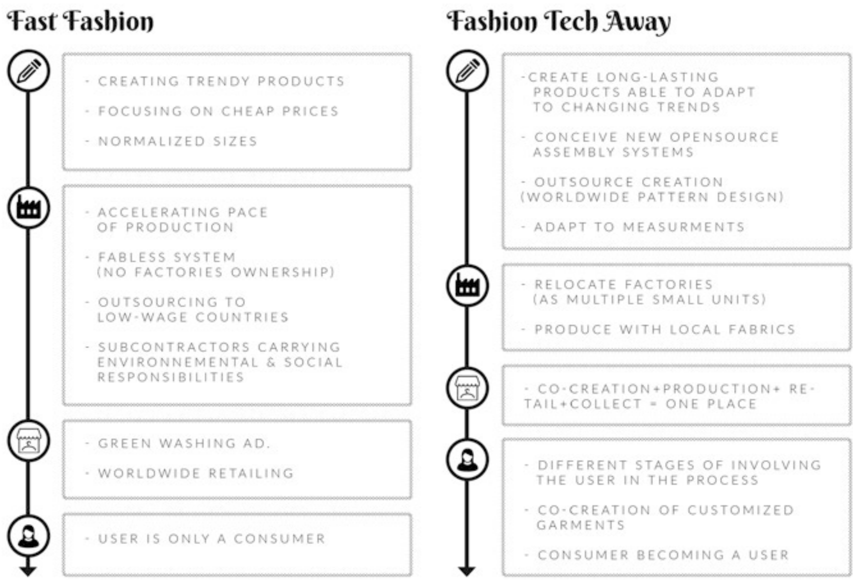

Fig. 3.13 Comparison of Fast Fashion supply chain and *FashionTechAway* concept

3.7.2 A Hybrid Place for Customization, Production and Sale

With new boutique-workshops that will be anchored in the urban landscape, they will gather a number of services, such as sale of ready-to-wear products, on-demand manufacture of customized clothing, bartering of spare parts, upcycling and collection of damaged parts for recycling. These mini-production units, open to everyone, will show all stages of the manufacturing process while raising awareness of environmental issues related to the clothing industry.

Showcases

Some of the codes from usual stores will be kept. Thus, *FashionTechAway* micro-factories will have large showcases where ready-to-wear modular clothes will be presented on traditional mannequins or racks. Nevertheless, the same clothes will also be seen being assembled together with the way the seamless fasteners are used. Screens will also display images of multiple personalized interpretations of one given basic patronage.

Boutique

It will offer ready-to-use seamless clothing as shown in the show-case but also upcycled ready-to-wear clothes made from second-hand spare parts issued from the dismantling of used clothes as well as a selection of spare parts, sold individually, in sets or in kits ready to be assembled, so as to update modular clothes already purchased.

Customization Area

A stylist-salesperson will accompany the visitor step by step in the structuring of his/her modular clothing: consultation of inspirational tools (database of available digital patterns, archives of variations already produced, notebooks of trend colors and materials); choice of basic patronage; parametric client measures; and choice of options, such as:

- Garment volume (e.g. slim, straight or oversize)
- Garment length (e.g. at the waist, above the knee, mid-calf length)
- With or without sleeves
- Sleeve type (e.g. length, shape)
- Neck or collar type (e.g. rounded, V-shaped, boat, shawl collar, tailored collar)
- Additional pieces (e.g. bolster, gun flap, belt, shoulder strap, pockets)

Fabrics Library

Once the choice of fabrics has been made from the fabrics library, the advisor will get the corresponding fabric coupons and hand them over to the CNC machines operator.

Making of

The operator will laser-cut the parts constituting the garment after having their optimum physical placing so as to limit textile waste. The garment might then be assembled by the buyer thanks to the mounting instructions engraved on the back of the fabric during laser-cutting.

Photography Studio

Once the garment is finished, it will be photographed in order to be archived digitally with the customer's measurements, details of options and fabrics chosen as well as the custom-made patronage.

3.7.3 Limit Environmental Impacts at Each Step

Whereas the main selling point of this project is the combination of style individualization and versatility, it nevertheless also tries to systematically apply at each production stage the principles of the 3R theory of the circular economy: reduce, reuse and recycle (Fig. 3.14).

Co-maker

The high personalization potential of such garments and their capacity for evolution—bringing it closer to a made-to-measure product—could contribute to increasing the emotional attachment of the user as co-maker of the object, thus favoring a longer life span.

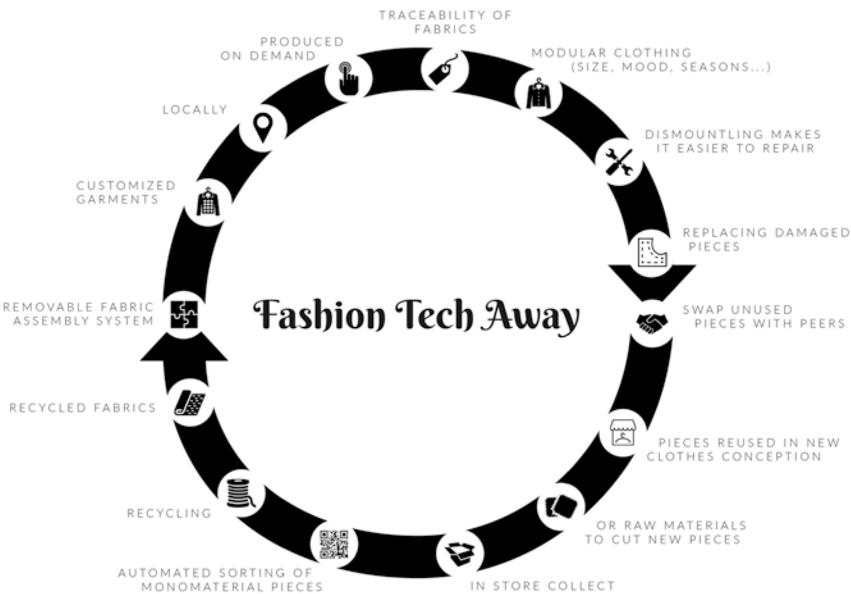

Fig. 3.14 Life cycle of *FashionTechAway* products

Production

Local production and sourcing limit transportation impacts while using fabrics made of 100% recycled polyester could help limit plastic bottle pollution in our oceans.

Re-make

The self-locking and easily removable assembly system allows the user to enjoy trends renewal, making it easy to transform and extend life spans of garments made of spare parts easy to be rearranged as need be, according to changes in style, season, size or need.

Repair

Easy disassembly facilitates flat mending and digitalized patterns storage allows for a reissue of damaged parts.

Second-Hand Spare Parts Market

Worn spare parts can be swapped or sold among users or exchanged against a purchaser voucher at the boutique.

Recycling

This first in-store sorting entices users to favor reuse and reduces the amount of material sent for recycling. The QR code, engraved on each piece, contains the metadata relating to the color and composition of the fabric, which allows for an automated sorting and monomaterial pieces sorted out by family of colors, allowing the creation of a colorful recycled thread that will not require bleaching or dyeing.

3.7.4 Toward Externalizing Numerical Design

Offering in OpenSource such fastening systems as well as the standardization rules relating to pattern making could help diversify the supply of modular clothing. All over the world, fashion designers could appropriate this design approach and offer their own creations for purchase on a digital platform. This would lead to reconciliation of worldwide design outsourcing and production relocation.

3.8 Results and Discussion

3.8.1 Practical Experiments

After having performed these various experiments, we conclude that this clothing design requires that the user be able to transform garments in a simple, fast, intuitive and playful manner and without specific skills or machines. The standardized self-locking system we designed fulfills such needs while allowing a real productivity gain. However, it poses problems, for instance where four pieces meet or around the armhole curve. The discomfort generated by the presence of the arrows inside the unlined textile would seem to restrict the use of this assembly system only to wide designs or to external clothing. In addition, these fasteners do not allow for the use of fine and light fabrics nor pleated or draped designs.

3.8.2 Towards a Zero-Waste Module Conception

In addition to previous remarks, the complex shape of *Tribute to Mondrian*'s standardized interlocking fasteners generates textile waste out of the laser cut spare parts. Consequently, for our new experiment started in June 2018 and titled *Fragments Garments*, we designed a new form of double-notched nesting arrow to be combined with zero-waste combinable square modules based on the OpenStructures grid dimensions. With such new 12 cm square module, we are able to laser-cut 70 spare parts all at once in one fabric panel in only 20 minutes. The project is not fully zero waste yet because specific pieces such as collar, sleeves and pockets still generate some cutting waste, but the small size module increases productivity and allows production textile waste to be reused as raw material.

3.8.3 Enriched Conceptual Extrapolation

New projects gradually integrating the state of the art have led us to enrich the idea of a production line based on the use of CNC machines.

The project *Direct Pattern on Loom* could allow to personalize not only the garment but also the fabric, because material and motive could be produced on-demand with a digital jacquard loom directly in the form of spare parts so that only the material necessary for the design of the garment would be manufactured, avoiding generating any cutting waste.

Another interesting technology to be used would be the textile micro-molding CNC machine created by designer Bas Froon. This machine applies heat with pressure according to the chosen metal matrix form on a textile- or felt-appearance bioplastic, allowing punctual changes in material properties in specific areas, so as to create localized reinforcements on clothing.

Jessica Joosse and Fabienne van der Weiden from the studio Labeledby experimented with 3D printing of garment fasteners, such as zippers and buttons, directly on clothes. To combine this extended personalization onto haberdashery accessories, ensuring material disassembly for recycling, it would be preferable they be redesigned to be removable and reusable and to make sure that they be produced with an environmentally harmless filament.

In addition, other CNC machines, such as digital embroiderers or Gerard Rubio's *Kniterate* CNC knitting machine, could further enrich the offers of these micro-manufactures.

3.8.4 Looking Ahead

During our experiments we gradually expanded the spectrum of user involvement within the product life cycle. Such enlargement might be conducive to allowing for a progressive user investment, softly leading to forgo current consumption habits. Our suggested diversified offer has been thought not only as an educational tool but also as a customer loyalty marketing tool.

Much will have to be done in terms of cooperation in order to mobilize Fablabs energies toward getting them to eventually evolve towards hybrid places where advising, producing, selling, repairing, reusing and recycling would be offered locally, making the best use of available CNC machines.

After this first year of theoretical and practical research, during which transposing the open object philosophy onto extended life span clothing has slowly been taking shape, new avenues are now open for redefining the designer, manufacturer, salesperson and consumer roles, as well as for gradually envisaging a synergic approach of design strategies for a circular economy.

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4

The Emergence of New Business Models to Foster Sustainability: Applying Technology to Revise the Fashion Industry

Nina Bürklin and Kathrin Risom

4.1 Introduction

The emergence and ongoing development of digital technologies in recent years has substantial effects on our business environments. Particularly, these technologies have an impact on well-established business models so that new IT-induced service structures are emerging and, thus, revising hitherto successful industries. At the same time, a new consciousness has become evident among consumers according to which they integrate concerns about matters such as environmental protection and fair labour standards into their purchasing behaviour. Numerous movements, for example, voluntary simplicity (McGouran and Prothero 2016), relate to a minimalistic lifestyle focusing on experiences rather than on materialistic possessions. The intertwining of these two societal developments enables higher economic benefits through innovative business models and at the same time provides vast opportunities for fostering

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sustainable development on a large scale. This becomes especially visible in the fashion industry which, even as one of the biggest drivers in the world economy (Eder-Hansen et al. 2017), is also one of the most polluting industries (Boström and Micheletti 2016). Hence, this chapter seeks to illustrate successful cases where technology-driven business model innovations co-create value by offering new kinds of services. We present two case studies, namely *Filippa K* and *MUD Jeans,* to show how conventional approaches to value creation have been revised and, in doing so, have created more social and environmental responsibility in the market.

4.1.1 Current Trends in Digital Technologies and New Consumption Modes

Customers nowadays, especially younger ones like the millennials, are characteristically technology-savvy and are sensitively aware of current developments regarding sustainability and social justice (Paulin et al. 2014), for example, climate change, social inequality or political instability. While they are becoming less brand loyal, they remain very price sensitive, although many base their purchasing decisions more on whether a company's practices and values align with their own values than purely on price (Amed et al. 2016). Specifically, two-thirds of the millennials are willing to spend more on brands that are sustainable, as is also illustrated in corporate growth rates. In 2014, for example, sales of consumer goods of brands with a demonstrated commitment to sustainability grew more than 4% globally, while those without such commitment showed a less than 1% growth rate (Nielsen 2015). When it comes to reported actions, customers consider their wallet as the most effective way to drive change, either through donating to good causes, buying a product with a social or environmental benefit, or by boycotting a company with objectionable practices (Cone Communications 2017). New opportunities to gather and exchange information on products or services such as their quality, price, availability or design that have arisen, also through direct internet access (Belk 2014), are now offered along with alternative consumption modes. Moreover, individual purchasing experiences have changed through the proliferation of digital channels that range from a traditional, linear purchasing model towards a highly complex journey, which includes various online and offline touchpoints.

Over the past few years, more and more relationships between customers and suppliers have been strongly influenced by digital technologies. First, formerly *high-touch* encounters have become *high tech* as customers no longer interact with service employees, but with self-service technologies (SSTs) (Bitner et al. 2000; Meuter et al. 2000, 2005). SSTs are applied along the whole consumption process (Meuter et al. 2000) and do not only reshape existing touchpoints but also entail an exponential increase in the interaction between companies and customers as well as within the customer base. This implies that ubiquitous communication between several actors in a network has become a characterizing feature of new forms of production and consumption (Bitner et al. 2000; Gentile et al. 2007). Practitioners agree on the revolutionary scope, set digital technologies at the top of their agendas and regard them as having the potential to "transform […] the world into one huge network […], in which] [p]eople, machines and systems are now constantly connected and communicate with each other in real time" (Roland Berger 2015, p. 3).

Second, existing dyadic relationships between suppliers and customers have developed into multilateral service structures with several actors (Benoit et al. 2017, p. 220). In these ecosystems, the involvement of customers in the service delivery process is enabled by the use of digital technologies (Akaka and Vargo 2014; Hilton and Hughes 2013; Jaakkola et al. 2015). New actors enter the market and seize lucrative opportunities for innovators (Barrett et al. 2015) by developing new service models, which could become the consistent next step in raising the co-production role of customers to the next level.

Following this development, companies often adapt the role of platforms (Lu and Kandampully, 2016) that entail technology-enabled temporal access of goods provided by another market actor, who can be either a conventional supplier or a peer customer (Bardhi and Eckhardt 2012). Hence, by drawing on innovative technology, literature frames it as "sharing the consumption of goods and services through *online* platforms" (Hamari et al. 2016, pp. 2047f.), a phenomenon which is often referred to as the *sharing economy*. The critical impact of digital technologies on this new concept of sharing is emphasized by Roland Berger (2015), who claims that "the idea of sharing things and using them together has worked perfectly well for hundreds of years. All of sudden, however, it has begun to spawn disruptive business models with spiralling customer numbers and revenues to match" (p. 3). The tremendous growth of the platform-enabled peer-to-peer services affects traditional market structures, not least in the fashion industry.

4.1.2 Relevance of the Fashion Industry for Sustainable Development Through Innovation

Due to its size as economic driver (Eder-Hansen et al. 2017), and its status as highly polluting industry (Boström and Micheletti 2016), the fashion industry, the focus of our research, is highly relevant. Amongst other negative effects, it pollutes waterways and oceans with more than 3000 chemicals that are used for producing, dyeing, coating and softening fabrics, of which the majority are hazardous to people and the planet (Greenpeace 2016). Furthermore, large amounts of non-renewable resources are extracted to produce clothes that are often used for only a short period, after which the materials are largely lost to landfill (Ellen MacArthur Foundation 2017). The quick disposal of clothing is one of the consequences of the recent "fast fashion" phenomenon (Laitala 2014). This linear system leaves some opportunities in the industry untouched, while having significant negative societal impacts on local, regional and global scales (Ellen MacArthur Foundation 2017). One solution to this is a systems perspective based on the circular economy (van Buren et al., 2016), that is strongly enhanced by innovative service offerings focussing on access to goods rather than on possession (Mair and Reischauer 2017).

The economic value of the linear model's negative externalities is difficult to quantify, although the recent *Pulse of the Fashion Industry* reportedly estimated that by 2030 the overall benefit to the world economy could be about EUR 160 billion (USD 192 billion) if the fashion industry were able to address the environmental and societal fallout of the current status quo (Eder-Hansen et al. 2017). By changing practices, the industry can both stop the projected negative impact and generate a very high value for society (van Buren et al. 2016), while also securing its own profitability. According to practitioners, "[s]ustainability will be at the centre of innovation in the fashion industry in 2018, with frontrunners harnessing the circular economy to unlock technical innovations, efficiencies, and mission orientation" (Amed et al. 2016). Therefore, it is not only environmentally necessary to facilitate a shift towards more sustainable systems that will allow for reducing the excessive use of raw materials, increase the number of recycled items in enhancing their life cycles, and enable responsible disposal of clothes; such actions will also advance the industry's economic potential.

Following this line of argument, alternative business models are one solution to the problem of fast fashion and are already considered to be one of the disruptive innovations in the fashion system (McKinsey 2018). Changes in business models are not limited to reducing damage, but are part of a transformation in how clothes are produced, sold, shared, repaired and re-used (Niinimäki 2013). They are centred on the idea of prolonging the life of a garment, be it through reuse or increased durability. These innovations "facilitate dematerialization and the traceability of materials, waste and collected clothes; challenge ownership patterns; redefine sourcing and marketing strategies; and involve customers in a new narrative where there is also space for creative and cultural diversity" (Greenpeace 2017). Such business models can complement existing models of fashion suppliers or form the foundation of a new company in its own right.

As outlined above, novel business models promote consumer access rather than ownership, putting redistribution of and access to resources ahead of the production of resources (Mair and Reischauer 2017). Examples of such models in the fashion industry include renting clothes at 10%–15% of their regular price rather than purchasing them, or following a concept like *Netflix*, giving consumers access to an unlimited number of items, based on a monthly subscription fee (Eder-Hansen et al. 2017). Even though these new business models currently prevail in smaller or medium-sized companies (Iran and Schrader 2017), there are signs that some larger companies are seriously considering these options in their future planning. Thus, due to the urgent need for innovation across the industry, a growing number of fashion companies are developing agility, collaboration and openness that formerly were seen as characterizing qualities of start-ups. Traditional players are now compelled to become open-minded regarding new types of talent, new ways of working, new kinds of partnerships and new investment models. Furthermore, fashion brands with targeted initiatives that have a societal impact will be the best placed to improve their environmental and social footprint and to counteract the rising costs of apparel production. They will pull ahead of their competitors with innovative ways of doing business and efficient production techniques that minimize the use of water, energy, and land, and at the same time potentially increase economic benefits. For all these models, refocused marketing based on the experience and capacity that retailers and brands have, as well as optimized logistics are key drivers stimulating growth of new service offerings (Ellen MacArthur Foundation 2017).

4.2 Background

4.2.1 The Role of Digital Technologies in Current Markets

Digital technologies are not simply tools that enable innovation in service industries; they are also seen as transformative resources in service innovation (Barrett et al. 2015), which is defined as the "rebundling of diverse resources that create novel resources that are beneficial [...] to some actors in a given context" (Lusch and Nambisan 2015, p. 161). Arthur (2009) explains individual technologies as partially a "means to fulfil a human purpose", and refers to technologies that consist of several individual ones as an "assemblage of practices and components" (p. 28). Akaka and Vargo (2014) build on these definitions in defining technology from a service-dominant logic perspective as a "combination of practices, processes and symbols that fulfil a human purpose" (Akaka and Vargo 2014, p. 377). As this interpretation bridges the gap between technology, service ecosystems and institutions, it reflects our understanding of the sharing economy.

Within service ecosystems, the role of digital technologies is characterized by a row of different tasks. First, digital technologies foster the flexible development of service ecosystems and ensure the structural integrity of the system. Second, they enable efficient information sharing among actors by means of service platforms, stimulating a shared worldview, which allows users to perceive opportunities for resource integration. Third, digital technologies ensure that the ecosystem's architecture is transparent and that actors' individual co-creating contributions are properly attributed (Lusch and Nambisan 2015). In the form of service platforms, digital technologies act on other resources by separating information from its devices, liquefying them through digital decoupling (Lusch and Nambisan 2015; Storbacka et al. 2012; Vargo and Lusch 2008; Ordanini and Parasuraman 2012.), and by increasing their density through data mining (Akaka and Vargo 2014; Lusch and Nambisan 2015). As such, digital technologies have been a transformative resource for intangible innovations such as Google and Facebook, or tangible-replacing service innovations such as *Netflix*, that build the technical and economical foundation for innovation (Barrett et al. 2015; Lusch and Nambisan 2015). Thus, technology can be summarized as "potentially useful knowledge […]" (Vargo et al. 2015, p. 65), the development of which can be explained as the basis for the market innovation of the sharing economy (Lusch and Nambisan 2015; Vargo et al. 2015).

Hence, digital technologies affect existing business models, disrupt markets and push service innovation. Particularly, the recent advancements in digital technology enable collaboration between actors beyond prior existing boundaries of time, space and security (Lusch and Nambisan 2015). Nowadays, technology plays a decisive role in managing transactions between all actors involved in co-creating value. Due to this feature, value co-creation is no longer limited to service-for-service exchanges between customers and companies; it is also a means of including various private and professional actors in the ecosystem. The sharing economy is a prominent example of this decisive role technology is playing in promoting service business development that focuses on digital platforms, but not on distribution channels (Mair and Reischauer 2017). Therefore, we discuss the sharing economy as a new business model enabled by technology.

4.2.2 The Concepts of C2C and B2C Sharing in the Sharing Economy

In trying to examine and understand the large number of evolving service offerings in the sharing economy, a large array of labels and definitions evolved, describing different or the same types of technology-based sharing models. Hamari et al. (2016) best reflect the technological foundation of the sharing economy by defining it as "[t]he peer-to-peer-based activity of obtaining, giving, or sharing the access to goods and services, coordinated through community-based online services" (p. 2047). While this comprehensive definition provides a valuable description of the mediated interaction in general, conceptual and expected experience-based differences require further differentiation between various forms of sharing on a lower abstraction level. Exchange relations between market actors provide the ideal basis for this as they allow for differentiation between two major forms of shared services as proposed by several authors (e.g. Benoit et al. 2017; Lu and Kandampully 2016; Möhlmann 2015; Botsman and Rogers 2010), namely access-based services and collaborative consumption.

Concerning access-based services, the emphasis is on value propositions formulated between the service provider and the customer and thus on their dyadic relationship (Benoit et al. 2017). Therefore, access-based services are a paradigm for business-to-customer (B2C) sharing (Möhlmann 2015). This means that customers can enter a platform to get access to a certain product or service provided by a professional company for a defined period of time (Bardhi and Eckhardt 2012). A critical review of this concept, however, indicates that simplifying this dyadic relationship provides only a narrow image of the service. Zooming out (Vargo and Lusch 2016, 2017) shows that there are also indirect effects between customers. In this regard, Bardhi and Eckhardt (2012) point out that "consumers need to co-create the service outcomes not only with the company but with one another" (p. 892). That is why trust between customers is foundational to the functioning of this sharing model (Bielefeldt et al. 2016). To account for indirect effects between peers, access-based services can be conceptualized as quasi-triangular ecosystems.

Collaborative consumption, on the other hand, is characterized by triangular relations between a platform provider, customers and peer-service providers, who offer underutilized assets for a short period (Benoit et al. 2017). For this reason, collaborative consumption has been labelled customer-to-customer (C2C) sharing (Möhlmann 2015). In this regard, a platform links a customer who wants access to a product or service to a peer customer who offers this particular request. This relational structure implies that, in addition to indirect effects between customers, direct effects exist through concrete value propositions (Benoit et al. 2017). Hawlitschek et al. (2016) refine the changing relationship as follows: "[U]sers engage in interactions with multiple parties, usually the platform operator and another private individual. Consequently, both the vendor's and customer's role is taken by private individuals […]. The platform, however, acts as a broker and mediator between both market sides […]" (p. 27). Thereby, trust between the peer-service provider and the customer is the basis for all exchange (Benoit et al. 2017, pp. 221f.; Lu and Kandampully 2016, p. 121; Hawlitschek et al. 2016).

4.2.3 Access-Based Services and Collaborative Consumption in the Fashion Industry

Although most research on sharing has focussed on industries like tourism or transport (e.g. Böcker and Meelen 2017; Bardhi and Eckhardt 2012; Brochado et al. 2017; Guttentag et al. 2018), there have been a number of calls for research in the context of the fashion industry (Iran and Schrader 2017; Park and Armstrong 2017). For this reason, in this chapter, we seek to capture and understand the large number of evolving service offerings linked to sharing in a way that contributes to sustainability. We do this by shedding light on the suggested sector of value creation, namely the fashion industry.

For a definition of alternative consumption modes characterized by the sharing economy regarding apparel, Iran and Schrader (2017) subsume both types of shared services, namely access-based consumption and collaborative consumption. They define collaborative fashion consumption (CFC) as "[…] fashion consumption in which consumers, instead of buying new fashion products, have access to already existing garments either through alternative opportunities to acquire individual ownership (gifting, swapping, or second hand) or through usage options for fashion products owned by others (sharing, lending, renting, or leasing)" (p. 472).

Thus, CFC mirrors the previously discussed approaches of B2C and C2C sharing as this relates to apparel. Specifically, the first type, C2C-models, encompasses forms of CFC in which fashion products are passed from one consumer to another. Therefore, CFC is a form of interaction between consumers only, which is also reflected in relatively high consumer engagement (Iran and Schrader 2017). In some cases, there is no monetary compensation involved in this type of fashion sharing. As outlined above, the consumption modes related to clothing exchange between peers can be defined as collaborative consumption (Möhlmann 2015).

The second type is characterized as direct B2C services. Here companies are integrated in the value creation process as service providers and engaged actors. In this case, fashion companies offer services such as renting and leasing to substitute product ownership (Iran and Schrader 2017). Consumers are usually less engaged here, as the company provides the platform and products for CFC and consumers can easily use the services. Monetary compensation is required for acquiring the fashion items, but mostly not for gaining access to the service. Hence, access-based services in the fashion industry are related to B2C sharing (Park and Armstrong 2017). In contrast to redistributing ownership as in the cases of gifting or swapping (Laitala 2014), Park and Armstrong (2017) characterize these sharing models by the classification of utility-based non-ownership.

For the remainder of this chapter, we turn attention to the second type of CFC, that is, to B2C services, and we provide case studies for innovative consumption modes. Thereby, we attempt to portray a viable alternative to traditional business models for conventional suppliers in the fashion industry.

4.3 Service-Based Business Model Innovations: *Filippa K* and *MUD Jeans*

This research is based on a case study (Yin 2013) of two specific cases in the fashion industry that highlight business model innovations and are intended to provide insights into the opportunities they offer for fostering sustainability. We take this particular route since alternative approaches to such a new field of research could be insufficient to provide an accurate and complete understanding (Eisenhardt and Graebner 2007). We investigate the cases of the ethical fashion brands *Filippa K* and *MUD Jeans* to shed light on how sustainable development can be enhanced through innovative business models that present alternative approaches for fashion brands. These two cases were selected because they are characterized by (a) a direct relationship and exchange from business to customer (B2C), and (b) financial transactions that increase economic benefits as well, as opposed to delivering only symbolic, environmental or social benefits as in the case of swapping. Yet, we wanted to differentiate further between the two sub-types of access-based consumption, short-term rental and long-term leasing (Park and Armstrong 2017) and therefore included one case for each type.

4.3.1 Short-Term Rental: *Filippa K*[1]

Filippa K is a leading Scandinavian fashion company that was founded in 1993 by Filippa Knutsson. Until today, its head office is situated in Stockholm where most of its 350 employees are working. *Filippa K* is present in 30 markets through its own e-commerce and has 50 brand stores as well as around 600 premium retailers worldwide. The clothing items are characterized by a clean look and simplicity in colours and clear patterns. The product portfolio consists of a womenswear as well as a menswear line and is complemented by a sport wear collection. Overall,

[1] All information is based on *Filippa K* (2018), unless otherwise indicated.

four collections are released every year. According to their website, *Filippa K* recognizes "innovative sustainability as its guide to growth" (Filippa K 2018).

Striving for sustainable development through alternative production and consumption modes is at the heart of the Scandinavian brand. While *Filippa K* has long engaged in research on new materials that reduce its environmental impact, as in using recycled PET bottles to create new and functional fibres, it has also reacted to recent customer needs. The trend towards more environmental awareness and a minimalistic lifestyle demands the development of new business models that enhance consumer responsibility through sustainable consumption. One way of doing this is for the company itself to collect garments that customers no longer wear rather than having them disposed of in landfills. If these used clothes meet fixed quality standards, they are offered for resale in the brand's shops or in dedicated second-hand stores; otherwise, they are given to charity.

Recently, *Filippa K* developed alternative business models as a further means of contributing to sustainability, while at the same time seeking service innovations that would secure economic benefits for the company. Keeping their customer base in mind, *Filippa K* developed a new option that would give them access to a curated and updated wardrobe. As a result, in 2015 the fashion supplier introduced their new service "*Filippa K* Lease", which offers their collections for rent and not as traditional purchases (Hammond 2015). Thus, as an ethical fashion brand, the company aims to provide access to fashion that meets current needs, yet is also created and distributed with a minimal environmental footprint.

Filippa K's renting model entails that customers can rent any piece of clothing from the current collection for four days. In contrast to conventional modes of purchase, for such rental customers pay 20% of the full price. The cost of professional cleaning of the garment is included in the rental price. Besides direct communication that explains the rental system in detail, *Filippa K* uses a weblog called *Circle* to provide information on this service as well as on related topics. In this way they provide relevant content to the target group in that they recognize current trends and envisage how to incorporate them in future planning. In introducing a specific topic, such as sharing or the circular economy, the company outlines future opportunities for reducing the negative social and environmental impact of clothing. For example, they explain new modes of consumption that support a circular economy or innovations in mass customization through 3D-printing. On their website, *Filippa K* gives various examples of brands and organizations that are already using technological innovations to foster sustainability in the fashion industry.

4.3.2 Long-Term Leasing: *MUD Jeans*[2]

MUD Jeans is an internationally renowned jeans supplier based in Almere, The Netherlands. It was founded in 2012 by Bert van Son, who had 30 years of experience in fashion during which time he realized the negative impact fast fashion has on the environment and society. Currently, *MUD Jeans* has seven staff members and works with three different factories of which two produce fabrics and one does stitching and washing (Ellen MacArthur Foundation 2018). Their product portfolio focuses strongly on producing denim jeans for men and women, and is complemented by a casual wear line of, for example, sweaters or t-shirts. In 2017, the company's turnover was €822,000, three quarters of which was generated through sales and the remaining 25% through their leasing model.

On the *MUD Jeans* website the company's mission statement is given as one supporting a zero-waste philosophy, and expressing the aim to realize that in their production and distribution. They announce this intention saying "Do you dream of a world without waste too? Let's make it happen!" Their approach is based on the idea of a performance economy put forward by Stahel (2010) in which products are seen as depots of raw materials which can be recycled once their primary function has been fulfilled. Following this, *MUD Jeans* strives to establish a circular economy in which services play a major role in contrast to the traditional, linear value creation system in fashion. *MUD Jeans* are made from about 405 kinds of recycled materials, resources derived from discarded jeans. Generally, the fabrics they use contain at least 98% cotton, with even the buttons made from recycled cotton. Further, the hangtags are made out

[2] All case information is based on *Mud Jeans* (2018), unless otherwise indicated.

of recycled paper. For shipping their products they cooperate with *RE:pack*, a company providing returnable delivery packaging which consumers can drop into any post box worldwide without additional costs. Such packaging can be used up to 20 times, and once a package is returned, the customer gets a voucher for *MUD Jeans* (Ellen MacArthur Foundation 2018).

MUD Jeans' leasing service called "Lease A Jeans" was initiated in 2013 with the aim of allowing their customers guilt-free shopping, while still fulfilling their needs for an up-to-date and modern look. To order a pair of jeans as part of this leasing service, the customer has to pay a one-time subscription fee of €20, an amount of €7.50 for the first month of lease, as well as the shipping costs. Customers thereby agree to pay a monthly leasing rate for a one-year period. The subscription fee allows the customer to lease up to three different pairs of jeans at a time, which he/she can keep without the option to change a specific pair for the duration of one year. After 12 months, though, the customer can decide whether to keep the jeans without additional costs, switch the jeans for another model without having to pay another subscription fee, or ending the relationship with *MUD Jeans* altogether. Once returned to the supplier, the jeans and its materials, respectively, will continue to flow in one of three loops: if the product is in a good condition, it can be cleaned and re-used in the leasing system; if repair is required, the denim can be treated with a stone wash or enzyme wash; and if the product is actually beyond repair, the materials will be returned to the denim manufacturer to be recycled. Due to the multiple options for buying and reselling *MUD Jeans*, multiple marketing opportunities arise, such as offering used jeans with a vintage character.

4.4 Findings

4.4.1 Innovations in Service-Based Business Models

According to Park and Armstrong (2017), the two fashion design and distribution cases discussed above are models of access-based consumption and utility-based non-ownership, respectively. This means that the company itself acts directly as a service provider in the value creation process. In contrast to how traditional economies function, both examples can be considered part of the sharing economy in which redistribution of and access to resources through services is of primary concern (Mair and Reischauer 2017). Even so, the approaches of the two fashion brands can be differentiated according to the specific type of renting each offer.

The case of *MUD Jeans* relates to long-term leasing, which can be considered a subtype of B2C in CFC (Iran and Schrader 2017). It is operated on a monthly subscription basis that includes renting items for one year, after which the contract is renewable or adjustable. It differs from the *Filippa K* case in that a fixed contract for a couple of months' leasing is required and consumers are obliged to pay rent for the contract period before they return the fashion products. In contrast, *Filippa K*'s approach relates to short-term leasing that is based on a single transaction. In the former case, there are reoccurring transactions such as monthly payments which ensure a steady cash flow to the company; and additionally, it bears higher potential for customer attachment. In the latter case, one transaction entails a single payment that usually implies lower customer attachment. Nevertheless, through the established second-hand system of *Filippa K*, customers are rewarded with a voucher when they return their used items and, thus, could eventually also be bound emotionally.

In contrast to alternative consumption modes on a C2C basis, both the above cases are characterized by private consumption (as opposed to public consumption) and thus result in high anonymity amongst the peers (Park and Armstrong 2017). While traditional business models of fashion suppliers focus on production of goods rather than on the provision of services (Mair and Reischauer 2017), these sharing economy business models depend more on resources of finances and time. They need to consider aspects of logistics and costs related to professional cleaning of clothing. In spite of developmental predicaments of these still relatively small companies, the above cases show that their pioneering character of business modelling can establish competitive advantages.

4.4.2 Opportunities and Risks Identified in the Two B2C Types of Sharing

While the customers of *Filippa K* and *MUD Jeans* appear to be motivated by economic, functional or political considerations, there is a lower sense of sharing compared to cases of redistributed ownership found in swapping or consignment (Park and Armstrong 2017). Despite emotional or economic relationships built by means of the reward systems, consumers are generally less engaged in access-based consumption than in collaborative consumption (Iran and Schrader 2017). This is due to the fact that in the case of B2C services, the company provides the platform as well as the products for shared access and consumers can easily use the services without high levels of engagement (Iran and Schrader 2017). Further, regarding the consumer-business relationship, the services *Filippa K* and *MUD Jeans* offer are highly convenient for customers as, compared to C2C-based approaches, they require limited time, effort and responsibility from the target group. A significant risk for such companies lies in that accepting new service offerings is highly dependent on consumers being familiar with access-based consumption. Customers' current lacking familiarity, as well as their fear of the unknown restrains their participation (Stahel 2016).

For companies, opportunities lie in service offerings that contain potential cost savings for customers that can be weighed against concretely purchasing a piece of clothing. On a long-term basis, reduced costs could increase consumers' motivation for collaborative consumption, even if the product attachment is lower than for traditional apparel ownership (Park and Armstrong 2017). Access to leasing or renting platforms as such is free (as in the case of *Filippa K*), or can be gained through a singular transaction (as with a subscription fee such as *MUD Jeans* requires). Then for the rent or leasing of a specific item, there is a fixed fee. Overall, CFC offers incentives for companies to invest in life extension of their products. If renting companies (formerly suppliers) and consumers know that after a first user, additional users will wear the garment and often also pay for this second-hand use opportunity, they might be willing to pay a premium price for such durability (Iran and Schrader 2017). In the case of *MUD Jeans*, this relates, for example, to used items marketed as unique vintage items, while *Filippa K* has established its own second-hand shop system. Lastly, companies that earn money by providing access instead of by selling goods have a greater incentive to increase product durability (Stahel 2010). Nevertheless, regarding quality standards companies carry the risk involved in whether consumers use rented or leased products as carefully as they would their own products. Such a concern could have negative effects on the quality offered in B2C CFC (Iran and Schrader 2017). Another added value, however, is that this circular process of access-based consumption on a B2C basis promotes job creation in the fields of recycling and remanufacturing. Generally, especially small- and medium-sized fashion brands are likely to gain a competitive advantage in the future if one compares the smaller risks they face compared to what confronts very large companies in introducing such a leasing or renting scheme.

On a larger scale, one must critically evaluate the overall impact that new, alternative forms of consumption in the context of apparel can have. Individual transportation and cleaning of fashion items after every use could curb some of the environmental upsides. A realistic estimation of total CFC ecological effects also requires the consideration of rebound effects. Eco-efficiency strategies, in contrast to an absolute reduction in use, could lead to a situation of increased resource use in which the additional used resources might even exceed the savings. Only if CFC substitutes the purchasing of new clothes instead of just adding to new garments circulating, do sharing models in fashion have the chance to contribute to sustainability on a long-term basis (Iran and Schrader 2017).

4.5 Conclusion and Outlook

This chapter sought to shed light on the potential of business model innovation to enhance sustainability in the fashion industry. Specifically, it has illustrated two business cases of access-based consumption that disrupted conventional modes of linear production. We have outlined opportunities to reduce negative environmental and social impacts through the reuse or recycling of materials, new service offerings as well as potential related to marketing. While the cases of *Filippa K* and *MUD*

Jeans demonstrated the potential of innovative approaches not only to reduce environmental damage but also to increase economic and social benefits, the future of the sharing economy in fashion remains unclear. One major obstacle is the current low consumer demand: in Europe alone, 90% of all consumers do not consider buying second-hand clothes at all (Eder-Hansen 2017). Still, one needs to reflect on examples other industries such as *Uber* and *Airbnb* present which only a few years ago seemed to be unrealistic and impossible.

Regarding the concept of B2C access-based consumption in fashion, it remains unclear how significant the effect of reduced use due to high rental prices might be. In most countries, the renting of clothing is still a marginalized form of garment distribution, often restricted to very specialized offers like carnival or theatre costumes, or dressing up for unique festivals. Many consumers might just buy affordable alternatives if renting is considered to be too expensive (Iran and Schrader 2017).

Finally, it remains uncertain whether even optimized concepts of access-based consumption will be able to develop beyond their current niche market status and generate a larger impact under the prevailing economic conditions (Belk 2014). Business models related to leasing or renting often require additional input of human labour which is either costly or needs to be done on a voluntary basis. Even so, as the two business cases above show, sharing in fashion on a B2C basis could become "a widely accepted way of fulfilling clothing needs in a sustainable world where external costs (and benefits) are internalized in prices" (Iran and Schrader 2017, p. 479). In conclusion, while these innovative business models have good potential to reduce the industry's environmental impact through the enhancement of secondary use of products or promotion of repair, their future success will depend on their economic viability on a larger scale than they currently achieve.

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5

Removing the Dye Kitchen from the Textile Supply Chain

Celina Jones and Claudia E. Henninger

5.1 Introduction

This chapter focuses on removing the dye kitchen from the textile supply chain; the latter is defined as a sequence of processes necessary to see a garment through from production to distribution (Lambert et al. 2006; Henninger et al. 2015). In the textile supply chain, the dye kitchen is the name given to the place where synthetic dyes and machinery apply colour to textiles. This process can occur in multiple stages, which implies that the textile can have a variety of forms: fibre, yarn, fabric or finished garment. The selection process of the actual dye for the textile is dependent on the fibre chemistry and method of application. Within the textile industry, the two main methods of dyeing are (1) exhaust or batch dyeing, which implies the immersion of textiles or garment into a dye bath containing predominantly water; and (2) padding, which is characterized by colour being padded onto the material through a pad mangle (McLaren 1986; Bird et al. 1975). The dyeing process is complex in nature and

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requires a certain pH (a figure describing the acidity or basicity of water) (e.g. Kobya et al. 2006; Claudio 2007) and temperature, as both can influence the ability of the dye to be attracted to the fibre surface and leave the dye liquor (Ingamells 1993). Both dyeing processes, exhaust or batch and padding, can be applied in a controlled manner, for the dye to diffuse into the textile substrate (Bird et al. 1975). Another method of applying dyes to textiles is by printing onto garments or accessories. This can be performed through using either printing paste via a silk screen method or printing ink via an inkjet printer. The choice of machinery used is dependent on the fibre type and end use of the textile product.

Prior to performing the dyeing process, textiles need to be carefully prepared by impurities being removed from the textiles through processes including, but not limited to:

- Desizing–removes the sizing agent applied to the warp yarns, which is applied in order to reduce friction and reduce yarn breakage on the loom (DuPont 2018)
- Scouring–removes grease and dirt from the fabric and implies a deep clean by boiling the fabric in a soda and water solution (Baxter Packwood 2001)
- Bleaching–removes residual colouring matter, with hydrogen peroxide (H_2O_2) being one of the most commonly used bleaching agents (Liu et al. 2018; Yu et al. 2018)

One of the reasons why materials need to be treated through any of these processes mentioned above is to ensure that the woven or knitted cloth is dyed in a homogeneous manner (Baxter Packwood 2001; DuPont 2018; Yu et al. 2018). Once cleaned and the dying process has been completed, post-treatments are required to fix the dye to the textiles. A majority of these processes require a vast amount of water and chemicals.

As such, it may not be surprising that the fashion and textile industry has received negative spotlight, as the dyeing process, including the pre- and post-treatment of these textiles, can have devastating environmental implications. To explain, in 2011, it was reported that a factory in China leaked dyes, which led to the Jian River turning into a deep red colour (Kaye 2013; Trusted Clothes 2016). A public outcry followed that called for tougher regulations and higher environmental protection standards to be enforced globally.

The chemicals used within the dyeing process as well as the vast amount of water not only have implications for the natural environment but also affect human health by increasing the risk of terminal illnesses (Kant 2012; Akarslan and Demiralay 2015; The True Cost 2015). As a result more attention is paid to the selection process of dyes—natural and/or synthetic dyes, adapting and modifying synthetic dyes, finding new and less harmful auxiliaries, reducing water consumption and implementing measures (in industry and at government level) to reduce harmful effluent released into the local environment (Chhabra 2015; Van Berkel 2017; Irfan et al. 2018). Whilst investigating new processes and solutions is of vital importance, a key question that thus far lacks in investigation is what are the implications of removing the dye kitchen in its entirety from the textile supply chain process, an aspect that has been explored in this chapter.

5.2 Textile Colouration Techniques

Traditional textile colouration techniques involve the object being observed absorbing various wavelengths of visible light through the use of colourants, pigments and dyes. Whilst this is the most common manner in which light interacts with objects and the human eye perceives colour, it is also possible through structural colour (Nassau 2001; Shao et al. 2016). Structural colour works by the microscopic structure of the object scattering or reflecting various wavelengths of light resulting in the observer perceiving colour (Kinoshita 2008). Attempts have been made in the textile industry to mimic structural colour observed in nature, particularly those of certain species of butterfly and beetle (Jones 2017; Yavuz et al. 2018). To explain, in both the creative and scientific worlds, butterflies have fascinated many, due to their aesthetic properties. The *Morphinae* group, which contains the male *Morpho* butterfly, has generated great interest as it exhibits a vibrant iridescent blue on its wings. This genus has been extensively studied during the nineteenth and twentieth centuries (Walter 1895; Ghiradella 1991; Tabata et al. 1996; Vukusic et al. 1999) due to the nature of its complex scale structure and combination of optical processes to achieve an iridescent optical effect. When the wings of the *Morpho* butterfly are examined under a scanning electron microscope, they contain ground and cover scales. Each cover scale overlaps a ground scale, and both scales align in rows with a specific amount of spacing between them (Kinoshita 2008; Saito et al. 2018).

Honing in even further on the structure of both the cover and ground scales, it becomes apparent that they contain a lamellar structure, which is often referred to as a Christmas tree or shelf-like structure. In the cover scales, these lamellar structures are attached to a thick base, whereas in the ground scale they are attached to a trabeculae, which is a connected series of rows (Kinoshita 2008). The cover scales provide thin-film interference. The combination of the cuticle-rich shelf-like structures and air-rich layers (between the shelf-like structures and the gap between the ground and cover scales) provides multilayer interference (Kinoshita 2008; Saito et al. 2018).

Between each shelf structure there is a random height distribution. This is allegedly responsible for cancelling out any interference between neighbouring ridges and enables each structure to scatter the light independently. The distance between each ridge also provides diffraction grating, which is partly attributed to generating the iridescent effect observed in this species of butterfly (Kinoshita 2008; Saito et al. 2018). The ground scale contains melanin, which is responsible for the absorption of the complementary colours and enhances the contrast of the blue colouring (Kinoshita 2008). A key question that emerges here is whether it would be possible to reproduce these naturally occurring optical processes in textiles, and thus be able to remove the dye kitchen from the textile supply chain.

One of the first companies that has managed to imitate the microstructure of the Morpho butterfly is the Japanese company Tejin (2010), naming their invention the Morphotex® fibre (Tejin 2010; Das et al. 2017). As previously indicated, the optical processes, such as thin-film and multilayer interferences, generated from the interaction of light with the lamellar structure on the surface of the wings of the butterfly, are responsible for generating the vibrant iridescent blue observed. The core of the Morphotex® fibre contains 61 alternate layers of nylon 6 and poly (ethylene terephthalate) (thereafter referred to as polyester) surrounded by a polyester sheath. This creates a fibre with a multilayer interference core, responsible for the iridescence created by the fibre. By manipulating accurately the thickness of the nylon 6 and polyester layers in the fibre core, Teijin fibres have managed to successfully create these fibres to give a red, blue and green iridescence (Tejin 2010).

Kinoshita (2008) highlights that the polymers selected to create the Morphotex® fibre have relatively close refractive indices (1.60 for nylon 6 and 1.55 for polyester) and the lack of vibrant iridescence can be attributed to this closeness. A cross section of the Morphotex® fibre was observed under a scanning electron microscope (shown in Fig. 5.1).

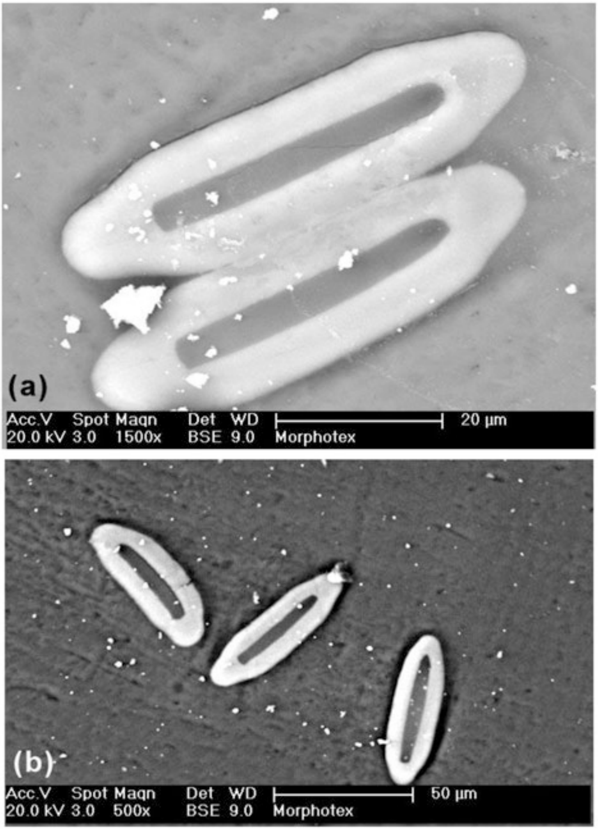

Fig. 5.1 (**a**) and (**b**) Scanning electron microscope images of Morphotex® fibre cross section

A melt-spinning process, similar to that used in the formation of bicomponent fibres, could have been used to create the fibre.

Bicomponent and microfibres are made from two different polymers, which either are extruded separately and then combined to make one fibre or are extruded together and combined as the fibres leave the spinneret. The most common of these structures are side-side and core-sheath. The purpose of manufacturing these types of fibres is due to the range of properties they can provide, aesthetically and/or functionally. The aforementioned butterflies are not the only creatures that exhibit structural colour; the bodies and wings of various beetles showcase similar attributes (Saito et al. 2018). However, the mechanisms responsible for causing the observer to perceive colour, differ from that of the wings of the male *Morpho* butterfly (e.g. Kinoshita 2008; Saito et al. 2018). To reiterate this finding, the exoskeleton of the *Chrysina gloriosa* beetle (see Fig. 5.2) contains regularly spaced cells with a siloxane oligomer-based cholesteric liquid crystal. This enables the exocuticle to reflect left (anticlockwise) circularly polarized light (Sharma et al. 2009). The orientation of the molecules inside the liquid crystals is responsible for manipulating light and creating the phenomenon viewed by the observer.

Researchers have successfully coated textile fibres with cholesteric liquid crystals (Lagerwall and Scalia 2012; Picot et al. 2013; Kang et al. 2017). In the research conducted by Picot et al. (2013) a solution containing cholesteric liquid crystals was spray-coated onto polyamide fibres, and then UV cured.

Picot et al. (2013) stated that cholesteric liquid crystals produce a fibre with intense and bright colours, due to the properties of these materials. These liquid crystals are independent of temperature as they are cross linked by free radical polymerisation. This implies that their colour cannot change (Picot et al. 2013). Textile designers have explored ways of applying microencapsulated cholesteric liquid crystals onto garments and other textiles; however, the outcome from these explorations has been that their (textile design) colour *is* dictated by a change in temperature. Typically, these types of cholesteric liquid crystals have been used on batteries and for medical applications. Textile designer Sara Robertson (2011) explored the use of heat as a design tool, silk screen printing these microcapsules onto textile substrates.

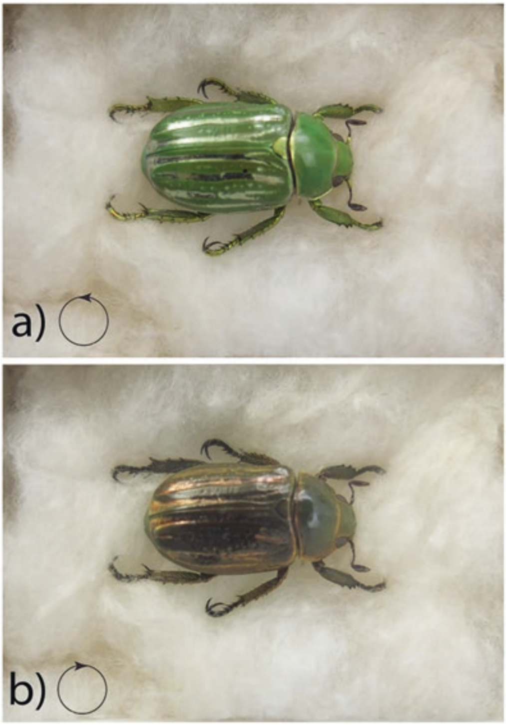

Fig. 5.2 Photograph of the beetle *Chrysina gloriosa*. (**a**) The bright green colour, with silver stripes, seen with a left circular polarizer. (**b**) The green colour is mostly lost when seen with a right circular polarizer

Along with beetles and butterflies, inspiration for incorporating structural colour into textiles has also come from observing opal stones, using self-assembled colloidal photonic crystals. In a recent study, Yavuz et al. (2018) applied these materials to woven cotton fabric, with the result displaying different iridescence at different viewing angles. This work used monodisperse and spherically uniform nanospheres of poly (styrene-methyl methacrylate-acrylic acid) synthesized by soap-free emulsion polymerization and deposited by an electrostatic self-assembly technique onto a chitosan-cationized woven cotton fabric (Yavuz et al. 2018). A further study conducted by Pursiainen et al. (2008) has managed to produce a stretchy material also inspired by structural colour in opals, with the colour of the material changing upon being stretched. Typically, previous films were susceptible to cracking; however, the aim of this research was to overcome this setback.

5.3 Concluding Remarks

This chapter was set out to explore whether it is possible to remove the dye kitchen from the textile supply chain, by looking at alternative modes of colouring fabrics. As indicated, mimicking nature and structures present in the wings of male *Morpho* butterflies or beetle provides a new way of applying dyes to fabrics. Yet, some of the more traditional dyeing techniques are still needed, as some of these examples mentioned previously required the use of a dark pigment or dye to absorb the remaining wavelengths of light that are not reflected. Thus, corresponding fibres or ground fabrics must be dyed either by exhaust/batch dyeing or padding. Therefore some may argue the use of synthetic dyestuffs to achieve these optical effects does not completely remove the use of the dye kitchen from the production process but rather alters it slightly whilst further providing new opportunities to researching colouring processes in nature. Although research in this area continues to grow, the benefits of combining this research with that exploring the adaptation and modification of synthetic dyes, and finding new and less harmful auxiliaries, cannot be overlooked. As trend forecasting shows, the need for brands to have the 'right' colour for the right season ensures that fashion products are in trend and will only sell if customers are satisfied. Textile colour is therefore an important property and is required by the consumer; consequently if current production methods have a detrimental impact on the environment, alternatives methods must be considered.

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6

Designing Products for the Circular Economy

David J. Tyler and Sara L.-C. Han

6.1 Introduction

The advance of globalisation has stimulated many initiatives in the USA and Europe. The "quick response" strategy was developed in the 1980s to retain a competitive advantage for domestic manufacturing; the Internet has made fast electronic communication a global phenomenon; and the rapid acquisition of technical skills in numerous countries has meant that many professional tasks could be outsourced (quality control, materials purchasing, sample making, fabric cutting etc.). Gereffi (1999) identified these trends for the apparel and textile sector. The trends have continued and globalisation has become the norm. Domestic industrial activity in the USA and Europe has dwindled.

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This chapter is concerned with the design process and the skills needed to make a success of circular economy (CE) ambitions. How has the design process been affected by globalisation? Do companies seeking to implement Circular Economy concepts need to revisit the way design is managed?

The hypothesis developed in this chapter is that the Circular Economy requires a radical culture change throughout the supply chain and that the design process is at the heart of the necessary transformation. Whereas measures to improve the sustainability of products can be "bolted on" to existing management structures, the Circular Economy requires companies to go back to the drawing board to set up processes that are fit for purpose.

The word *sustainability* can take different meanings depending on the context. However, all the meanings endorse the wording of the World Commission on Environment and Development: sustainable development is the development that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (*Our Common Future* 1987). In the world of business, the primary sense is that of economic efficiency (leading to the consideration of innovation in products and services, to growth and long-term prosperity, and to measures for increasing productivity). Those interested in sustainable social development tend to focus on indicators of community well-being (the reduction of poverty, growth of entrepreneurial initiatives, improvements in public health and respect for human rights). The champions of environmental sustainability give their attention to impacts affecting the land and the seas. This principle is applied to the use of the Earth's resources, the production of wastes, the way we use products and the way they are discarded when they have no further use to the owners. This chapter uses the term *sustainability* in the latter sense.

The term *Circular Economy* (CE) is more problematic. Kirchherr et al. (2017) have analysed 114 definitions gathered from academics and practitioners. They find many indicators of an immature discipline:

> The circular economy (CE) concept is trending and thus much lip service is given to it these days. Trending concepts tend to diffuse in their meaning and many have claimed that this has also happened to the CE concept.

They point out the difficulty of people using the term:

> We note that this abundance of CE conceptualizations, this 'circular economy babble', constitutes a serious challenge for scholars working on this topic. […] If scholars are not aware of their conceptually different understanding of CE, knowledge accumulation attempts may lead to misleading results.

Rather than entering into a discussion of meanings, this chapter adopts a definition of CE given by WRAP (2018):

> A circular economy is an alternative to a traditional linear economy (make, use, dispose) in which we keep resources in use for as long as possible, extract the maximum value from them whilst in use, then recover and regenerate products and materials at the end of each service life.

This has the merit of contrasting traditional production (linear) with a pathway that treats wastes as resources (circular). The definition brings out several important elements of the strategy: extending useful life, improving efficiencies of the use of resources, followed by recovering and regenerating materials at the end of the service cycle.

In the pre-globalisation years, the first drivers for improved environmental practices were legislative. This is the theme of the first section.

6.2 Legislative Drivers

Considering just the UK, early environmental legislation set out to clean up the rivers, the air and the land. In 1937, trade effluent could be discharged into the public sewer only by satisfying quality standards and only with the consent of the regulatory body. Health hazards posed by smoke in Manchester and other industrial centres stimulated local restrictions on discharges into the atmosphere, but it took over 4000 deaths from London smogs to bring in the Clean Air Act of 1956 (Heys 2012). The Water Act 1989 made many changes to the provision of clean water to consumers and industry, but particularly it empowered the National

Rivers Authority to manage pollution and established the principle that the polluter pays for damage done. A year later came the Environmental Protection Act, which introduced a system of integrated pollution control for the disposal of wastes to land, water and air. A key development was to introduce the concept of "statutory nuisance." Those fitting this description are defined as "premises which are deemed to be detrimental to health or a nuisance, or are emitting dust, steam, smells, effluvia or noise with this effect" (Defra 2011). The concept of "contaminated land" was introduced a shortly afterwards with the Environment Act 1995. The major impact on the textile sector was on dye-houses and the effluents they released into the rivers. The effect was to either compel businesses to install water treatment plants or to close their doors in the UK. This "end-of-pipe" intervention achieved a significant improvement in environmental sustainability.

In the 1990s, EU regulation became more prominent, subsuming national initiatives. In 1994, a directive was issued on packaging and packaging waste. This set out targets for the reduction of landfill by recycling and reuse of packaging materials. The concept of "producer responsibility" was subsequently introduced so that producers were responsible for ensuring the recycling and reuse targets were met. These regulations affected the whole of the apparel supply chain, with managers and technologists finding ways to satisfy the regulators.

Until recent years, apparel product design has been undertaken without attention to environmental regulation. However, the legislative framework has increasingly constrained design decisions relating to the use of hazardous chemicals, especially with the advent of REACH regulations within the EU (Registration, Evaluation, Authorisation and restriction of Chemicals). REACH was introduced in 2006, replacing 40 previous legal documents (European Commission 2018a). As the acronym indicates, according to the principle of producer responsibility, companies are required to register all chemical products being offered for sale and to test them using specified protocols. The results are then evaluated by the European Chemicals Agency and substances are either approved for sale, authorised for restricted use, or banned altogether if they pose an unacceptable risk to health or the environment. Most retailers and brands now have their own lists of the large number of chemical substances that are prohibited in the dyeing and finishing of textiles. This information is known in the trade, but is largely the province of technologists and managers. Those involved with design are aware of REACH but have no direct involvement with the process.

Consequently, whilst legislation is affecting the textile/apparel sector in many ways, the response is primarily for technical solutions to be found at the locations where problems are observed. The emphasis is on compliance. It is significant that the design process continues without needing to address any of these environmental issues.

6.3 Design for Sustainability in Use

The increasing adoption of environmental management systems has expanded the vision for initiatives promoting sustainability, including those in laundering and care. Principles for product design and development are recognised that will lead to a more sustainable goods and services. As identified by Cooper et al. (2013), the design stage is the key phase for introducing strategies to increase product longevity, thereby creating opportunities for the greatest resource savings throughout the product lifecycle. Spangenberg and Lorek (2002) calculated that although 80%–90% of a products' environmental impact occurs throughout the use phase, over 80% of these impacts are determined at the design stage. If the average life of garments were to be extended by one-third, and the need for new clothing reduced, the carbon, waste and water footprints of apparel could each be reduced by more than 20% (Gracey and Moon 2012). Areas fundamental to determining longevity and durability at the design stage encompass size and fit, fabric quality, colour and style, and care practice information (Cooper et al. 2013). Consumers' understanding and adoption of circular economy practices into their own personal identities is also key to the success of sustainable design strategies.

Fashion consumers constantly reconstruct their own identities by modifying and incorporating fashion styles, rules and acts into their own self-reflection and individuality (Niinimäki 2010). Designing for a responsible identity addresses the imperative to make sustainable design strategies appealing to consumers as information and practices which they can incorporate into their own personal representations of themselves as individuals. Consumers want to behave ethically and identify with ethical practices, but feel judged when their failure to do so is highlighted by the more virtuous actions of others (Zane et al. 2016). In order to mitigate this effect, production best practice needs to be translated into clear and engaging information for consumers, so that they can feel included in the message of good practice, without feeling that others with more knowledge stand in judgement over them (Zane et al. 2016). Consumers can also be encouraged to maintain and value their garments through the development of ongoing emotional and empathetic relationships between wearers and garments (Gwilt 2014). By identifying a garment with a significant, positive emotional experience, event or narrative, a sense of meaningful connection and attachment to a garment can be created (Connor-Crabb et al. 2016).

Products designed with new models of consumption in mind may also encourage consumers to strengthen the person-product relationships and hence postpone early product replacement (Mugge et al. 2005). Creating products that can be customised in the design (or redesign) process enables greater personalisation (Niinimäki 2013; Connor-Crabb et al. 2016). As stated by Bocken et al. (2017):

> A circular economy aims to keep products, components, and materials at their highest utility and value at all times. The value is maintained or extracted though extension of product lifetimes by reuse, refurbishment, and remanufacturing as well as by closing of resource cycles—through recycling and related strategies. An alternative strategy for the extension of product lifetimes through sharing them or making them multifunctional. All these strategies may be facilitated through changes in ownership relationships, such as leasing and product-service systems.

Shared or collaborative consumption can be defined as the coordinated acquisition and distribution of resources, such as swapping and resale (Park and Armstrong 2017). Designing products for shared use or collaborative consumption necessitates purposeful design considerations, such as designing in greater durability, versatility, multifunctional uses, modularity and low wash frequency. Modular design in particular, refers to multifunctional garments that can be altered by the wearer to bring greater variety into a wardrobe (Niinimäki 2013). Design considerations that meet these specific needs, rather than market place "wants," offer the potential to reduce the overproduction of unnecessary products, limiting resource use in both production and distribution (Gwilt 2014).

The use phase is the second most dominant lifecycle phase for clothing; however, wash frequency is dominated by subjective standards of personal cleanliness, about which there is little agreement (Gracey and Moon 2012; Gwilt 2014). In the UK, the average adult owns around 100 items of clothing, and washes between 274 and 343 items each year. The financial cost of this is estimated to be ~£3.4 billion (including electricity, water, wastewater and detergent). The use phase represents just over 26% of total greenhouse gas emissions in the total lifecycle. Washing is the largest contribution to this (15% of the total), followed by drying (10% of the total).

Consumer research has found that laundry practices do appear to be changing, with evidence of good practice but have potential for further change. A high proportion of people wash full loads and at low temperatures, although around a third do not normally sort clothes (to facilitate more efficient washing/drying) and nearly a quarter use tumble driers in summer. Consumers have expressed a willingness to consider wearing clothes for longer before putting them in the laundry (Gracey and Moon 2012).

6.4 Design for Environment and Design for Disassembly

The impact of producer responsibility regulation has been noted already for packaging waste. Some industries, particularly those involved with electrical and electronic equipment, have extended obligations placed on them, known as extended producer responsibility (EPR). The procedures implemented in Japan, Germany, Switzerland and China are described and compared by Wang et al. (2017). In essence, producers are required to take responsibility for the take-back, recycling and disposal of the waste electrical and electronic equipment (WEEE) that these companies release into the market. Faced with significant additional costs, many of these companies have considered how design decisions affect end-of-life processes. The producer responsibility obligations have triggered thinking about Design for Environment (DfE), Design for Disassembly (DfD) and Design for Disposal.

Twenty years ago, it was possible to report quantifiable benefits for companies responding to WEEE regulation and examples were supplied by Bhamra et al. (1998). In the intervening years, product development tools have been improved and significant progress has been made to identify design principles. As an example, a case study on mobile phones is provided by Long et al. (2016: 5):

> An additional benefit of forcing this cost onto the producer is that they are encouraged to make their EEE products as easy as possible to recycle or dispose as they have to pay to cover the costs of such actions. This motivates the producer to design their products to contain fewer hazardous substances, lower the chance of obsolescence or failure and be easier to recover value from during the recycling process as this will reduce the EOL [end of life] expenditure faced. At the same time, companies may be able to use the recycled material to repair or manufacture new EEE products at a reduced cost.

A voluntary extended producer responsibility scheme for carpets is in place in the USA (Choi 2017). After two years of negotiation, in 2002 the industrial sector was given the liberty of establishing its own approach to recycling. Targets were set to achieve a diversion rate from landfill of 10% by 2005 and 23% by 2010. Due to the technological challenges, to variations exhibited by the organisations involved and to the location of recycling businesses, three business models emerged. These were in-house recycling, recycling and supply, and small independent recyclers. Whilst economic and environmental factors are analysed, Choi's paper records that the sector did not reach its goals on recycling rates. Significantly, Choi makes no mention of the role of design, and the main strategy identified is to search for residual value in post-consumer waste.

Contrast the USA experience with that of the UK. Again, the extended producer responsibility scheme for carpets is voluntary, coordinated by

Carpet Recycling UK that was established in 2008. They report that the diversion rate of carpets (from landfill) has increased from 2% in 2007 to 42% in 2017 (Carpet Recycling UK 2018). The strategy is to move towards implementation of the Circular Economy, connecting design with the collection, reuse and reprocessing of carpets. Gardner (2017) made a direct link between the redesign of carpets and the development of technologies to produce recyclable carpets in the future.

This link between design and technology is apparent in the work of the Dutch company Niaga (2018):

> At Niaga—the word *again* spelled backwards—we redesign every day products from scratch. Our aim is to make products fully recyclable in an easy and affordable way, without compromising on quality or price. Carpet was the first product we redesigned, and today we offer our carpet manufacturing technologies to make carpet that can be fully recycled back into new carpet.

Companies in Europe and the US are now offering products for sale that have been manufactured using this technology.

> Mohawk Industries launched their product Air.O in the US market in early 2017. Air.O is made with Niaga® Technology, and represents an entirely new flooring category called Unified Soft Flooring (USF). Air.O eliminates the "new carpet smell", is easy to install and is 100% recyclable. (Niaga 2018)

If products have not been designed with recycling in mind, it is not surprising that the processes of recycling are complex and expensive. However, when product design operates within a circular economy framework, there is potential for recycling processes to be simplified and made much more cost effective. This is where product development tools (assisting with environmental sustainability, recycling and reuse) have an important role to play.

To develop products for the circular economy, collaborative design activity affecting two or more supply chain partners becomes the norm. When analysing the circular economy products of eight companies in the textile sector, Franco (2017) found that codesign practices were essential.

Three types of collaboration were observed: (1) modification or substitution of chemicals for yarn and fabric manufacturing, (2) codevelopment of circular materials and component parts and (3) customisation of existing materials for new textile applications. The interdependency was strong, with firms relying on the competencies of their supply chains in order to achieve innovation. A robust approach to both product and process design is needed to deliver circular economy goals.

6.5 Extended Producer Responsibility in Textile Sector

To date, only France has introduced legislation on EPR for apparel, linen and shoe products. There are voluntary initiatives in several countries, and some companies have voluntarily developed strategies influenced by circular economy concepts. However, it is fair to observe that the business models of most apparel companies are silent about end-of-life issues. Nevertheless, the concepts of EPR and CE are being actively explored, and each year that passes brings significant additions to the discussion.

The European Commission is supporting a transition to a Circular Economy (European Commission 2015). The Press Release was optimistic in tone, anticipating benefits for both the environment and the economy. The funding package would contribute to “broad political priorities by tackling climate change and the environment while boosting job creation, economic growth, investment and social fairness.” Targets were set, notably a common EU target for recycling 65% of municipal waste by 2030, and a landfill target to reduce landfill to a maximum of 10% of municipal waste by 2030.

Subsequent debate has been mixed. Some gave strong support to the transition, arguing for more stringent targets and greater use of EPR. Others questioned the economic arguments and suggested that the targets were unrealistic. It was pointed out that “circular” solutions do not necessarily lead to sustainable outcomes. All waste materials are affected by some form of downgrading, and there must be a cost when we seek to turn wastes into resources for the next economic cycle. In most cases, these costs are non-trivial and there must be a business case if recycling is to proceed. As expressed by de Man and Friege (2016), "Creating endless material cycles without continuously adding energy would be counter to the Second Law of Thermodynamics." One way to quantify the challenge for industry is to use Life Cycle Analysis (LCA). An example is provided by Bjørn and Strandesen (2011: 9) who found that a proposed Cradle to Cradle (C2C) processing route was not sustainable:

> It can be concluded that products designed after the C2C concept are not always sustainable. This is highly influenced by the fact that the sustainability of products greatly depends on external systems such as energy supply and waste management infrastructure.

Of course, these "external systems" are not unalterable, and the situation can be greatly improved by product and process design. However, there is no magic wand to ensure that the CE pathway is either sustainable or cost effective—these goals emerge only by rigorous research and development. This brings us to the other assumption discussed by de Man and Friege (2016): that "circular" solutions are available and can be realised in practice. The lessons from experience, although limited, reveal that implementation of CE strategies is difficult. The goal of 100% circularity is an unrealistic ideal. EPR has had more of an impact on WEEE producers than any other sector, and yet these companies have not reached the stage where all wastes become resources.

> Not surprisingly, studies on electronic consumer products have shown that recovering all materials present in a certain product in their original grade is not possible without creating substantial additional environmental impacts. (de Man and Friege 2016, 94)

Further impediments to the circular use of material resources are discussed by Velis (2018). One paragraph particularly is worth noting here.

> While 'circular economy' contains the term 'economy', strangely enough, it is not necessarily a theory about economics—macro or micro—but mainly a theory for how to manage material flows. The concept enjoys little

> traction and understanding among the current theoretical economists, both orthodox and heterodox. This one may sound a bit academic—but, it is not as such. We need to ensure that the actual and perceived societal benefits of a new circular model are established in a more fundamental and sound manner than just traditional cost-benefit analysis, which is an insufficient tool to describe transformation at a systems level. Maybe heterodox economics looking at how to analyse a system of systems (e.g. systems of provision) or the environmental economics explicitly considering internalisation of the 'externalities', are a sounder basis to discuss how a circular economy could perform as a whole and for the future economies of our World. (Velis 2018, 759)

This point has relevance to assertions that wastes have value. Materials do not have an inherent value until there are people who are prepared to put a value on them. In a Circular Economy, there are processing pathways in place to convert wastes to something that people or organisations are prepared to purchase.

The European Commission has funded several research projects to help implement CE among member states. These include:

- Resyntex (2018) aims to create a new circular economy concept for textile and chemical industries. Using chemical processing of unwearable textile waste, the outputs are chemical feedstocks supplying other industrial sectors.
- Trash-2-Cash (2018) aims to create new regenerated fibres from preconsumer and post-consumer waste. The project is also pioneering a new collaborative Design Driven Material Innovation (DDMI) methodology, a whole new way of developing materials.
- R2π (2018) examines ways to shift from the broad concept of a Circular Economy to one of circular economy business models (CEBMs) while searching for both market failures and policy failure that hinder the broad implementation, use and acceptance of CEBMs.

Additionally, other relevant projects are as follows:

- Worn Again Technologies (2018) are developing a polymer recycling technology that can separate, decontaminate and extract polyester polymers, and cellulose from cotton, from non-reusable textiles and PET bottles and packaging and turn them back into new textile raw materials as part of a continual cycle.

- re:newcell (2018) has developed recycling technology to dissolve used cotton and other natural fibres into a new, biodegradable raw material, re:newcell pulp. This can be turned into textile fibre, be fed into the textile production cycle and meet industry specifications.
- Relooping Fashion Initiative (2018) uses a cellulose dissolution technique to process worn-out cotton clothing and to generate new fibres, yarns and garments. The initiative has developed a CEBM to coordinate the contributions of companies and consumers.

The net effect of all these projects is to lay the foundations for informed choices about CE implementation. It is essential that the technologies deliver the needed material transformations, and it is also vital that businesses investing in CE can identify a route to achieve profitability and an adequate return on investment. Some of the projects are focused on fibre-to-fibre recycling, whereas others are broadening the scope of CE by using wastes from one sector to be transformed into feedstocks for other industrial sectors. Both of these options are legitimate implementations of CE.

In 2017, Mistra Future Fashion published a report that evaluated two different policies to promote the fibre-to-fibre recycling of textiles in Sweden. These were a mandatory extended producer responsibility scheme and a refunded virgin payments (RVP) system. In the case of RVP, there would be producer charges for virgin fibre usage with refunds based on use of recycled textile fibres. The report Elander et al. 2017) recognised that numerous changes in practice would be necessary, but found more positive outcomes with EPR than with RVP.

In May 2018, the European Parliament approved "a set of ambitious measures to make EU waste legislation fit for the future, as part of the EU's wider circular economy policy." The measures included the promotion of the use of economic instruments, including Extended Producer Responsibility schemes. Household textile wastes are required to be collected separately by 2025. Member states are required to prioritise prevention, reuse and recycling above landfilling and incineration. The declared goal is to make "the circular economy a reality" (European Commission 2018b). Clearly, fiscal and legislative drivers are to be used to promote the policy.

Recognising that there are major challenges in adding value to textile wastes, Tyler and Hall (2018) have modelled the costs identified as part of the Resyntex project. Preliminary work suggested that the business case for CE technologies and processes was not strong enough to attract potential investors. Drawing on the concept of industrial ecosystem services, it is possible to identify benefits not normally costed when making a financial appraisal. Some of these services can be measured financially, whereas others are indirect and can only be quantified by incorporating policy-related assumptions. When textile ecosystem services are quantified and incorporated into the business model, the outcome for CE is considerably more healthy. However, to attract the significant investment needed, the conclusion is drawn that an EPR subsidy of the processing costs is needed to turn the concept into a reality.

6.6 Culture Change for Circular Economy

The linear model of production has been popularised as "take–make–dispose." This format has worked when natural resources are plentiful and disposal is not an issue. However, natural resources are finite and the disposal of unwanted materials is a significant problem all around the world. According to MacArthur:

> Within the past decade, however, businesses have been hit by an increase in commodity prices that has effectively erased the (average) decline of the entire preceding century. Coupled with this, we expect three billion more middle-class consumers by 2030. This unprecedented rise in demand for a finite supply of resources calls into question our current predominantly linear economic system. (Ellen MacArthur Foundation 2014, 3)

According to this report, it is necessary to address the problems of "leakage" of materials and product flows outside the framework of a circular system. It sets out to identify the many barriers to circularity associated with the phenomenon of "linear lock-in," described as "the engrained structures that have anchored themselves around our linear-based growth models" (p. 29).

Moving from linear to circular flows requires a culture change at all stages of the supply chain, including consumers and the waste industry. This represents a paradigm shift affecting the whole sector. Consequently, implementation of the Circular Economy necessarily brings disruption to existing linear supply chains.

> The circular economy is of academic interest for its potential as a disruptive, innovative economic model that relates to government policy, businesses, and consumers. It is restorative and regenerative by design, structure, and objective: products, components, and materials are designed to continuously add, recreate, and preserve value at all times. The circular economy is disruptive as it changes the incumbent model and forces a rethinking of the many various aspects of production and consumption across the entire production and consumption chain. (Esposito et al. 2018, 6)

A review of two decades of CE implementation concluded that the worldwide picture is one of initiation, mainly addressing recycling rather than reuse. The initiatives studied pointed to the need for culture change that is comprehensive in scope:

> The lesson learned from successful experiences is that the transition towards CE comes from the involvement of all actors of the society and their capacity to link and create suitable collaboration and exchange patterns. (Ghisellini et al. 2016)

Whilst recycling is an integral part of the CE framework, the reuse of products is not a hallmark of CE. Reuse can and does take place in linear supply chains and does not imply that a culture change has been achieved. It can mean only that discarded products have residual value making it feasible for businesses to sort and resell the products. At present, the economic case for reuse is significantly stronger than for recycling, suggesting that financial drivers as well as regulations are needed for companies to commit to recycling. Technical innovation is also needed, as beneficial environmental impacts of recycling and reuse are not always found:

> The reviewed publications provide strong support for claims that textile reuse and recycling in general reduce environmental impact compared to incineration and landfilling, and that reuse is more beneficial than recycling. The studies do, however, expose scenarios under which reuse and recycling are not beneficial for certain environmental impacts. (Sandin and Peters 2018)

The focus of this chapter is on design and the product development process. There is potential for design decisions to radically change the extent to which technological and economic barriers impede the transition to circularity. The problem faced by most retailers and brand owners is that their design processes are dominated by the aesthetic considerations of seasonal colour and style trends, and the availability of novel fashion fabrics. Furthermore, there is the continuous pressure to reduce lead times for range and product development. To a large extent, the technical skills required for sampling, product development and fabric procurement are provided by global partners.

When tools of Design for Environment and Design for Disassembly and Design for Disposal are introduced, numerous technical issues need to be addressed. This represents a significant culture change. In other industrial sectors, a team-based product development process has been found to address the challenges, whereby designers work alongside specialists from other disciplines (Tyler 2008a, 2008b). Underpinning teamwork is the concept of concurrent product development, which requires culture change in the thinking of most brand owners, and a departure from the practice of separating the design process from the product development process. In most cases, this will bring disruption to any globalised industrial sector.

There are designers who are giving a lead about these issues and acknowledging the importance of culture change in their own discipline. The example that follows comes from Andrews (2015, 312):

> Designers cannot wait for the development of a remanufacturing, reuse and/or recycling infrastructure and other alternative business models, however, before they start to design for the Circular Economy; they must anticipate and prepare for the alternative economy particularly where there is a

long product lead time from initial concept to shop floor. Designers now have the opportunity to lead the paradigm shift and in addition to designing for the 'closed loop' they have the potential to influence business and consumer behaviour and consumption by extending actual product life and increasing perceived value of products. In order for this to happen, however, some designers need to change their practice while others need to change their practice and thinking.

6.7 The French Experience of Adopting Producer Responsibility for Apparel Goods

As noted in Sect. 6.5, France has pioneered legislation on EPR for apparel, linen and shoe products. As from 1 January 2007, companies offering garments, household linen and footwear to the French market are held responsible to taking them back, and then recycling or disposing of these products. The companies have a choice: either set up their own take-back programme (which has to be approved by the French public authority) or contribute financially to an accredited Producer Responsibility Organisation (PRO) that will act on their behalf. France has one PRO, which is a not-for-profit organisation, which collects tariffs from member companies based on the previous years' sales. A case study of this organisation, Eco TLC, is by Bukhari et al. (2018). This paper considers the first decade of Eco TLC's activity, identifying the many organisations that are contributing to textiles waste recovery in France, the collection and recycling processes, the impact of EPR and the barriers to further movement towards the circular economy. Much information about this PRO, including annual reports, is accessible via its website (Eco TLC 2018a).

The 2018 report gives an overview of the investment in recycling and the circular economy:

> Since the initial call for project proposals was launched in 2010, Eco TLC has provided financial backing for 36 projects, amounting to a total commitment of €3.2M. A breakdown of the projects according to their state of

> progress indicates that 17 projects have been completed, 10 are ongoing and 9 are in the process of starting up. (Eco TLC 2018b)

Most space in the annual reports is devoted to the project work, and there can be little doubt that these projects have made an impact for the companies concerned, and the PRO is providing a stimulus for innovation in the management of waste.

Bukhari et al. (2018) point out that the sorting of waste textiles in France was undertaken by 1400 full-time workers, of which 49% were reserved for people facing employment difficulty. Eco TLC provides financial support for these otherwise excluded workers, not just to incentivise the sorting organisations but also to buffer the financial volatility of the used-clothing market. The commitment to this financial support is substantial:

> by applying the tariff schedule, the PRO collected €17.2 million from the members (an average of €0.0067 per piece and €28.7 per tonne) in 2016. This contribution was used to cover the following 2015 expenses: €477 thousand spent in projects finance, €2.1 million subsidised local communities for consumer-awareness campaigns, €12.8 million in subsidies paid to charities and private organisations for sorting the collected textiles and clothing, and little budget spent in taxes, staff, offices and out-sourced services. (Bukhari et al. 2018, 327)

So, although the budget for projects is €0.5 million, over 4 times this amount is being spent on consumer-awareness campaigns, and over 25 times this amount is given as subsidies to sorting organisations. There is a mismatch between the messages communicated in the annual reports and the actual usage of the tariff contributions.

The Eco TLC tariffs include discounts for producers incorporating recycled materials into their products. The volumes are too low for producers to take the trouble to declare the quantities and certify the origin of the recycled materials. Furthermore:

> We observe that the PRO does not give producers incentives such as eco-module tariff when they ecologically design and source other materials. (Bukhari et al. 2018, 329)

This comment gets close to the heart of the problem: the French EPR scheme is not incentivising producers to implement eco-design. There is no culture change for the producers – they pass over the sustainability issues to the PRO and to motivated suppliers. The drivers to use DfE and DfD tools are lacking. The organisation Eco TLC has shown what can be done with relatively small sustainability projects, but there is a fundamental weakness in that culture change in the design process of producers and brand owners is hard to discern.

6.8 Conclusions

The quest for more sustainable products begins by defining desirable characteristics and seeking out ways to achieve them. It is found that the design function is central to greening products. As Sect. 6.3 demonstrates, there are solutions that designers can bring to the goals of increasing longevity, reducing the energy requirements for garment care, imparting multifunctional use and modularity, and selecting materials with low environmental impacts. To achieve these goals, a greater technical awareness is required when design decisions are made, together with significant collaboration within the supply chain. However, whilst all of these developments can be part of a circular economy, none of them actually close the loop. Consequently, producers of sustainable textile products do not necessarily move away from the conventional linear production pathways. Sustainability does not necessarily lead to culture change.

This chapter has argued that implementing the Circular Economy necessarily involves culture change, new tools and new collaborations. At the heart of the paradigm shift is the design process, which brings into view the way products are handled when they are worn out or no longer needed. In the circular economy, unwanted materials become resources for the next production cycle. As Franco (2017) has shown, some companies have started to change their culture, but we are at a very early stage. The major projects identified in Sect. 6.5 are an indication of immaturity, but provide some confidence that the textile Circular Economy is not a pipe dream.

As indicated in Sect. 6.4, the centrality of design needs to be recognised, and designers find ways of operating with an awareness of the whole supply chain. The potential for teamworking in both design and product development has been noted. Codesign will be crucial, affecting the supply chain as a whole.

The updated legal framework from the European Commission (2018b) is clear about the use of regulative drivers: "The new rules […] promote the use of economic instruments, such as Extended Producer Responsibility schemes." EPR has the potential to facilitate the financing of CE in its early stages, as discussed by Tyler and Hall (2018).

France has already a regulative driver, and Eco TLC recognises that eco-design is an integral part of the pathway to CE. However, by spending the bulk of its income on subsidising labour-intensive sorting, it is undermining its stated principles. (If the sorting process needs to be subsidised, the appropriate funding would appear to come from the social services budget).

To promote culture change, regulative drivers are not enough. There must be a clarity about why change is essential: its benefits and its challenges. To achieve this, educational programmes must make the connection between principles and purposeful actions.

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7

Digital Technology for Global Supply Chain in Fashion: A Contribution for Sustainability Development

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7.1 Introduction

After a difficult competitive period at the start of the century, significant impacts on turnover and exports and also on the disappearance of hundreds of companies and many thousands of jobs, the Portuguese textile and clothing industry has managed to reinvent and restructure itself. It has managed to relaunch its growth based on new competitive factors like design and fashion, technological innovation, service and internationalization of companies.[1]

Thus, to increase the competitiveness of an enterprise in the fashion industry from a global economy perspective, it is necessary and

[1] Statistical data drawn from the Book: Textile and Clothing Industry Statistics, World, Europe & Portugal; Fashion from Portugal, 2017.

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fundamental to find better solutions for all players involved in the creative and production process, with the goal to achieve an efficient way to communicate and to conduct business.

When a company competes in any industry, there are several challenges it has to deal with as it performs several discrete but interconnected value-creating activities, such as operating a sales force, producing a component or delivering products and these activities have points of connection with the activities of suppliers, channels and customers (Azevedo et al. 2007).

According to the aforementioned literature references, this chapter seeks to present an approach to business-to-business (B2B) online sourcing platforms, in particular the U.MAKE.ID project. It also presents how this tool can be a plus for the fashion business and the benefits in using these kinds of platforms in a supply chain context from an environmental, market, policy and societal point of view.

This research was based on a mixed methodology, based on three different approaches. First, a project methodology; second literature analysis of papers related to the fashion field and authors that have studied themes related to sustainability in fashion supply chain; and finally, to verify the credibility of the platform, by way of conducting a qualitative study based on exploratory interviews with fashion professionals, in this case, fashion designers.

This project can create a new dynamic global economy in the fashion business, giving it a positive impact, increasing the sourcing efficiency and improving communication and business performance.

7.2 Methodology

First of all, in regard to the project itself, linear project methodology was adopted (Munari 1983). Munari believed that anyone could be creative if someone provides them with the right tools.[2] A project methodology is no more than a series of innumerable operations with a logical application and with the objective to achieve the best results with minimum

[2] http://specialprojects.studio/article/design-methodology/.

efforts. So for website development, the team made an adaptation of the project methodology in order to achieve the best solutions for designers.

On product development, a systematic method will help the process of creation and that process demands normally an interdisciplinary approach. Apart from the use of a style and aesthetic concept, the product also requires marketing and engineering methods. The U.MAKE.ID project development was no exception once was compounded by a multidisciplinary team including experts in design, management, tic's and engineering's.

The second approach focuses on the theoretical part. The literature review used in this chapter was mainly based on scientific papers related to fashion and sustainability, regarding the aforementioned keywords.

On the route of an investigation, one is bound to find problems. In the case of this investigation, one of the problems found was the difficulty that the designers have in their sourcing of possible suppliers and manufacturers. Therefore, the platform U.MAKE.ID appears as a hypothesis created with the intention of being approved as an agile, facilitative and effective search tool (Pina et al. 2017).

The third approach, the practical one, also considered the qualitative data that has been collected and analysed it from the initial interviews with fashion professionals. A live questionnaire was developed based on interviews with five fashion specialists. For this phase, the authors developed a script that was used as a tool for the interview composed of open- and closed-ended questions.

The script for the interviews was composed of three main parts, where the last two were separated along with the presentation of the platform U.MAKE.ID. The first part focused on the geographical location of the interviewees. These interviewees were questioned on the type of product segment that they work with, the existence of the brand, the dimension of the company and finally the position of the interviewee in the company.

The second part of the questionnaire contained seven different questions but all based, related and connected with two major questions:

RQ1 : How designers usually do the sourcing?

RQ2 : What is the level of satisfaction regarding this task?

In the presentation of the website, interviewees were shown the main objectives and potentialities of the platform, how it works and how prospective users can subscribe and start to use it. The third part of the interview was made after the presentation of the platform, and nine questions were posed with a view to understand the following:

RQ3 : The opinion of the interviewee regarding the platform according to the idea/project?

RQ4 : How can U.MAKE.ID contribute for the sourcing of products, services and to the brand?

Fashion specialists located at a distance were interviewed via Skype. The main objectives of these interviews was to further establish how fashion specialists nowadays, in this case fashion designers, undertake the sourcing of products or services and to understand how a B2B platform of online sourcing could be a helpful tool for their work or business.

It is important to understand fashion entrepreneurs and fashion specialists' feedback regarding their own way to do sourcing and what they think about B2B sourcing platforms like U.MAKE.ID.

7.3 Fashion Industry and Sustainability in the Production Chain

Considering a first approach on the meaning of the word, the term sustainability itself originates in the French verb *soutenir*, "to hold up or support" (Brown et al. 1987). The term does imply limits; however, according to Caniato et al. (2012, p. 660), sustainability means, considering the Brundtland report (1987), "being able to satisfy current needs without compromising the possibility for future generations to satisfy their own needs." Thus, it is a concept that can be posed as a transformation of human lifestyle that can optimize health, well-being and security (Geissdoerfer et al. 2017) and not less important the reuse, rethink and reduce products' concepts.

Assuming that sustainability has been emerging in the last decade as a megatrend (Henninger et al. 2016) the industry and the creative scenario in fashion also has changed drastically. This change is mainly related to the awareness of consumers that are now more aware of the issues that emerge from the fashion products manufacturing processes.

So, fashion brands and factories try to increase their sustainable performance because they know that their acts can compromise their business and the truth is that according to Li et al. (2014), 45% of successfully and highly efficient supply chains are now applying new technologies and also laying a tremendous emphasis on sustainable strategies.

Having in mind the triple bottom line approach that considers that the three pillars of sustainability are based on people, profit and the planet (Elkington 1998), each fashion company should consider operating their business in order to implement and achieve new sustainability practices.

Moretto et al. (2018) say that sustainability practices can start at the manufacturing process but they can however be extend through the others company activities in supply chain, becoming like this, more aware of their potential for new sustainability models in their business.

According to Kawamura (2005), "A fashion system is the interrelationship between highly fragmented forms of production and equally diverse and often volatile patterns of demand" and of course efficiency. To demonstrate the last point of view (Fletcher 2014), fashion businesses provide garments at specific price points for specific target markets; as a result of this demand, the quality and quantity of other options often declines.

Christopher et al. (2004) noticed and proposed in 1999 that the foundations for agility in the fashion business are a solution for the company's success. It is based in four different dimensions where the next two topics focus, more precisely, the objective of a business-to business online platform:

- Virtual—where the information has to be shared on real demand, collaborative planning and end-to-end visibility
- Process Integration—where the inventory has to be managed, the design must be collaborative and all the suppliers should be synchronized

From a production chain point of view, supply networks are complex adaptive systems for contextual changes (Macchion et al. 2015), and these changes can be suppressed by technical, social and organizational innovations through the productions chain (Witjes and Lozano 2016).

Lieder and Rashid (2016) said that it is important to understand that to expand the benefits of the production activities, it will be important for companies to adopt sustainable techniques; however, and on the other hand, they must know that their competitiveness can be threatened, once sustainability resource prices can be extremely volatile.

In fact, to invent and develop a new range of products with a claim for sustainability, firms need to have dynamic capabilities to make their business model function effectively (Boons et al. 2013). However, what about the sustainability between all the players involved on the task of the product development? For Manzini and Vezzoli (2003), "client does not really demand the products or services, per se, but what these products and services enable a user to achieve."

Complexity arises mainly out of the impact of sourcing products with short life cycles from a large number of different suppliers in a global context (Masson et al. 2007). More companies must be able to supply a growing variety of products, often personalized to customers' individual needs (Macchion et al. 2015).

Nowadays, the procurement task or sourcing work, considering that the meaning of both terms are quite similar, in the fashion industry and more specifically speaking for fashion brands is a task that requires a lot of time.

This also implies a strong sense of organization and flexibility skills when sometimes the flow of the communication with the suppliers is not at its greatest. Because firms are increasingly involving suppliers in the development of new products and facing new management problems (Roseira and Brito 2014), are business to business (B2B) online platforms an example of a service that could provide better opportunities for product design innovation, and can they be an effective tool to achieve transparency and consistency between businesses?

Because supply chains comprise both buyers and suppliers, measuring and monitoring performance requires inputs from multiple organizations and across systems (Korta and Perry 2013). Hence, demand planning allows a company to minimize its supply chain costs by minimizing inventory, purchasing, logistics and production costs (Moon et al. 2000).

The relationship between companies is something that should be based on the following requirements: compatibility, mutual understanding, open communication, shared commitment, fairness, flexibility and trust (Ab Talib et al. 2015).

Consequently, Awwad and Akroush (2016) said that in today's turbulent business environment, firms should pay more attention to improve new product developments, as to maintain substantial growth for business survival. The main driver that urges organizations to develop new products is responding to change in the business environments efficiently and effectively, thus the need of finding solutions to facilitate communication between all the involved organizations.

Circular economy provides opportunities for innovation in product design, service and business models; as a result, it establishes a framework and building blocks for a long-term, resilient system (Todeschini et al. 2017). To have an agile supply chain, it is necessary that the company has an effectively rapid response to their clients' demands because the fashion industry has irregular changes in the market, in terms of both volume and variety (Carvalho et al. 2012).

Therefore, the necessity of new models is based on the B2B model. In this new era of digital business, it is necessary to develop and optimize the fashion industry, allowing the establishment of new partnerships with factories, brands and suppliers in the European and global markets, boosting the business of current users and new ones that can appear from the creation of new brands (Pina et al. 2017).

7.4 U.MAKE.ID: An Example of a Project with a B2B Approach

According to Pina et al. (2017), U.MAKE.ID is fundamentally an instrument for the improvement of processes, which translates into the economy due to the collaboration of users, presenting itself as a tool that can ease the productive processes and streamline established competencies, as well as act as a tool for internationalization of products, services and knowledge.

This project can provide proximity between markets and create easy communication among fashion professionals, and it is based on three main ideas:

1. Facilitating the sourcing process for fashion brands and fashion manufacturers
2. Providing social and economic marketing relations
3. Creating a place where designers are allowed to create and develop their projects and then share them with potential manufacturers, with the focus of trying to be closer to and aware of the production phases

Taking into account the objectives of the U.MAKE.ID project, the following main purpose was the creation of a platform that can integrate services and that can be able to reduce the barriers of communication between players (brands, factories and suppliers), building connections that can reduce the distance between conception and production, through the simplification of the sourcing process onto the production, and simplifying the communication and organization between the different players.

Especially in times of crisis, captivating new clients means direct opportunities of new income (Pereira et al. 2018).

Table 7.1 shows the main challenges, purposes and contributions of the U.MAKE.ID. platform, as mentioned by Pereira et al. (2018). It is important to understand what type of challenges the fashion industry, fashion brands and designers face in their daily work regarding sourcing, and how this platform could be a solution to their problems.

7.5 Data Analysis

On a first approach and once the *Castelo Branco* County had some industry related to fashion, the sample was chosen following "convenience" aspects, therefore, considering the geographic location of the

Table 7.1 Challenges and purposes of the platform U.MAKE.ID

Challenges	Purpose
Reactivate old clients	1. Contact old clients or build promotional actions; focusing on these clients can bring fast results. 2. Improve commercial relationships. 3. Companies that can establish this kind of communication sell the most.
Flexibility and simplicity in the purchase of a product or service	1. For manufacturers, it is easier to manage and replace stocks. 2. For brands and designers, it is more simple to communicate and to achieve their needs.
Sell to small costumers or fulfil small orders	1. What if these small clients could make their orders through these platforms? The costs could be reduced and relationship between cost and benefit will be improved.
The geographic covering	1. Without a geographic barrier, a company can now look for costumers that before weren’t economically viable selling to regions that could never approach before. 2. This platform will approach European manufacturers to worldwide brands and designers. 3. Seek transparency in the supply chain regarding all the ethical preoccupations, considering the final consumer and all the players involved in the production process.
Work efficiently all the products available	Building communication and marketing strategies to get the clients to know all the products will bring significant gains to the company that will in this way diversify the sales and consequently increase the average value of the products.
Complexity of the product	1. With a complete exposure of the product capabilities and characteristics on a platform, it will be easy for all parties to understand the product and its advantages. 2. Increase the share of products with greater margins of profit.
Launching new products	With a B2B e-commerce platform, this task can have a great aid from the digital world. It is much faster and cheaper to create videos, virtual experiences and digital technical descriptions and spread this work through the internet than doing everything in person.
Approaching new potential brands and designers to manufacturers and vice versa	U.MAKE.ID can be a useful tool once it provides a simple manner of research and easy communication.

University of Beira Interior in the city of *Covilhã*, on the region of Beira Interior, Portugal.

For ethical reasons none of the brand or interviewee names will be mentioned in this chapter, being identified as "cases."

Regarding the field, fashion designers related to classic and casual clothing, eco-clothing and textiles were considered.

Fashion specialists are mainly professionals that:

- Are working in factories that possess their own private label
- Are new designers that create their own brand
- Are working in fashion *ateliers* and developing products for several brands

Concerning the existence of the brands, the timeline comprehends new brands with one year and almost a decade of existence.

In the second part, the interviews were based on a series of approaches related to the level of difficulty/simplicity of doing sourcing, of what are the places and softwares used to do sourcing, at which point of the year and product development they do the search of new materials, what are the three main and most important facts that they care about when they do the sourcing, and to conclude, what is the level of their satisfaction regarding the sourcing.

Regarding the first question, "In terms of difficulty, find the right product attending your necessities as a fashion professional is…," most of the interviewees responded that this task was easy, but, in case two, a new eco-clothing brand, this process can be very difficult.

Most of the brands mentioned that they used the internet as a tool to do the sourcing. There were three main aspects that brands considered as the most important in the manufacturing or materials sourcing, these being the price and the quality—the two major aspects referenced by the interviewees—and also time. Other associated costs like flexibility, geographic location, availability and production time were also considered. It is also important to say that in the fifth case, the brand considered the minimum orders imposed by the suppliers and manufacturers as being more important.

Regarding the sixth question, attending the way as brands normally do the sourcing and how satisfied they are, on a scale of very satisfied, satisfied, less satisfied and not satisfied, they all responded satisfied.

When confronted with the seventh and open question, regarding why are they just satisfied with their way to do sourcing, case one mentioned that:

1. "Suppliers that I work with can equilibrate the three factors that I mentioned before (Quality, Price and Time) in a way that please me and as a result I can please my customers as well with a good and quick response."
2. "I believe that talk and meet people directly can open other doors that fashion events or another type of sourcing are not able to. I think that potential manufacturers, with a production type based in quality do not have information on the internet and I can only found them through other references."
3. "The company where I work is based in a part of the country where is simple to find a supplier or a manufacturer. Because there is so much competition between them (manufacturers, suppliers) we can always achieve the lowest price."
4. "I am satisfied because in the majority of cases the manufacturers and suppliers can meet our demand and deadlines and the most important is they can meet this demand without losing their patterns of quality."
5. "I am satisfied because apart from some suppliers and manufacturers that doesn't care and doesn't meet our expectations some others are concerned about meeting and following our demand."

Finally, the third part consisted of comprehending how much the platform U.MAKE.ID was appreciated by the interviewee, to understand how this service could be or not a better solution for their professional activity and to finalize and recognize in which tasks or situations this tool could be more useful.

Therefore, when questioned about "[…] how much do you appreciate this new sourcing service?" most of the brands answered that they "really appreciate" U.MAKE.ID.

In the first case, a brand with almost a year of existence mentioned that "this service can facilitate the communication between different brands and suppliers," and it also mentioned the convenience of having in one unique platform all the phases that a designer or a brand has to deal with since the beginning, the creative process, crossing the production demands and finishing in the distribution phase.

It is important to note that most of the brands mentioned the convenience of having a service like U.MAKE.ID. A designer that works with several brands said that, "I liked, for example, the fact that I could be seated in my office and I could be able to find good suppliers instead of being visiting them to understand how they work."

Regarding designers that work in a factory that has its own private label, they replied that what they appreciate more in this new service is "the possibility of being able to find new partners and satisfy possible needs that can append in the moment and the capacity of seeking suppliers for a specific product and eventually be able to contact not only national suppliers but also international ones."

All of the interviewees said that this new B2B sourcing service could be important for their business, except one case that was a brand with one year of existence that said that a service like U.MAKE.ID could be really important.

However, it is imperative to cite the words of a designer regarding what it is that could be less appreciated in this new service: "I don't know the platform very well, but what worries me first is the fact that the platform cannot guarantee a large number and good selection of suppliers and contacts; and second, what is the cost of being part of this platform."

Moving now to the next question, "How this new service can contribute to improve the sourcing process in your brand?", the interviewees talked about the difficulties of having a brand based at Covilhã and the fact that the location is a difficulty factor to reach potential suppliers.

In case one, the designer demonstrates his displeasure saying that "The truth is that sometimes we don't have the response to the emails that we sent" and concluded saying that: "With this platform and have all of them (suppliers and manufacturers) united here, it is like a guarantee that they will respond. It is more familiar and quick to obtain an answer."

It is also important to focus on other interviewees' responses to this same question. They exposed several aspects, like "Be able to start working with companies that I did not know," "the major advantage on this platform is to have several tools into a single system," "good way to achieve new prices and new deadline timings" and "it can contribute for better methods, faster respond and a wider offer than the usual."

Regarding the two following questions, the first questioned what could go wrong with this new sourcing service and it is interesting and important to note what the last case answered about the U.MAKE.ID sourcing strategy. "Seems that I am dealing with suppliers and manufacturers that I don't know any information about. In an initial approach how will I have a concrete idea of business about the suppliers? Are they working correctly or not? Are they reliable or not?"

In the second and final question, when we asked them if they have any suggestion for U.MAKE.ID, they answered, "I suggest the implementation of a rating system that will allow me as a user and brand to rate other users like suppliers and manufacturers. This tool could help me to realise and to identify if it is worth to work or not with that potential partner. With that I can choose a business partners with a clear idea about its problems and its values."

To conclude this chapter, it is important to mention that some of the interviewees' doubts were clarified after the interview.

7.6 Conclusions

It is important to recognize that all the interviewees are fashion professionals that are familiar with the internet and use it as a tool on a daily basis at work to do their sourcing tasks. Thus, these five cases can already be potential future users of U.MAKE.ID.

Kawamura (2005) as explained above said that the fashion system is an interrelationship between highly fragmented forms of production and equally diverse and often volatile patterns of demand, therefore the necessity to have new business models to confront this diversity of demand.

According to the cases that were interviewed, all respondents were just satisfied with the way they undertake sourcing, and for specific brands and specific products, like eco-clothing, this task can be very difficult. The general opinion of the specialists regarding U.MAKE.ID functionalities was reasonable, and they showed interest in using the website and considered that this service could have a great contribution to their sourcing tasks, emphasizing the fact that it could be a great system that could provide several tools not only for the sourcing but for their project management as well. “It can contribute for better methods, faster respond and with a wider offer than the usual.”

However, to conclude, the authors have to demonstrate not only the strengths of U.MAKE.ID but the weaknesses too. Thus, focusing the concerns that the interviewees demonstrated, it is important in the next phase of the project to understand how the platform can be improved regarding this question: “The information provided by the supplier/designer is real? Is the information certified and trustworthy?”

Having in attention the concern about sustainability, business models serve to provide a linkage between producer and customer, and for a new range of products with a claim for sustainability, firms need to have dynamic capabilities to make their business model function effectively (Boons et al. 2013).

In the last few years, there was a tendency for designers and fashion brands to make smaller productions with a bigger diversity of products with the objective to expand their range of customers, so it is appropriate to provide new services that can provide them the best manufacturer for their needs.

With the belief that the U.MAKE.ID platform can be a great solution, regarding the collaboration and sustainability of the business between manufactures/suppliers and brands/designers in the fashion field, reaching companies that allow them to make productions with acceptable quantities, it is still a problem to solve. Even more now that the fashion industry is passing through a new transition phase where new business models, such as co-creation, are starting to gain importance in terms of manufacturing. Can this be a struggle for the industry and for the development of new products?

To end, as contribution, U.MAKE.ID can be a helpful solution to new designers and entrepreneurs that do not have the necessary knowledge to pursue and discover potential product manufacturers with the purpose of businesses transparency between all the fashion players involved in the product development process.

7.7 Limitations of the Study and Further Investigations

This practical and qualitative study was made with a limited number of interviewees where only designers were interviewed. It is important, in the next phase of this project, to understand how other specialists or fashion professionals, like product developers or client managers that work with manufacturers, do the sourcing and how B2B online sourcing platforms, such as U.MAKE.ID, could help them to reach new clients, new materials/products and other potential services that they need.

After the data analysis, it was realized that some questions were limited. If the authors could expand the range of questions to listen and understand other preoccupations and suggestions, then this could lead the team to other facts and conclusions that were not conveniently explored until now.

The geographical area and the field of investigation were also limited, so, the authors should take into account not only the enlargement of the number of respondents but also of the geographical regions. The north region could be an excellent choice taking into consideration the large number of companies related to clothing and textile production.

In the future, it is also important to analyse shoes, watchmaking and jewellery sectors to understand how fashion designers and other professionals do the sourcing.

It is important to emphasize the need of a focus group, with a practical exercise focusing on the use of the several tools that the website provides to realize how potential users will react and what is their feedback regarding U.MAKE.ID functionalities.

Regarding the practical study, it seems appropriate to say that in the last phase of the project, questionnaires were sent to fashion brands and manufacturers all over Europe, but the results were not considered for this study; hence, the number of the questionnaires answered until now is very limited.

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8

3D-Printing in the Fashion Industry: A Fad or the Future?

Helen McCormick, Ran Zhang, Rosy Boardman, Celina Jones, and Claudia E. Henninger

8.1 3D-Printing in the Fashion Industry: Its Origin and Current Use

The twenty-first century has seen the emergence of disruptive innovations that have changed business models used within the fashion industry, such as renting and swapping, as well as new technologies, including but not limited to three-dimensional (3D)-printed fashion, zero-waste garments and those designed for circularity (Henninger et al. 2017a; Park and Armstrong 2017). This chapter focuses on 3D-printing technologies and, more specifically, Chinese millennial consumers' perceptions of 3D-printed garments, which currently lack research (Perry 2018).

The 3D-printing technology is not a new phenomenon per se but was introduced three decades ago when Charles W. Hall patented the process of stereolithography (Huang et al. 2015). Three-dimensional printing can best be defined as "an automated additive manufacturing process that

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builds a product by depositing material into successive layers until it is complete" (Vanderploeg et al. 2017: 170). Within the fashion industry, automated additive manufacturing, also known as three-dimensional (3D) printing, is predominantly used to visualise and test new product developments for fit and form. This implies that prototypes are often created using this technology. A key advantage of implementing an additive manufacturing process is that it reduces risks in the manufacturing process, as items can be tested prior to being mass produced. However, prototyping is not the only use of 3D-printing; it is further utilised for customised made-to-order garments and within haute couture fashion houses (Fitzgerald 2013; Perry 2018). A key question often posed and addressed in this chapter is *"are we ready to 3D print our own clothes?"* (Mariott 2015).

As indicated, the predominant use of 3D-printing technologies or additive manufacturing processes is within the prototyping phase of producing new garments and/or accessories (Yap and Yeong 2014). Today, this has changed, with a Dutch designer Iris van Herpen making 3D-printed garments more accessible, as she introduced 3D-printing as a "staple piece" to the haute couture fashion scene almost one decade ago (Lewis 2013; Logan 2015). Today 3D-printed fashion items are increasingly popular and have trickled down from being solely used within haute couture fashion (Yap and Yeong 2014) to being used for jewellery (Shapeways 2018a), bikinis (aRks 2016) and shoes (Heater 2018) and thus have become available for a wider audience. To reiterate this further, the popularity of 3D-printed garments excelled in 2014 when a red dress dominated the media, which was inspired by nature to replicate fish scales and thus created an elegant flow that looked irresistibly light and fashionable. Newspaper outlets indicated that there was *"finally a 3D-printed dress that drapes, [and] moves like actual fabric"* (Meinhold 2014), as opposed to being static and artificial looking. The "red dress" is revolutionary in that it is not only 3D-printed but also a kinematics dress and quite literally printed to order. This provides a sense of exclusivity, further enhanced through the fact that it was featured as *future couture* in the Museum of Modern Art in New York, thereby adding to the luxury vibe (Lenander 2015). The term "kinematics" finds its origin in the field of mathematics and describes the motions of points. Three-dimensional printing enables designers to make use of these *motion of points*, allowing the creation of geometrically complex structures that are not only elegant but also fluid, translating into a naturally flowing fabric (Rosen 2014). Figure 8.1 provides a visualisation of the geometrical pattern used to create the red kinematics dress. Triangular shapes are carefully positioned next to one another, which allows for movement and makes it easy to wear.

Traditionally, garments are initially designed as a sketchup, which is transferred into a pattern that can be applied to a fabric of choice, cut and sewn together to create a finished prototype (Berman 2012). The 3D-printing technology revolutionises the traditional supply chain process by reducing not only the steps necessary to create a finished garment but also the waste created when manufacturing a garment and/or a collection. Additive manufacturing is a "cost-effective and time-efficient way to produce low-volume, customized products with complicated geometries and advanced material properties and functionality" (Huang et al. 2015: 1). To reiterate this further, traditional garment manufacturing processes produce off cuts (unwanted surplus material) as patterns are transferred onto fabrics, leaving enough space to cut the shapes out of the material (Berman 2012; Economist 2012). Contrarily, for the 3D-printing manufacturing process, only the necessary amount of raw material is used, resulting

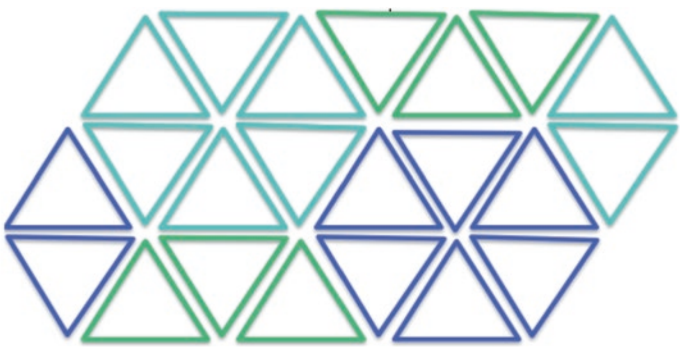

Fig. 8.1 Red kinematics dress pattern (authors' own)

in zero waste (Bak 2003; Vanderploeg et al. 2017). Although 3D-printing has its advantages over the traditional way of manufacturing clothes, a key drawback is the time and energy it takes to create a piece, which further implies that only low volumes will be produced, making 3D-printing more relevant for the luxury market as opposed to fast fashion. To provide an example clearly illustrating the energy and time usage, in 2016, threeASFOUR created the Pangolin dress, which used 10 printers simultaneously, working for a total of 500 hours, not including the assembly process (Jacobson 2017), thereby highlighting a "shattering truth of 3D-printed clothing" (Jacobson 2017). Current 3D-printed garments are available only to a fashion elite that is able to spend large sums of disposable income on these items. Yet, massification can still be reached, as jewellery provides an entry level item that can be affordable, depending on the material used for printing (Shapeways 2018b).

8.2 Chinese Millennial Consumers and Their Perceptions: Luxury Fashion Industry

This chapter focuses on Chinese millennial consumers who were chosen purposively for this research. As highlighted, 3D-printing technologies within the fashion industry are predominantly used within the luxury fashion industry and the haute couture setting. Chinese consumers are key economic drivers of this luxury sector (Deloitte 2017), as one-third of global luxury sales is attributed to them (Hancock 2017). Bu et al. (2017) highlight that Chinese consumers are not only becoming more global, enabled through China opening up its borders, but also increasingly demanding new products, new technologies, and new ways to interact and engage with them (e.g. Mackerras et al. 1998; Wang 2017). Enhanced through the one-child policy, millennial consumers feel a sense of entitlement (Wang 2017) and are currently aged between 19 and 35 years (Economist 2016). The key characteristics of millennial consumers are as follows (Doctoroff 2007; Solomon 2017; Bu et al. 2017; Henninger et al. 2017b):

- Technology savvy and accepting new technologies
- Social generation: not only sharing their lives on digital platforms but also seeking social acceptance through showing off wealth (especially in China)
- Looking for new opportunities and adventures, which is also linked to purchasing items that are new and novel and pushing boundaries
- Passionate about values, including companies they may purchase items from

Despite the economic importance of Chinese millennial consumers, current research lacks investigations into this consumer group (Kapferer and Michaut-Denizeau 2014; Henninger et al. 2017b), which is addressed in our chapter.

Annually, Chinese consumers are spending an average of 71,000 RMB on luxury goods, making them a key target market for 3D-printed garments and accessories (Bu et al. 2017). Bu et al. (2017) highlight that a key driver in the decision-making process is the initial consideration phase, whereby brands that are recalled are the ones that are at the forefront of consumers' minds, known as the "top-of-mind" recall. This top-of-mind recall mechanism is enhanced through consumer perceptions, defined as "the process by which an individual selects stimuli from his or her environment, organises information about those stimulus, and interprets the information to form a coherent, meaningful view of the world" (Wells and Prensky 1996: 257). As such, consumer perceptions are rather subjective and can be influenced by an individual's culture (Kastanakis and Voyer 2014). Prior to 1978, China's value system was dominated by Confucius values, which see individuals sacrificing their own interests for the benefit of society at large (An et al. 1999). Yet, this has since changed with China opening up in 1978, exposing Chinese consumers, especially millennials, to the West and Western values, making it increasingly acceptable to broadcast one's own individuality and wealth through materialistic items, such as garments. Three-dimensional printed items allow for high customisation and uniqueness, and thus, designers, such as Iris van Herpen, who currently use additive manufacturing processes, have an opportunity to market their products to an increasingly affluent market (Doctoroff 2007; Deloitte 2017; Henninger et al. 2017b). Peng

(2017) further indicates that Chinese middle-class consumers follow a *xiaozi* (小资) lifestyle, which implies that they are increasingly showing off their uniqueness and wealth through their consumption behaviour (Henningsen 2012; Ibrahim 2015). For Chinese millennial consumers, fashion products are one way of portraying their uniqueness and individuality to their peers (Ye et al. 2012; O'Cass and Siahtiri 2014). This further justifies this research context of 3D-printed garments and accessories, as these are classified as customised luxury products that allow consumers to portray their individuality.

8.3 Methodology

This qualitative research explores Chinese millennial consumers' perceptions of 3D-printed garments and their likelihood of purchasing these. A total of 15 in-depth semi-structured interviews were conducted with Chinese millennial consumers. Interviews were conducted in Mandarin Chinese in order to make it easier for participants to fully express themselves. Interviews were carefully translated from Chinese into English and back again in order to ensure that no meaning was lost. All interviews were conducted on a face-to-face basis and lasted on average 35 minutes. Participants in this research were recruited following a snowball sampling technique, which implies that interviewees recommended others to participate in the study. Key requirements to participate in the study were as follows: (1) must be aged between 18 and 35 years and thus can be classified as millennials; (2) are Chinese and (3) consume luxury goods and have an interest in new innovative luxury items allowing them to express their uniqueness.

Participants were almost equally distributed between males and females, with the majority of them being in their mid-20s (Table 8.1). Interview questions for this research were guided by topics concerning 3D-printed garments and current reports in the media, as well as their perceptions of brands utilising adaptive manufacturing processes (e.g. Nike, Iris van Herpen, Shapeways).

Although 3D-printing in the fashion industry is not new per se, it has thus far not been explored from a marketing perspective, more specifically to investigate consumer perceptions towards these products and the

Table 8.1 Summary of the data set (authors' own)

Participant	Age	Gender	City	Field of work
1	19	Male	Foshan	Engineering
2	18	Male	Chengdu	UG student
3	30	Female	Zhuzhou	Medicine
4	23	Female	Wenzhou	Fashion retailing
5	24	Female	Nanjing	Business
6	22	Female	Hangzhou	Education
7	24	Male	Hangzhou	Computer engineering
8	22	Female	Ganzhou	Chemistry
9	24	Male	Guangdong	Social development
10	22	Male	Handan	Business
11	28	Female	Xinyang	Fashion management
12	22	Female	Haerbin	Chemistry
13	24	Female	Linyi	PGT student (business)
14	23	Male	Xingtai	Business
15	23	Male	Cangzhou	Engineering

likelihood of purchasing these items. As such, this qualitative research allowed us to gain an insight into how consumers feel about these products (Bodgan et al. 2015). Following in line with Easterby-Smith et al.'s (2012) grounded analysis approach, rich data sets were coded and recoded multiple times, first individually by each of the researchers, before discussing the emerging themes and discrepancies. The latter were carefully reviewed and recoded.

A limitation of this research could be the interpretivist nature of the study and its limited sample size of only 15 participants. Yet, findings provide an interesting insight into the perceptions Chinese millennial luxury consumers have about 3D-printed garments and their likelihood to purchasing these in the future.

8.4 Findings and Discussion

8.4.1 Perceptions of 3D-Printed Garments

Prior to exploring the perceptions of 3D-printing technologies, it was vital to understand why these millennial Chinese consumers engage in luxury shopping. The majority of participants indicated that they felt a lot of pressure in their everyday life with individuals seeking to not only please their managers but also fulfil family expectations at being the best. Participants 3, 7, 8 and 15 insist that although the pressure is high, they seek to enjoy life more and reward themselves with gifts. To reiterate this further, participant 7 stated "I work for pleasure and my work should be entertainment-focused." From the conversation it is apparent that one way of gaining this "pleasure" is by purchasing luxury items that clearly demonstrate how well they are doing in their career. At the same time, the act of purchasing luxury items is a part of their "retail therapy," which enhances their personal well-being. This concurs with the research by Henninger et al. (2017b) highlighting that key drivers to purchasing luxury items are expression of wealth and well-being.

An interesting observation that could not be fully explored due to the scope of this chapter is the fact that Chinese consumers' attitude towards materialism is changing. Whilst Chinese consumers previously were heavily influenced by Confucianism and Daoism (An et al. 1999), which implies a more communal spirit and looking after individuals in society, this has changed with the emergence of new technologies (Wang et al. 2016). Participant 5 states that "material is the base for everything," which further reinforces this point. This cultural shift could have implications for today's market economy and is an area that should be explored further in future research.

Key to this research was to understand how Chinese millennial consumers perceive 3D-printed garments and/or accessories. The interview began by discussing 3D-printed garments in general terms and whether participants had previous experience in purchasing anything that was 3D-printed. The majority of participants were aware of the Iris van Herpen dress "having seeing it on social media" (P3), with only Participant 1 indicating that they had previously bought 3D-printed accessories, which was a gift for a friend.

The general feeling about 3D-printed garments was mixed with some indicating that they felt these products were too unique and extravagant, implying that they would not be able to wear them on a daily basis (P2, 3, 5, 7 and 8). This notion emerged from the Iris van Herpen dress, as it is a part of the haute couture scene. Although all participants in this research have previously bought luxury fashion and accessories, none of them would associate themselves with haute couture, stating “the rich and famous … only they can buy stuff like that” (P2). Participants 6, 9, 11 and 12 expressed their thoughts on additive manufacturing implying limited functionality. As the printed fabric is always based on complex geometrical forms, “they cannot replace what normal fabrics do … it’s just less functional … look at the red dress, it’s transparent, when can you wear that?” (P11). Issues surrounding the materials used within 3D-printing are not a new phenomenon: Sun (2016) indicates that raw materials, such as poly-lactic acid are neither comfortable nor flexible enough for fashion garments. Similarly, in an interview with Wired’s Bradley Rothenberg, co-designer on the threeASFOUR project, it is highlighted that “with fashion there is the potential to control the weave and control the structure to get exactly the properties you want. […] The issue is that today, it’s still potential. That’s why I think Gabo (Asfour) is, like, the most exciting person in fashion. We need people like him to push the limits, to show what’s conceivable” (Jacobson 2017). This clearly highlights that although 3D-printing has made a début in the fashion industry, it is still in its infancy, which may explain the negative connotations towards it from the side of the consumer. The material aspect is further linked to low quality: “I thought the clothes looked quite fragile because of the exaggerated design and I had to be really careful about it” (P10). Similarly, participant 4 states that “3D-printing products are fashionable and creative but they seem to be too fragile at the same time.” Although the highly complex geometrical structures can create elegant and fluid-looking materials (Rosen 2014) as well as be cost effective and time efficient in terms of production (Huang et al. 2015), consumers enrolled in this research felt that it also made them look more fragile and something that they would not want to wear. During the interviews it became apparent that although they wanted to have unique luxury fashion items that are slightly unusual, they felt that 3D-printed garments are taking this one step too far. Whilst 3D-printed garments may have unique designs and look unique, their performance properties are seen to be inferior to those of traditionally manufactured garments. Similar to Bradley Rothenberg, participants 7 and 11 believe that 3D-printing technologies have not yet matured enough to be part of the luxury fashion scene.

In summary it could be said that Chinese millennial consumers currently remain unconvinced of 3D-printing technologies. Although millennials are seen to be technology-accepting, using additive manufacturing processes for fashion items seems to be too *avant-garde.* Three-dimensional printed garments are associated with haute couture fashion that is not within their reach and, as a result, is seemingly impractical, as the elegant, yet fragile-looking structures are not seen to be suitable for everyday use.

8.4.2 Purchase Intentions and Attitudes Towards New Technologies (3D-Printing)

The previous section paints a rather bleak picture for 3D-printed garments and accessories, as the majority of participants had negative connotations towards them. An explanation could be that only one out of the 15 people interviewed had an actual purchase experience. Participant 1 highlights that they liked the fact that products could be printed to order, yet also pointed out that it can be challenging to create your own set of 3D-printed earrings. Looking at the example of Shapeways (2018c), this remark may become more obvious, as customers who wish to get their own object 3D-printed need to upload a 3D model. Although support is available on the website in terms of a detailed tutorial, this may not always be a possibility due to time commitments or the inability to work with different software components.

Interestingly participants also insisted that although they had heard of Iris van Herpen and the kinematics dress, they felt that 3D-printed fashion garments and accessories are not well advertised. The majority of participants felt that 3D-printed items could have great potential in China, as new technologies are readily accepted in the market, and if promoted correctly, it could be adopted very quickly. Participants 8 and 10 indicate that if their friends would purchase 3D-printed items, they would too, even though they may be hesitant in the first instance due to the feeling that 3D-printed items are inferior, if the majority of people adopt these technologies, they would too. Participant 9 further insists:

> 3D-printing not only has potential in China, but all over the world. It could probably be a revolution in the manufacturing industry. If 3D-printing technology matures enough to become a household appliance, then, what retailers sell will no longer be the products, but the materials and data used for printing the products … but the selling of data would bring out a series of problems like the protection of intellectual property rights and some regulations and laws should be established to protect them.

This quote further supports Huang et al. (2015), who highlight that 3D-printing can have an impact on the manufacturing process as a whole, whist further demonstrates the new business opportunities of the digital age: the collection of data. Ethical implications associated with this aspect are beyond the scope of this chapter yet are an interesting area of research for the future.

When asked whether participants would purchase 3D-printed items, the answer was surprisingly positive, as individuals could see themselves engaging with products that are described as "high-tech" and revolutionising in the industry. This links to an earlier point made, in that the way that 3D-printed garments are portrayed is vital. Retailers need to clearly communicate the positioning of their 3D-printed products; if seen to be high-tech and revolutionary, then consumers in this research seem to be more inclined to purchase them, whilst simply promoting them as customised items used in the haute couture scene seems to make them unattainable and not targeted towards them. A further interesting finding is that currently our participants feel that 3D-printed garments should be marketed as low-end fashion, whilst if there was a shift to broadcast the high-tech aspects, 3D-printed items could move into high-end and luxury markets. This demonstrates that participants were aware of neither the amount of energy 3D-printing needs nor the long production times or the design efforts currently going into the additive manufacturing process (e.g. Jacobson 2017; Chandavarkar 2018). This further highlights that retailers need to strengthen their communication strategies when it comes to promoting 3D-printing. This may also explain why only one-third of the participants indicated that they see 3D-printed garments as a type of luxury product.

The background information presented is essential when exploring purchase intentions of 3D-printed garments and accessories from the point of view of Chinese millennial consumers. The previous sections indicate that 3D-printed garments are currently seen as not matured enough to be classified as luxury—only 5 out of the 15 participants could see a resemblance with the luxury market. This has key implications for retailers in terms of price. Whilst some participants indicate that they would pay up to £500 for an item that was 3D-printed (e.g. luxury bag or jewellery) (P6), others do not want to invest more than £200 for a 3D-printed garment and between £30 and £40 for accessories (P2). Participant 3 highlights that "I do not think that 3D-printed products have an obvious advantage, I would pay the same price as I usually spend on other high-street brands, around £100." Participant 5 further emphasises:

> I think the price of 3D-printed products should be around £20 as these kind of products are relatively unknown by people. Retailers should lower their costs and produce them in huge quantities to generate awareness of the products and attract consumers' attention.

Interestingly, participant 15 points out that items that are produced using automated machine processes, such as additive manufacturing, should never be more expensive than those that are manmade, as costs, such as wages and people insurance (e.g. medical), do not have to be paid. He further highlights that there are no "obvious advantages of 3D-printed garments" and that one of the only reasons these items are currently high-priced "is the fact that the technology has not matured yet … but the technology will mature one day so the costs will be reduced dramatically then." On the other hand, it was pointed out that:

> How much I pay for products depends on the positioning of the product. If it has been positioned as a luxury 3D-printed product, made with really sophisticated techniques and fashionable design, I would probably spend hundreds or even thousands of pounds. If it has been labeled as a high-street brand, I would probably spend less than £100 on it. The point is not about the technology, it is about how designers use this technology. (P9)

Overall it becomes apparent that the willingness to pay for 3D-printed garments and accessories depends on the individual and how they perceive these items, and highlights the power of branding in determining price points for 3D-printed garments/accessories. From the interviews it becomes apparent that these consumers would like to see more inclusive designs, which implies being able to actually wear 3D-printed garments, rather than seeing kinematic dresses that are for the elite only (P2, 11). Our participants insisted that marketing communication is vital, as 3D-printed garments, at the moment, are seen more as a gimmick rather than a luxury item, as consumers are unable to identify any advantages that 3D-printed clothes have over "normal" garments. The only "benefits" that were identified are cost effectiveness in the manufacturing process (Huang et al. 2015); yet this is not translated to the end consumer as the production in itself is more expensive, as it can take up to 500 hours to print a dress (Jacobson 2017).

8.5 Conclusion and Future Research

Our research has highlighted that 3D-printed garments currently have a negative connotation, as consumers are unable to associate any benefit with this production technique. Yet, the use of technology within garment production is seen to be novel and of interest to these luxury millennial consumers. We found that the biggest challenge is marketing communication for 3D-printed garments. Only one out of 15 participants had the experience of actually purchasing a 3D-printed item, which highlights that the user experience is missing. Participants based their opinions on media articles and imagery, with the majority of news outlets currently highlighting that additive technologies are currently not mature enough to enter the mass market, yet have great potential in the future.

Future research could look into marketing communication strategies and how 3D-printed garments are advertised to consumers. In line with results reported by Perry (2018), it is suggested that further studies are necessary to explore consumer perceptions, which could also take a quantitative form to obtain generalisable results.

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9

Augmented Reality and Virtual Reality: New Drivers for Fashion Retail?

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9.1 Introduction

In today's global economy, advanced technology plays an important role in the fashion retail industry. With the development of advanced technologies, Augmented Reality (AR) (Azuma and Fernie 2003) and Virtual Reality (VR) (Dörner et al. 2014) have emerged as key interactive technologies, which are increasingly being utilised in the fashion retail setting (Javornik 2016a; McCormick et al. 2014). This chapter focuses on both AR and VR, two different types of technology that have gained increased interest and attention in both academia and the fashion industry over the past few years (Mann et al. 2015; Javornik 2016a; Poushneh and Vasquez-Parraga 2017).

AR and VR are part of what is termed 'consumer-facing' technology; this implies that they are technologies and/or devices that a consumer

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interacts with and directly experiences whilst being either in the physical store or browsing the online store. Examples of AR are magic mirrors or smart mirrors, and filters that can be imposed on a setting or person via a mobile app. A key commonality of AR technologies is that computer-generated content is superimposed on the real world, thereby providing a composite view (Gibbs 2017; Reality 2018). To illustrate this further, Snapchat celebrated the introduction of the Karl Lagerfeld × Kaia capsule collection (Newbold 2018) by allowing its users to superimpose Karl Lagerfeld's and Kaia's avatars onto a real-world background.

A variety of companies, from high street to high end, choose Snapchat as a unique strategic tool that appeals to predominantly millennials and younger generations by targeting them through Snap Ads, sponsored geo-filters, which are location specific, or sponsored lenses, which are "interactive augmented tool(s) that Snapchat users can play with in real time" (Isaac 2016). Similarly, River Island, a UK high street retailer, created various filters for London Fashion Week, whereby the logo was displayed at the bottom of the picture frame and was accompanied by slogans such as 'But first, coffee', 'Work hard shop harder!' and 'Every week is fashion week' (Arthur 2017). It could be argued that this type of geofilter promotes the brand and raises awareness, yet may only target a specific demographic that is interested in the brand. Alternatively, AR is also being used in stores as in April 2018 Zara used the technology in their window displays and designated places within a store to show a virtual catwalk with models wearing selected items (Mintel 2018). In comparison, VR differs quite dramatically from AR technologies in that it is a three-dimensional immersive illusion, which is entirely computer generated and can be explored and interacted with by an individual through the use of specialist headsets (VRS 2017; Rubin 2018). The American department store Macy's was one of the first stores that managed to create a fully functioning VR retail environment, allowing its consumers to virtually walk through the store, and gain product information and the option to purchase items by simply gazing at them (Alibaba Group 2016). As such, they allowed their consumers to shop 'in-store' from anywhere in the world, as long as they had a VR headset and were able to access the technology and software. What currently is unclear, however, is whether consumers accept these new technologies and whether or not they are the future of the fashion retail experience or whether they are just an expensive fad.

9.2 Consumer Acceptance of Technologies

Technology has had a significant impact on our daily lives, not only in the way that we communicate but also in the way that we interact and shop, as technological innovations, including AR and VR, have the ability to change traditional shopping patterns and customers' attitudes towards purchasing fashion outfits (Carmigniani and Furht 2011; Landa 2015; Moorhouse et al. 2018). These technological advancements have led to increased consumer power and control when shopping (Piotrowicz and Cuthbertson 2014). Statista (2017) reveals that millennials in Europe spend on an average 180 minutes per day on social media sites. As such, it may not come as a surprise that online fashion sales have doubled in value since 2012, with online sales accounting for 24% in 2017 and thus increasing by 7% since 2013 (Mintel 2017). Mintel (2017) predicts that the online fashion market will "continue to see strong double-digit growth, with the market forecast to increase a further 79% by 2022, reaching just under £29 billion". This is further reflected in the recent news that major high street chains, including New Look, Debenhams and House of Fraser, have announced drops in sales, whilst pureplay-only retailers, such as Boohoo and ASOS, have seen "an impressive 53% increase in the three months to 31st May" (Insider UK 2018; Clark 2018). Footfall to retail stores is also declining year-on-year. For example, in March 2018, the UK experienced an 8.6% decline in footfall, and the number of shoppers in London decreased by 7.5% year-on-year (Hardy 2018). As a result, retailers are now turning to technology in the hope of providing a more exciting and innovative experience to increase customers back into stores. In particular, AR and VR have garnered a significant amount of attention from retailers (Moorhouse et al. 2017), and they are anticipated to be adopted increasingly across various industries, including the fashion industry, due to their promised ability of creating unique shopping experiences (BOF and McKinsey and Company 2017; Grewal et al. 2017). Indeed, Jiang (2017) argues that consumers' adoption of these advanced technologies will drive the most opportunities for fashion retailers over the next decade, and so research needs to explore whether consumers will be willing to adopt them or not.

However, with technology developing rapidly, aspects that are considered novel ‘gimmicks’ can become essential ‘must haves’, as consumers become accustomed to interacting with and seeing technological enhancements and thus leaving their favourite brands with no choice but to implement them in order to keep up. This implies that retailers have to invest more in technology if they seek to enhance their sales in the future, with AR and VR emerging as increasingly viable and essential options (Mintel 2017; Bonetti et al. 2018). It is essential that brands and retailers move with the times as consumers are now no longer brand loyal (Llopis 2014) but rather change their brand preferences in accordance with their current needs. In order to entice consumers to stay loyal, Pachoulakis and Kapetanakis (2012) suggest that the introduction of technological innovations, such as AR and VR, can create a strong bond between customers and brands, as the gamification of products and brands fosters excitement and a thrill for exploring the unexpected. As such, a question that arises is why are all retailers not investing in new technologies that could potentially lead to increased customer satisfaction and loyalty.

From a theoretical perspective, the attitude-acceptance gap of technological innovations is a longstanding research theme, with the technology acceptance model (TAM) being one of the first models to address this (Davis et al. 1989). TAM provides an insight into why consumers may accept or reject the use of a certain technology and thus provides fashion retailers with a better understanding of whether they should invest in technologies such as AR and VR. TAM focuses on two key aspects, namely *perceived usefulness* and *perceived ease of use*, for determining an individual’s *intention to use* new technological innovations. Thus, according to TAM, *intention to use* acts as a mediator for consumers’ engagement with new technologies (Davis et al. 1989; Nysveen et al. 2005).

Perceived usefulness can be defined as “the prospective user’s subjective probability that using a specific application system will increase his or her job performance within an organisational context” (Davis et al. 1989, p. 985). In this case, consumers evaluate the *perceived usefulness* of, for example, AR filters superimposed on a real-life setting or a VR-created environment. For example, Specsavers have implemented an AR feature on their website and mobile app to help people select the right pair of glasses. The technology enabled consumers to virtually try on glasses, superimposing the frames on their face. It could be argued this feature was useful for consumers when buying glasses online as it provided them with more of an idea of what the glasses would look like on them, thereby mitigating one of the biggest drawbacks of online shopping (Jai et al. 2014).

On the other hand, Macy's VR shopping experience may be beneficial for customers who want to shop at the store but are unable to visit the physical premises in New York. A key drawback, however, could be the fact that anyone wanting to experience the virtual Macy's store needs to be in the possession of VR glasses and linked up to the specifically designed computer programme, which could be technologically challenging. This links to the second part considered by TAM: the *ease of use* of these technologies (Arthur 2017). The perceived ease of use refers to "the degree to which a person believes that using a particular system would be free of effort" (Davis et al. 1989, p. 320). In order to create a bond with customers through technologies, these new technologies need to be readily available and user friendly. With technology and the shopping experience becoming increasingly common and intertwined, AR and VR technologies have the ability to significantly influence the decision-making process, but in order to do so, they must be easy to use.

TAM has previously been used for research purposes within an online (fashion) retail context to better understand the consumer acceptance of virtualisation technologies (Kim and Forsythe 2007, 2009) and the social aspects of online shopping (Shen 2012; Kumar et al. 2015). Yet, although TAM is widely cited, it has been criticised for being too simplistic as it solely focuses on utilitarian values (task-related values), and as such, it has been developed further with new dimensions added (e.g. Venkatesh and Davis 2000; Venkatesh and Bala 2008; King and He 2006; Schepers and Wetzels 2007). A further criticism is the fact that TAM is predominantly linked to the use of technology in organisations, rather than consumer's every day usage. Nevertheless, TAM and its two key components, *perceived usefulness* and *ease of use*, will be used to analyse the barriers and opportunities of AR and VR for the fashion industry.

9.3 Opportunities and Barriers of Innovative Technologies

As previously alluded to, AR and VR are relatively new technologies and, as of yet, their full potential may not have been reached within the fashion retail sector. The following section will discuss the current uses of AR and VR and the subsequent opportunities and barriers that retailers face in adopting them through the provision of examples.

9.3.1 Augmented Reality (AR): Case Examples

Augmented Reality (AR) refers to an interactive technology that integrates physical environments with virtual elements including information or images (Javornik 2016b). This advanced technology, which can be employed on multiple devices such as interactive screens and smart phones, has been increasingly adopted in the retail sector both publicly and privately (Javornik 2014). Prominent examples of AR applications are 'magic mirrors', also known as 'virtual mirrors' or 'smart mirrors' (Javornik 2016c). The so-called magic mirrors have become increasingly popular since 2010 (Poulter 2010), particularly in stores, whereby they utilise AR technology to enable consumers to superimpose garments onto themselves (Yuen et al. 2011; Kipper and Rampolla 2012). The magic mirror is life sized and overlays the shoppers' image with pictures of their selected clothes through touch-based interfaces or gestures (Kim et al. 2017). This facilitates consumers being able to virtually try on clothing without actually having to take off any of their garments, as well as change the colours and sizes of garments (Hwangbo et al. 2017). Magic mirrors could be seen as enhancing the customer experience, as it reduces waiting times for fitting rooms and could potentially increase customer satisfaction, reducing stress, particularly for young families, as children can be impatient when having to wait for family members to try on garments (Telegraph 2018). Moreover, the technology is designed to be easily accessible and thus can be used by anyone. Yet, due to the high cost of these magic mirrors, it may not always be feasible for retailers to (1) acquire this technology and (2) to install multiples of these mirrors in store (e.g. Carmigniani et al. 2011; Jiang 2017). Thus, it could be argued that the *perceived usefulness* may be evaluated as being low by consumers as the majority may not be able to try it, as queues can be long.

UNIQLO is a prime example of a high street retailer that invested in magic mirrors for their San Francisco flagship store when it opened in 2012 (Holition 2018). UNIQLO “created a seamless retail experience that allowed consumers to try on the full range of colours for a variety of UNIQLO Fall/Winter jackets” (Holition 2018). Additionally, Neiman Marcus installed what they called the ‘memory mirror’, which showed customers’ outfits in 360 degrees and what they would look like in different colours, also allowing customers to share images and videos through email, social media, or with sales staff for further recommendations (Marian 2015). With consumers, especially millennials and younger consumers who are characterised as generations that are technology savvy (Gardner and Eng 2005; Valentine and Powers 2013), it is vital to stimulate their interest and actively engage and capture their attention with new technologies. AR technologies, such as magic mirrors, create a connection with these younger generations that are often time pressured and live a busy lifestyle (Hill 2017; Holden 2018), as it allows them to make decisions faster, without having to queue and wait for changing rooms to become available and/or see how different colours of the same garment suit them. Consumers thus have the opportunity to select garments according to their needs and preferences and gain a real-life experience of what the product may look like on themselves (Cirulis et al. 2015; Pavlik 2015; Rauschnabel et al. 2016).

Amazon, a pureplay retailer, has recently been granted a patent for a smart mirror that has the potential to revolutionise the way consumers shop for clothes online (Hetherington 2018) and thus hone in on a current gap in the market of combining new innovative technologies with the economic potential of an ever-growing online fashion market segment (Statista 2017; Hetherington 2018). Yet, Ramanathan et al. (2014) state that AR technologies remain an expensive gimmick that may not be implemented on a mainstream basis for a long time. Although AR has gained increased attention, and consumers and retailers alike have shown an interest in its uptake, the technology, especially in terms of smart mirrors, is not yet fully matured. The majority of visualisations shown on magic mirrors superimpose garments in a very artificial manner that still do not give the feel of wearing a real garment. At times, images look like paper cutouts that are put on individuals and, thus, they are not providing a real representation of the actual garment (Poulter 2010). Yet, the global smart mirror market is predicted to increase from 10% in 2018 to 15% in 2023, thereby hitting a total value of $1.2bn boosted by the retail industry (Daniel 2018). A reason for this relatively low yet significant growth rate is the cost of creating these mirrors and the relative low consumer awareness and uptake (Daniel 2018).

Whilst AR technologies can be perceived as *useful* and may potentially be *easy to use*, such as the Snapchat filters, which superimpose images by simply swiping to the left, the *intention to use* these AR technologies may be limited due to availability in physical stores and online, or simply may not be of interest to consumers, as they may target a specific segment. Yet, it can also be risky to not be part of an avant-guard movement, as consumers can switch brands at any time.

9.3.2 Virtual Reality (VR): Case Examples

In contrast to AR, the environment created by VR does not occur within physical surroundings and is separated from the real-life environment via a screen or a head-mounted display (Javornik 2016c). Recently, this technology has been employed by fashion retailers to offer memorable and innovative experiences for customers (Moorhouse et al. 2017) primarily for entertainment purposes. For example, the fashion retailer Tommy Hilfiger was among the first to provide VR headsets in stores, enabling their consumers to enjoy their 2015 autumn/winter fashion show as a 360-degree experience (Jiang 2017). Since then various other retailers have followed their example and provided these immersive experiences to their consumers (Jiang 2017). In 2017, Coach installed VR headsets in their stores to provide full access to their latest fashion show (Jiang 2017) and Oasis also used VR headsets to promote their collaboration with the Zoological Society in London, whereby consumers could experience a virtual safari sitting in a jeep (Geoghegan 2017). This 'fun' element of VR was also capitalised on by Topshop who installed a VR waterslide in their flagship store in London in 2017 as a part of their summer campaign (Dickinson 2017). Brands capitalising on VR fashion shows could potentially create a bond with their customers, as they provide them with an opportunity to enjoy an event that they (their consumers) may otherwise not have access to, as fashion shows are primarily 'invitation only'. Similarly, brands using VR to create an entertaining experience could provide consumers with another reason to visit the store more and stay there longer. Yet, a key question that emerges is whether "virtual reality is just an over-priced gimmick, nothing more" (Kain 2016). The statement could be supported, as similar to AR, VR technologies are expensive and thus may not be a viable option for every retailer (Carmigniani et al. 2011; Jiang 2017; Moorhouse et al. 2018). Moorhouse et al. (2018) further indicate that a key drawback of VR is related to health implications, as the closeness of the headsets can cause strains on the eyes and also lead to motion sickness, which can cause dizziness, distortion, and eye fatigue (Berryman 2012).

A further limitation of VR is the fact that it can be classified as being inflexible in that the headsets need to be connected to computers to allow the consumer to experience the virtual reality (Bastug et al. 2017). Yet, this can also be seen as an opportunity, especially if companies make their experience available at home. As aforementioned, gamification is a thrilling element that attracts consumers and can provide close relationships between retailers and customers (Pachoulakis and Kapetanakis 2012). Computer games such as Second Life provide players with an opportunity to create avatars that can be based on the player's own body shape and enable them to select garments from fashion brands (VRS 2017). As such, consumers may be inspired to purchase similar garments to their avatars, as they like the way their avatar looks (Lau et al. 2013; Andone and Frydenberg 2017). Hye et al. (2015) further insist that these gamifications provide an opportunity for customers to select clothes that fit their body-shapes, as avatars can be created in accordance with their body measurements. As such, VR can be seen as valuable tool for fashion retailers to stimulate sales (Carvalho and Santos 2015). Yet fashion retailers need to be careful to not overuse innovative technologies, especially since news outlets have reported "fears grow for children addicted to online games" (Walker 2016), which is further supported by research conducted by Jung and Dieck (2017). A further risk associated with any technologies is increased 'anti-social' behaviour, in this case referring to the lack of contact with others in a real-life social environment, thus reducing the ability to socialise with other people (Carmigniani et al. 2011; Eakin et al. 2015).

Similarly, as with any type of technology, VR and AR face challenges in terms of online security and data breaches. Authors such as Hwang et al. (2012), Bastug et al. (2017), and Bonetti et al. (2018) insist that personal data storage is currently not fully secured and thus, can be accessed relatively easily. This is an issue that will need to be addressed as soon as possible, as countries are increasingly cautious of privacy issues and GDPR regulations (EUGDPR 2018).

Thus, it can be argued that currently the *perceived usefulness* of VR technologies is limited in that it is predominantly location bound and requires not only technology support (e.g. in the form of computers, VR headsets and the actual programme to run the immersive illusion), but also may not necessarily be an option for everyone, as the close proximity of these headsets can cause motion sickness. Whilst the 3D-experience may be simple to use, it is questionable whether customers will show any *intention to use* these technologies on a regular basis, as any health concerns could be cut out by simply shopping online or going to a store.

9.4 Concluding Remarks

As indicated, our world is changing and technology is playing a vital role in facilitating these changes. Consumers are now more technology savvy than ever and are constantly demanding new innovations to keep them engaged and entertained. One way of measuring the success of, in this case, AR and VR technology implementations is based on their *perceived usefulness* and *ease of use,* which are mediated by the *intention to use* these technologies (Davis et al. 1989). Ishaq (2012) insists that perceived value, which is based on perceived usefulness and ease of use, can influence customer purchase intentions; thus, if retailers manage to create an engaging customer experience with AR and VR technologies, then this could potentially lead to an increase in sales.

Currently there is still limited research looking at AR/VR specifically in the fashion retail context and its impact on the industry as a whole, yet there is plenty of scope for potential uses of them there. As online sales have increased, VR and AR could provide an opportunity to revive the high street by providing exciting, entertaining and useful experiences for consumers. Furthermore, AR in particular could help facilitate a better omnichannel experience for customers by bridging the gap between channels and limiting their drawbacks, such as in Specsaver's glasses try-on mobile app and website feature. Future research could therefore investigate what opportunities and barriers there are for implementing AR and VR technologies, from both a retailer and consumer perspective, as well as measuring the direct benefits that either AR or VR could provide for a retailer. Finally, research could investigate whether particular consumer segments, demographics, genders or cultures would be more receptive to these innovative technologies than others and how it contributes to an omnichannel shopping experience.

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10

Three-Dimensional Body Scanning in Sustainable Product Development: An Exploration of the Use of Body Scanning in the Production and Consumption of Female Apparel

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10.1 Introduction

Poor fitting of apparel, particularly in womenswear, causes waste, inefficiency and high carbon emissions for several reasons. First, ill-fitting garments will lie unsold and contribute further to the problem of wastage and carbon emissions due to disposal in the clothing global supply chain (Gribbins 2014; Mintel 2018). When consumers are purchasing garments

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online, they resort to buying multiple sizes in order to increase the chances of finding a proper fit. Online sales of garments are still increasing relative to in-store sales (ONS 2017). Retailers therefore increasingly have stock taken out of the system as customers order several sizes, resulting in inefficiencies. The carbon emissions associated with transporting returned and reordered garments are also likely to be growing, not to mention the overheads and staff costs needed to process the movement of stock (Choi and Guo 2018). Against this background, the appeal of a technological solution which can solve clothing fit problems and thus help drive a more sustainable, cleaner production in the construction and distribution of garments is enormously strong.

Three-dimensional (3D) body scanning appears to offer a superior and reproducible method of measuring the human form that overcomes the limitations of traditional manual methods. Theoretically, mass customisation could be achieved by using 3D body scanners to capture the true size of retailers' target populations and, through integration with existing computer-aided manufacture technology, efficiently produce well-fitting garments suitable for the mass market.

Despite this potential and the availability of 3D body scanning over the past three decades, this integration has not been achieved. This apparent failure is due to the incompatibility of body scan data with existing apparel procedures and technology (Bougourd et al. 2000; Pandarum et al. 2011), accuracy in body data capture (Han and Nam 2011) and the potential financial implications associated with supply chain transformation (Choi and Guo 2018). These limitations have prevented developments, and minimal progress has been made.

To understand the reasons behind this situation and identify potential areas for improvement, we first define and explain 3D body scanning. We then evaluate international sizing studies and the application of these data in clothing garments. Following this, we review its use in the garment construction and the role of female body shape in clothing fit. We examine the technical issues of measurement inconsistencies with production processes and accuracy and the ways in which body shapes can be derived from data points. We finally consider the technology in the context of the consumers and their clothing purchase preferences. We conclude that 3D body scanning does not presently meet the promise of a technological fix to improve the sustainability of the industry. Finally, we propose areas for future research which can take the area forward in theory and practice.

10.2 Three-Dimensional Body Scanners Explained

Digitisation of the human body evolved from the motion media industry where virtual characters were adopted to replace actors in complex productions (e.g. *Terminator 2*) (D'Apuzzo 2009). The outline of the human body could simulate individuals when transformed into an avatar, and due to their accuracy, they are later used for human measurement. These applications predominantly explored the field of ergonomics (using measurement in workspace design) and anthropometrics (human measurement) (D'Apuzzo 2009; Gill 2018). The first full-body scanner was developed by the University of Loughborough in 1989 and adopted by the military for ergonomic then anthropometric purposes for uniform fit in the late 1990s (D'Apuzzo 2009). These applications marked the beginning of introducing human full-body scanning for garment applications. Body scanners did not reach commercialisation until 1998 when a US company, TC2, introduced the first 3D body scanner for the fashion industry (D'Apuzzo 2009; TC2 2018).

Three-dimensional body scanners act like a virtual tape measure and therefore have the capability to replace the function of manual measurements that garments are designed from. The scanner resembles a roomy photo booth that maps the shape of the surface geometry of the body in a matter of seconds. An image of the body scanner can be seen in Fig. 10.1. Scanners adopt either laser, white light or, more recently, infra-red depth sensors to distribute a projection pattern over the human form that captures the height, breadth and depth of the human body (TC2 2018; Size Stream 2018). From this, the scanner produces a '3D point cloud' of thousands of data points in less than nine seconds. This is presented in Fig. 10.2a. The data points are then rendered, and the body landmarks, namely shoulders, chest, navel and hips, are identified using pre-programmed parameters of where they should occur on the body (TC2 2018; Size Stream 2018).

Fig. 10.1 Three-dimensional body scanner

Finally, a virtual tape measure extracts key measurements to calculate size and shape features. This is presented in Fig. 10.2b. These include circumferences, heights, lengths, volumes and surface areas guided by the landmarks identified (Apeagyei 2010; TC2 2018; Size Stream 2018). The measurement outcomes can then be used to develop sizing systems through an understanding of the size of the population based on analysis of the similarities in human measurement at core measurement locations (e.g. bust, waist and hips).

Three-dimensional (3D) body scanners therefore allow the rapid capture of multiple scans from a population, since a 3D body scan can be conducted in one second and processed in less than nine seconds (TC2 2018). This removes the need for time-consuming personal intrusion found in manual measurement techniques where body landmarks require feeling for specific bones to determine their location (Gill 2018). Three-dimensional body scan data can be stored for ongoing comparative analysis alongside other consumer data to segment the population into target customer groups for the fashion and other industries.

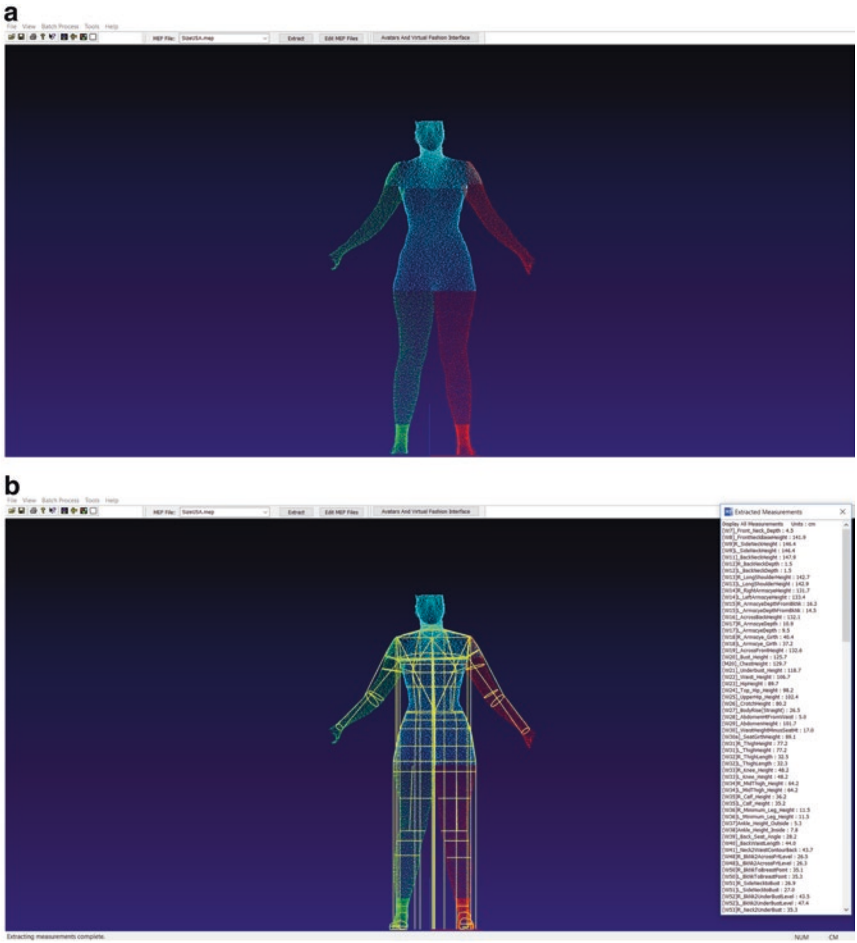

Fig. 10.2 Sample body scan. (**a**) Body model. (**b**) Body model with measurements extracted

Scanners require that the person is wearing only undergarments. However, the scan is taken in privacy, thus reducing the reluctance of participants to have body measurements taken (TC2 2018; Size Stream 2018). Overall, 3D body scanners allow efficient collection of much larger, replicable and more consistent data sets than a manual measurement collection.

It can also provide individual consumers with an objective image of their body shape which could then be used to guide garment type and size selection for online and in-store purchases.

10.3 Three-Dimensional Body Scanning Adoption

Since their introduction, 3D body scanners have been adopted by large retailers (e.g. Levi Strauss and Speedo), made-to-measure specialists (e.g. Brookes Brothers) and industry specialists in the production of fit mannequins (Alvanon 2018). This adoption complements the manual garment production process and does not replace it. Adoption within the entire commercial fashion production process has not yet been achieved at mass market level. Scanner adoption is explored predominantly within academic studies through consumer types (Park and Park 2013), measurement variance in the scanning process (Gill and Parker 2017) and its use as a method of defining body shape or types (Simmons et al. 2004; Park and Park 2013).

The focus on academic applications or informing the measurement process (e.g. sizing systems or overviews of target markets) prevails due to the variance between body scanning and manual measurement meaning garments produced may either be too large or small (Gill 2015, 2018).

To introduce the industry use of 3D body scanners requires adaptation within garment development, body shape determination and sizing system design, meaning a transformation of traditional manual practice to a digital garment production solution. However, the success of using body scanners within the production process remains unproven; it is therefore no surprise that retailers have not adopted this method.

We now evaluate the use of 3D body scanning in sizing survey measurement collection, body shape research and the translation of measurement and body shape into garment construction. Key issues which emerge are measurement errors, the different definitions of measurement locations and classifications and processing methods to produce body shape types.

10.4 Three-Dimensional Body Scanning and Sizing Surveys

Examples of the use of 3D body scanning in sizing surveys include a national sizing survey 'SizeUK' (2001/2002) and surveys conducted in the USA, China, Spain, Mexico, Thailand, France, Korea and Taiwan (Apeagyei 2010). Whether these findings were integrated into the design and development of fashion garments remains unknown.

Technology allows characterisation of 'the shape of the nation' using digital measurement and subsequently enhances accuracy in health applications (e.g. Body Mass Index calculations) and for apparel design (Apeagyei 2010). Measurements collected in UK studies for apparel allowed retailers to revise their sizing systems with a view of improving garment fit for the population.

The shape of the population is continuously evolving. To add value to apparel production, 3D body scanning or manual measurement is needed to regularly update retailers sizing systems and ensure garments produced fit the shape of the population. Retailers appear to employ adaptations of national sizing surveys and adopt women's (larger hip: 96 cm) rather than high-street (smaller hip: 94 cm) sizing strategies to gain a wider coverage of the population and increased profitability (Apeagyei 2010; Gribbins 2014). Size UK found the female waist was 16 cm larger than the previous sizing survey in the 1950s (Sizemic 2011). Since no national survey using this technique has been employed, it is no surprise dissatisfaction in apparel fit remains (Song and Ashdown 2013; Mintel 2018). The implication of ill-fitting products is responsible for the high consumption of low-cost items and 'throw away' culture that contributes to environmental decline (Gregson et al. 2002).

Three-dimensional body scanners therefore have the potential to contribute digital measurement solutions to better understand the size and shape of the population. To understand how this knowledge can be applied it is essential to explore the role of body scanning within garment design. The next section seeks to achieve this.

10.5 Body Scanning and Shape Within Garment Design

Garments cannot be produced to perfectly fit each person. Garment fit is a key determinant of purchase intent. Therefore, it is important to determine the most popular female shapes within target markets to ensure clothing fits most of this population, to reduce the volume of garments required within production (Chen 2007; Brownbridge et al. 2016).

Body shape forms the outline of clothing garments and determines how apparel needs to fit the physical body. Understanding human shape through measurement therefore should allow well-fitting products to be developed. Body shape measurement has progressed through a range of subjective techniques in the past six decades.

Conceptualisation began with somatometry where the differences of body features were described and categorised (see Sheldon et al. 1949). Visual somatometry, where angles of body curves (e.g. the waist) are determined by photographing participants against a grid were next explored over two decades (see Douty 1968; Farrell-Beck and Pouliot 1983; Heisey et al. 1986). Self-definition is performed using line drawings (see Pisut and Connell 2007) or the Body Shape Assessment Scale (BSAS) scale where shape is defined following the visual appraisal of body proportions using 3D body scans (Connell et al. 2003; Alexander et al. 2012).

Within these techniques where difference is determined by human perception of the physical form, limitations exist because the determination of shape is based upon personal impressions (the researcher or the participant) that vary on an individual basis (Grogan et al. 2013). This may be due to the notion of self-identity being based on a combination of 'self-verification' and 'self enhancement' (Kalkhoff et al. 2016, p. 15). These processes are also very time consuming meaning less of the population can be captured. Accuracy of retailers' understanding and application to clothing design are therefore limited.

Researchers next explored numerical techniques to provide a more efficient approach to capture a larger representation of consumers in a short period of time and in a consistent way. Largely, these techniques explore propositions similar to traditional techniques. For instance, body shape definition using angles (Petrova and Ashdown 2008; Lee and Imaoka 2010), mathematical calculations (Lee et al. 2007; Vuruskan and Bulgun 2011) and statistical analysis of relationships between components (Song and Ashdown 2010) have been explored. The addition of 3D scanning allows body shape to be measured more frequently and in a more cost-effective manner to provide greater representation of the breadth of the population.

Theoretically, this allows industry sizing strategies to remain up to date as body proportions (i.e. shape) form the foundation of apparel patterns that determine garment fit. This in turn should enhance consumer satisfaction (Gribbins 2014) through well-fitting garments and allow the move away from disposable consumption which Gregson et al. (2002) observed is prevalent amongst fashion consumers. Thus, higher investment in apparel production could prevent large volumes of ill-fitting apparel (Brownbridge et al. 2016). The breadth of differences in cultures, age groups and individual preferences creates further dimensions to the limitations in apparel fit, particularly as retailers operate on a global platform. The next section explores these variances in body types that contribute this complexity.

10.6 Body Shapes Across Global Markets

Body shape ensures the proportions between key dimensions (bust, waist and hips) of clothing are consistent with body proportions and to allow mass-produced garments to fit as wide a range of consumers as possible (Liechty et al. 2010). Body scanners can help achieve this by revealing the proportional balance of consumers within retailers' customer segment (Brownbridge et al. 2016).

Body shape and size vary by age, culture and geographic location. Some similarities do prevail within target markets. However, the distribution of shapes within these age groups is different based on geographical regions and lifestyle factors. Table 10.1 compares body shape results across different cultural groups.

Body scan data provide solutions to determine shapes that can be integrated into garment production (Lee et al. 2007; Park and Park 2013) or at the least garment distribution. Comprehending the shape of the population is imperative, as when garments fit despite the slight measurement variances between consumers, proportions do not matter. Understanding

Table 10.1 Comparison of selected methods

Female body shapes defined within the 18–35-year-old market				
Female body shapes	Lee et al. (2007) FFIT (USA)	Lee et al. (2007) FFIT (Korea)	Vuruskan and Bulgun (2011) (Turkey)	Lee and Imaoka (2010) (Japan)[a]
Hourglass	7%	0.5%	26%	Small bust: 85% Large bust: 6%
Spoon	7.9%	7.7%	23%	–
Bottom hourglass	6.3%	4.3%	42%	–
Top hourglass	1.3%	–	Shapes excluded during pilot stages	–
Inverted triangle	0.1%	–		–
Triangle	2.3%	11.4%		–
Rectangle	22.3%	26.7%	4%	Small bust: 10% Larger waist: 0
Oval	–	–	5%	–
No. of scans	2985	919	83	11,057[a]
Year of data collected	2003	2003	Not indicated	1992–1994

[a]Body shapes relate to target market, but sample size is overall

body shape is therefore a desirable solution for garment construction that body scanners can provide.

While a range of body shape methods prevail, and proportions can be integrated within the development of fashion garments, the applicability of measurements from 3D scan data directly into fashion garments presents errors where measurement inaccuracies occur.

10.7 Body Scanning Inconsistencies and Errors

The application of body scanning data still presents limitations for garment production due to differences in measurement techniques (body scanner and manual) and errors that can occur within the body scanning process. To address these limitations, academics have explored measurement consistency (Bougourd et al. 2000; Pandarum et al. 2011), body capture difficulties and landmark identification (Han and Nam 2011). To allow the 3D body scanner to be integrated into retailers' existing supply chains and achieve a more sustainable solution, these inconsistencies must be addressed.

Body scan capture can be problematic, which Apeagyei (2010) and Han and Nam (2011) explore in their research. Body landmarks are identified through the separation of the body at key points and parameters which can be problematic. For instance, the crotch is determined by where the two legs meet the torso. In cases where the meeting point of the thighs is can be mistakenly identified as the crotch, missing data results. The presence of hair at the back of the neck prevents the identification of the 7th cervical vertebra at the back of the head, which is needed to calculate heights in the body that determine other measurement locations (e.g. armpits). The armpits and crotch region landmarks can be distorted by improper limb placement (e.g. non-muscular arms), shading or reflection on the body or small underwear that does not define the difference between the legs and torso regions. Han and Nam (2011) indicated that misplacements of 0.3 mm to 37.7 mm predominantly occurred at the crotch, armpit, neck (front, side and back) and shoulder regions. This level of inaccuracy, predominantly at the shoulder, is equivalent to the size of garment for fashion retailers. This means different locations on the body could be measured and as the parameters are interrelated the error results in further compounding measurement inaccuracies.

To address these limitations Ashdown and Na (2008) and Gill et al. (2014) presented the correct location of some landmarks for clothing production. An extensive scan cleaning procedure is therefore needed to ensure consistency within correction of these landmarks to ensure accuracy.

Measurement locations used by retailers is another issue as differences in pattern construction method exist within garment producers throughout fashion supply chains (Gill and Chadwick 2009). These include the placement of key measurements which can alter body shape calculations and comparability with the consumers' measurement across retailers. Gill et al. (2014) and Gill and Parker (2017) explore the measurement differences between waist location and hip measurements across a range of placements on the body. Their findings further demonstrate that the location of the body measurement or positioning of the body during the scanning process can create different measurement results.

Similarly, Pandarum et al. (2011) captured breast measurements using manual and scan techniques. Their findings suggested the body scanner presented a measurement 11% smaller than manual techniques between the bust and under bust locations. Coltman et al. (2017) established that scans of women with large descending breasts taken in the standing position underestimate the breast volume by 7%–10%. These findings collectively illustrate the complexity of the body and need for a process of standardisation for the use of body scanners within garment production or the integration of new techniques that address body scanner limitations. Gill et al. (2017) support this through their indication that not all body scanning measurements are valid for traditional garment development methods. Change in design and product development practice in industry is therefore needed for all 3D body scanners to be adopted in the fashion apparel supply chain.

The discussion so far reviews only the use of body scanning within physical representations of the body. In clothing purchase contexts psychological comfort also influences consumers' personal satisfaction with any product. If 3D body scanning is to be successful, not only physical measurement must be considered. The next section explores how consumers' psychological comfort in relation to body satisfaction with clothing requires review.

10.8 Consumer Satisfaction with Clothing Size

Clothing comfort relates to the consumers' psychological satisfaction with how the body looks in a garment and physical comfort of the product on the body. Chattaraman and Rudd (2006) explored both physical and socio-psychological dimensions of the clothing comfort model to identify whether a relationship was evident between body image, body satisfaction, body size (measurement) and garment styling features. All these factors combine to determine the suitability of the garment for the consumer. The authors designed a scale for customers to tell the researcher their preferred relationship between the garment and the body. This related to length, closeness of fit and style details for a specific wearing occasion (Chattaraman and Rudd 2006).

The relationship between these preferences was then compared with body image (using the body image avoidance scale), body satisfaction (adapted body cathexis scale) and body size (Chattaraman and Rudd 2006). Consumers with lower personal body image and body satisfaction ratings preferred clothing that covered more of their body (Chattaraman and Rudd 2006). Both body image and satisfaction are therefore interrelated and determine garment product selection. These findings are supported by similar studies by Kim and Damhorst (2010), Shin and Baytar (2014), Sidberry (2011) and Pisut and Connell (2007). Sidberry (2011) further indicated that satisfaction varied by body shape, reiterating the importance of understanding physical proportions alongside psychological preferences.

Clothing garments are used as a tool for correcting or moderating the visual appearance of the individual. The core goal is to achieve vertical balance and the dimensions representative of an hourglass figure that conceal personal discrepancies (Abraham-murali and Littrell 1995a, b; Fan et al. 2004; Sidberry 2011). Females compare their body to that of idealistic models online (Alessandro and Chitty 2011; Diedrichs and Lee 2011; Onge et al. 2016), resulting in lower body satisfaction (Shin and Baytar 2014; Yu and Damhorst 2015). Whether these preferences are more important than accuracy in physical measurement remains unclear and provide avenues for future research. Clothing selection is therefore greatly more complex than physical fit alone. Size coding plays an important role in this self-perception. The next section explores these challenges.

10.9 Clothing Fit and Size Coding

Retailers' garment fit, and size coding strategies create further dimensions to the interpretation of garment measurements. In an ideal situation, 3D scanner measurements could determine the right size of garment and allow consumers to select their size remotely from a retailer. Due to the variances within the current compatibility of manual and body scan measurements and differences in sizing strategies provided by retailers, this cannot yet be achieved.

Sizing coding combines physical fit challenges, psychological preferences and self-perception of the consumer. Size coding in retailers' clothing garments exists to communicate to the consumer the dimensions of the garment and to allow them to select clothing that fits their body type (Ashdown 2007). British standards (BSI 1982, 2005), International Standards (ISO 2018) and other authors have proposed European Sizing Standards using body measurements (Faust and Carrier 2009) attempting to standardise production. However, if these were implemented, only a very small proportion of the population would be catered to.

Retailers' garment fit strategy is defined within size categories. Size coding in the clothing market therefore exists as retailers each have individual sizing systems that cater to their target consumer as part of their competitive strategy (Ashdown 2007; Aldrich 2015). The media define this as 'vanity sizing' rather than an attempt to meet their customers' needs, as they do with other product features (e.g. colour). Differences in fabric properties, production methods, body shape of different cultures and style create further inconsistencies that lead to consumer confusion (Shaw 2006; Gill and Chadwick 2009; Reid et al. 2016). Using 3D body scanning or manual measurement of the consumer therefore cannot define garment suitability, as the fit preferences that brands attempt to integrate are not a simple calculation. Communicating and achieving the right fit is therefore as much subjective as it is scientific (Wang 2014). This explains where variation evolves from and why measurement alone cannot determine a garment's suitability for the consumer.

The focus of sizing research relates to building sizing systems (Ashdown 2007) for garment construction (Schofield and LaBat 2005; Gill and Chadwick 2009), body measurement procedures (Bye et al. 2006), technology in body measurement (Apeagyei 2010), garment fit (Rasband and Liechty 2006), size communication (BSI 2005; Faust and Carrier 2009), or sizing and fit selection satisfaction in children's clothing (Otieno 2000). It is evident the dominance of sizing research relates to industry applications and not to exploring of the preference or psychological determinants of clothing purchase combined with physical measurement. For 3D body scanning to present a superior solution achievement of this is essential.

10.10 Conclusion

The chapter critiques the current use of 3D body scanning in apparel production and highlights existing challenges of adopting 3D body scanning in ways that can meet consumer needs and progress towards a sustainable mass customisation model. The incompatibility of 3D body scan measurements with existing garment production methods means without a change in apparel practice, further integration of the technology cannot be achieved within a garment construction context.

Sizing surveys have been used to inform the measurement practice in the pattern construction phase of garment production from a holistic population perspective within target markets. At present, 3D body scanning contributes measurement data to garment production. To progress towards a more efficient and sustainable solution for garment manufacture, body scanners need to form the foundation of the production process and traditional methods of garment construction need to be revised into a digital production solution.

Measurement inconsistencies, however, create further limitations as the quality of records and data of the 3D body scanner can affect the accuracy of the measurement output. Consistency within practice and scan cleaning is therefore essential for body scanning to be considered a feasible alternative.

Body scanning can provide a clearer understanding of the female body shape and differences within the global population. Psychological fit preferences, size code perceptions and physical body shape measurement must be combined to ensure provision of well-fitting garments at the individual level. Three-dimensional body scanners can therefore act as an initial stage of garment size determination and need to be complemented by the development of fit preference technology to enhance the application of this technology in apparel production. This may evidently provide the missing links within current production models.

To overcome the limitations of body scanning technology and progress towards a more sustainable business model, the following areas for future research need to be addressed:

1. Development of a method of determining scan data integrity in large samples to ensure the correct placement of landmarks that inform measurement extraction of core body dimensions.
2. Integrate consumers' ideal shape and fit preferences within body shape and measurement data to understand the role garments play within the consumers' lifestyles to better cater to their needs and wants.

Only when these limitations are addressed will 3D body scanning be able to add value to sustainable practices and provide retailers with enough information to develop well-fitting apparel. Furthermore, this could allow the focus on quality over quantity and support the introduction of a slow fashion approach that will enhance sustainability of the fashion industry.

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11

Does Technology Affect Customer-Brand Relationships? A Study of Premium Fashion Consumers

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11.1 Introduction

Advanced technologies have seen an increase in physical retail stores in recent years as a means to integrate different sales and marketing channels and deliver a superior shopping experience to customers (Reinartz et al. 2011; Blázquez 2014). As consumers become increasingly connected and empowered through technology, they demand new innovations that have the potential to create more experiential retail spaces which, in turn, satisfy consumers' hedonic and utilitarian needs (Blázquez 2014). As such, the fashion retail landscape is changing dramatically (KPMG 2018).

Through the quality of interactions and (ideally) long-term relationships established with customers, brands create their competitive advantage (Rayport and Jaworski 2004), which are dependent on factors such as brand experiences, brand satisfaction and brand trust (Horppu et al. 2008;

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Şahin et al. 2011). Both brand experience and trust can foster an increase in sales and a competitive advantage (Ha and Perks 2005), as both can create customer loyalty, an emotional connection to the brand, which will develop a stronger customer-brand relationship (Ha and Perks 2005; Şahin et al. 2011). This is vital in an increasingly volatile environment, such as the fashion industry, in which premium consumers have various options to choose from. As such, brand loyalty can further be linked to economic sustainability; customers can seemingly make or break a brand.

From a retail perspective, it is challenging for brands to understand customer expectations and provide them with relevant and real-time experiences. Research (Blázquez 2014; Giordano and Zollino 2016; KPMG 2018) highlights that the physical store remains key for customers in terms of their shopping habits, which reiterates the importance of introducing technology into these physical stores in order to deliver a superior experience. As such, successful retailers utilise innovative technology in a way that improves the shopping experience by engaging with dynamically changing customer behaviour (Molenaar 2013). Each stage of the consumer decision-making process provides different touchpoints, which are vital in order to understand what information consumers need and what type of experiences they are expecting (Schmidt 2010). For retailers a major challenge lies in identifying truly transformative technology that can create a superior shopping experience instead of simply providing add-on strategies that may not have an impact on consumers.

This research investigates the role in-store technologies have in fashion retail and analyses the ways in which premium fashion brands can enhance customer-brand relationship through technology adoption.

11.2 Literature Review

11.2.1 In-Store Technology

Fashion retailing has significantly changed due to the introduction of new technologies and cross-channel touchpoints in stores (Pantano and Timmermans 2014), such as digital mirrors, digital signage, augmented reality (AR) (Piotrowicz and Cuthbertson 2013), smart shelves

(MailOnline 2017), virtual reality (VR) (Drapers 2017), mobile innovations (Vecchi et al. 2010), mobile applications (Vecchi and Brennan 2009) and Wifi access (Dennis et al. 2012; Pantano and Laria 2012).

The introduction of new technologies in the physical space responds to both retailers' expectations and consumers' preferences (Renko and Druzijanic 2014). Meuter et al. (2000) highlight that new technologies can positively influence consumer experience and lead to high levels of satisfaction if technologies save time, are easy to use, are related to a significant need and offer more control over the shopping experience. As such, they can support decision-making linked to utilitarian needs. Yet, it is also vital to focus on hedonic aspects that can be satisfied by the adoption of in-store technologies (Childers et al. 2001; Blazquez and Puelles 2014). The presence of advanced technologies is key in terms of experiential retailing as these technologies can enhance the expected hedonic experience and provide improved services for customers (Rigby 2011; Pantano and Timmermans 2014; Kent et al. 2015, 2017). The various applications of innovative technologies in retailing has proved to be beneficial to both retailers and consumers as they can enrich customers' behaviour in-store and decision-making process along with enhancing the space for the exchange of information (Kent et al. 2015, 2017). Technologies can act as bonding touchpoints that enhance the customer-retailer relationship (Pantano and Migliarese 2014; Pantano and Timmermans 2014).

Technological innovations can be classified under three key areas: retail-customer management, supply chain management and customer satisfaction (Dunne et al. 2002). This research is focused on retailer-customer interface in-store technologies, which are a part of front-end interactions between retailers and customers and are aimed to enhance the customers' shopping journey within stores. The most relevant technologies introduced into the premium physical fashion stores can be categorised in Table 11.1.

11.2.2 Customer-Brand Relationship

Interactive technologies highlighted in Table 11.1 affect the dynamics of retailer-customer relationships, which in turn affects the relational capabilities of a retailer (Comer et al. 1998). Relationship marketing becomes key for

Table 11.1 In-store technologies in premium fashion retailers (authors' own)

In-store technology	Description
Digital fitting rooms	– Detect garments through RFID technology– Provide recommendations to match with the garments– Offer the option to order different sizes and colours clothing (Drapers 2017).
Magic/smart mirrors	– Virtual fitting technologies that allow trying different garments without the need to physically try them (Holition 2017)
Digital signage	– Devices that communicate with customers during their shopping process and make it more entertaining (Dennis et al. 2012; Alexander and Alvarado 2014).– Technologies that keep the customers informed about new products in-store (Pantano and Pietro 2012)
Beacon technology	– Send alerts when someone approaches or leaves a location– Can detect customers at any given point and send promotional messages and other useful information– Customer can get personalised offers and even speed up the checkout process (Forbes 2015)
Smart shelves	– Provide in-depth analytics about the consumer behaviour.– Show digitised price tags and detailed information about the products when the product is picked up; allow providing customised offers (MailOnline 2017)
Interactive store windows	– Self-service systems based on projection mapping and gesture control– Help to engage people with a brand and its products on a 24/7 basis– Physical products are augmented with contextual digital content to improve the consumer experience (Zagel et al. 2016)
Window shops	– Temporal digital installations on the front window area of stores– People can browse products and place orders on the spot through touch screens– These window shops have a motion sensing technology to change the displays showing dynamic content to passers-by (Tomar and Saha 2016)
Virtual reality (VR) headsets	– Provide access to an entirely digitally immersive world through virtual reality headsets and hand controllers (Euromonitor 2017).
Augmented reality (AR)	– Allows the user to transform the real world by adding a digital component of touch and feel information in the physical world creating an exciting in-store experience (Pantano and Servidio 2012; Alexander and Alvarado 2014).

retail brands in order to meet customers' expectations (Şahin et al. 2011) and to make their brand appealing to their target audience (Ailawadi and Keller 2004). Customer-brand relationships are defined as the psychological bond that is formed by the customers with the brand (Fournier 1998). In order to develop a strong bond retailers need to increase brand loyalty through the development of brand trust and brand satisfaction (Şahin et al. 2011).

The concept of satisfaction comes from the judgement that determines if a product or service has provided a pleasurable level of consumption and has met customers' expectations (Oliver 1997). According to that, this research will look at satisfaction as meeting customers' expectations through the use of in-store technologies (Bridson et al. 2008) considering that functionality and emotional content improves customers' relationship with the brand (Liljander and Strandvik 1997; Mosley 2007). Customers' purchase intentions and repatronage decisions are the result of their holistic experience with a brand, which is considered as cumulative satisfaction (Ha and Perks 2005); as such, brand loyalty cannot exist without brand satisfaction (Hofmeyr and Rice 2000).

Brand satisfaction is further linked to brand trust, which is characterised by customers being able to rely on organisations to keep their promise about a product or service (Delgado-Ballester and Munuera-Alemán 2001; Agustin and Singh 2005; Hess and Story 2006). Customers build trust based on their own assumption and beliefs, as well as experiences that they have with the organisation (Bowden 2009; Şahin et al. 2011). Well-established relationships are based largely on trust, categorised by feelings of personal connection, while satisfaction is a primary indicator of functional connection (Şahin et al. 2011).

Previous research has identified that brand satisfaction and brand trust result in brand loyalty (Şahin et al. 2011). Brand loyalty is defined as a commitment held by the consumer to repeatedly purchase a preferred service or product (Oliver 1997) and is considered to be one the most important factors in a customer-brand relationship (Fullerton 2003). Ha and Perks (2005) establish that brands should provide the certainty that the brand is trustworthy and takes into consideration consumers' needs, which can lead to a positive relationship. Strong brand loyalty is considered highly valuable to a company, as it can act as an entry barrier for new brands (Delgado-Ballester and Munuera-Alemán 2001).

This research focuses on brand trust and brand satisfaction as dimensions of customer-brand relationships and explores their relative impact on brand loyalty.

11.2.3 Premium Fashion Customers

Customers today have access to a wide range of choices, which exacerbates the need for creating brand loyalty. For premium fashion customers, innovation, differentiation and establishment of long-term relationships have become more relevant (Euromonitor 2017). To explain, 98% of UK customers expect retailers to introduce advanced technologies within their brands by the end of 2018 (Business Insider 2018). Data further indicates that 81% of these premium fashion consumers purchase premium goods %due to better quality compared to cheaper alternatives and that they prefer to buy classic and seasonless pieces (81.6%), thus prioritising quality over quantity and adopting a more sustainable shopping behaviour.

In terms of shopping motivations, premium fashion consumers seem to shop mostly for hedonic reasons (Globaldata 2017). Previous literature has established that the reason for shopping and the way consumers perceive their physical shopping experience has an influence on the satisfaction gained from it (Puccinelli et al. 2009). Customers have a growing interest in experiences and services, and the premium fashion brands with iconic branding, product design, innovation and aspirational store experience are well positioned to exploit this segment and drive revenue outside the traditional retail channels (Globaldata 2017). This is expected to drive interest and build brand loyalty.

11.2.4 Conceptual Framework

This research looks at the intersection of three different areas: in-store innovative technologies, customer-brand relationship and premium fashion customers. The literature suggests that following the constructs of Technology Adoption Model (TAM) and the dimensions of customer-brand relationship, the effect of in-store technology on the customer-brand relationship for fashion premium consumers could be explored following the conceptual framework presented in Fig. 11.1.

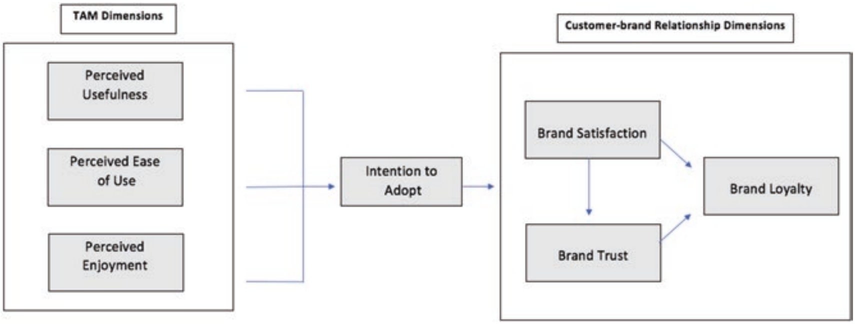

Fig. 11.1 Conceptual framework (authors' own)

The TAM has widely been used to analyse the determinants of adoption of new technologies by users. Perceived ease of use and usefulness of technology are the main variables that affect user acceptance of technology and affect behavioural intention (Davis 1989). Perceived usefulness and enjoyment are extrinsic and intrinsic motivations, respectively, that drive the intentions of a customer to use an innovative technology (Davis et al. 1992; Nam et al. 2007). An entertaining and innovative technology should satisfy diversion, escapism, aesthetic enjoyment and emotional release of customers' needs (Ducoffe 1996). Providing informative, useful and fun content is important to increase perceived value and adoption intention. Also if customer perceptions are positive enough to outweigh the disadvantages, perceived value would increase, and consequently the intention to adopt will be higher (Teng and Lu 2010).

Additionally, customer satisfaction with a specific brand is essential to generate loyalty with that brand (Levine 2003), while trust is a brand characteristic that enhances confidence in customers (Brudvig 2014) and is important to build resilient customer-brand relationships (Fournier 1998), which in turn is positively related to brand loyalty (Lau and Lee 1999).

11.3 Methodology

Following an interpretivist philosophy to explore the role of in-store technology and its impact on customer-brand relationship, this research adopts a sequential multi-method qualitative research design. Both focus groups and in-depth interviews have been used to collect primary data. Focus groups are aimed to assess customers' perception towards technology in premium fashion stores, while in-depth interviews look into the adoption of in-store technology and its impact on brand relationships. All the questions were based on the conceptual framework proposed and built on previous literature. The data obtained was analysed using thematic analysis technique.

Non-probability sampling strategy was followed to recruit focus group participants. The target sample comprised men and women aged 22–40 years, having relevant experience with premium fashion brands and insights into the factors affecting the present and future of fashion retail. The focus group interviews involved two intensive group discussions with a small sample of four participants each. The discussion guide consisted of 17 questions designed to draw information from personal experiences with in-store technologies and expectations for the future of innovative technologies in fashion retail.

Semi-structured interviews were based on a purposive sample (Kothari 2004) of six customers, aged 23 and 30 years and interviewed to explore and understand customers' perspectives based on previous theory (Boyce and Neale 2006). The guide included 36 questions divided into three parts: a broad exploration of overall experiences of customers with in-store technologies within premium fashion stores; a discussion about how various factors determine the adoption of technologies by customers; and an understanding of the development of customer-brand relationships through technology use.

11.4 Analysis and Findings

The data obtained from the interviews and focus groups shows evident relationships between the different constructs of the TAM, namely perceived ease of use, perceived usefulness and perceived enjoyment, and customer's technology adoption and customer-brand relationship dimensions, namely brand satisfaction, brand trust and brand loyalty. Table 11.2 shows the main sub-themes found in the different dimensions analysed.

Table 11.2 Sub-themes linked to different dimensions (authors' own)

Key themes	Sub-themes
Perceived ease of use	1. Easy to learn 2. Easy to use 3. Controllable 4. Flexible 5. Clear and understandable 6. Implementation
Perceived usefulness	1. Work more quickly 2. Easy to use 3. Increases productivity 4. Effectiveness 5. Makes shopping easier 6. Useful 7. Extrinsic motivation
Perceived enjoyment	1. Entertainment 2. Relaxation 3. Excitement 4. Fun 5. Value addition
Brand satisfaction	1. Convenience 2. Effectiveness 3. Unique and pleasurable experience 4. Clear and understandable 5. Probability of purchase 6. Probability of participation
Brand trust	1. Confidence 2. Security 3. Reliability 4. Useful 5. Satisfaction
Brand loyalty	1. Brand awareness 2. Repeated purchases 3. Provider 4. Buying intention 5. Facilitator 6. Efficiency

11.4.1 Perceived Ease of Use

Most of the respondents prefer technologies that are easy to learn and represent a value addition to their shopping journey "I would say mobile payments, magic mirrors, smart fitting rooms and click and collect, those kinds of experience makes my shopping easy and efficient. I am more of a utilitarian person so I want tech to have a purpose and fit in with my journey than visual effect." (I13). A variety of technologies attract customers, because they have not previously experienced them. Technologies, which are in sync with customers' life may attract potential buyers and influence their intention to adopt those technologies.

In terms of brand relationship and satisfaction, it seems technologies play a crucial role "it definitely influences my impression of a brand if a brand is embracing tech I automatically think they are embracing the future, they are innovative, motivated and exciting… I think tech would definitely influence my purchase intention and choice of brand as it would affect my relationship with the brand" (I13). However, it all depends on the implementation of technologies, or it could lead to dissatisfaction and disappointment among customers "some tech is hard to understand without any guidance, I would not use it even though I want to try it because if I use it the wrong way, I would feel like an idiot" (I13).

11.4.2 Perceived Usefulness

Respondents usually judge a technology within store based on the advantages and benefits provided; "the main reason for me to use those technologies is that it reduces the time I have to waste in standing at the tills or at the fitting room or to wait for the sales assistant to help me" (I5). However, technology needs to be accurate and perform as expected "it has to be really really accurate and up to mark technology so that when I am seeing myself as an augmented person, it should look good on me and fit properly and be accurate…" (I7).

In some cases, there is a lack of understanding about the usefulness of new technologies "… digital catalogues aren't much interesting. I don't think technology influences much of my experience as most of the times I enter a store, I might not even realise technologies in store" (I11). On the other side, a technology will be perceived as highly useful when the customer believes in the existence of a strong and positive user-performance relationship "I went into Rebecca Minkoff, all I know if they sell handbags and I don't know anything about what makes it a really good handbag. So, it's the technology that's showed me the craftsmanship and making process or what makes it different from a Michael Kors handbag, that's cool" (I4).

11.4.3 Perceived Enjoyment

While some technologies are used for functional purposes, others may be purely used for hedonic purposes looking for a fun experience through the engagement with the technology; "I think shopping is like entertainment. It is nothing else but enjoying yourself. I shop to treat myself or if I am sad, to make myself happy, so it is like entertaining myself. I would not like shopping, if I don't enjoy it or I can have a pleasurable time" (I1). Customers prefer technologies which are interactive and provide a relaxed shopping journey. They also demand the presence of technology in specific spaces "… we do need technologies in the fitting room as I believe that it is the least utilized space in the store and has a potential to offer consumer a unique experience. Fitting room is the place where most consumers make any purchasing decision" (I5).

Nowadays, social media affects the way customers perceive technology and social networks act as facilitators in the adoption of new technologies. "In today's time social media is such a big thing and a lot of different blogs are promoting free events here and there, things to do and stuff. I would definitely go and we also went to the topshop VR one" (I10). Perceived enjoyment represents an intrinsic motivation related to the use of new technologies and should complement the functional use of technology, providing a holistic experience.

11.4.4 Brand Satisfaction

The findings show that the in-store technologies that help customers to make more informed decisions have an effect on customers' satisfaction and stimulate their emotions "I think when it works for you, you probably feel really happy and cool and satisfied, that is more likely to come in and try it again and if you have a good experience with it, you think why don't all stores use it where I shop at that level" (I4). In-store technologies need to be convenient, effective and meet customers' expectations as they are the main functional factors to enhance brand satisfaction. They should help customers to feel confident making decisions and indirectly satisfy their needs. "Emotionally I become more confident in my choices" (I2).

11.4.5 Brand Trust

The findings show that security is a major concern for customers nowadays "I don't like the brand watching you wherever you go, it's violating my privacy. I am not a very big fan of beacons" (I13). Therefore, if customers experience trust in a brand and with the services provided by them, their perceived risk will be reduced "Although I am still sceptical about the use of high tech applications in the fitting room and it's not because I do not trust the brand but it's because if it might get hacked, it will breach my personal security" (I5). Brands need to incorporate technologies that customers can rely on. They need to be sure they are not leaking out their details and intruding on their privacy, but on the other side, brands should use that information to provide exclusive and personalised services to them "Also, the digital screens help me know what's trending" (I2).

11.4.6 Brand Loyalty

The development of an emotional bond between the brand and their customers created through satisfaction and trust enhances positive customer perception towards the brand. The research findings do not show obvious evidence that in-store technologies impact brand loyalty, but it does further help in creating brand preference and repeated purchases (Jacoby and Kyner 1973) "I think any type of service or experience would affect my purchase decision and relationship with the brand" (I1).

For some customers, in-store technologies communicating brand values and brand history may stimulate brand preference through engagement, as it does leave a good impression in their minds. Technologies should be compatible to what the brand stands for and should not completely remove the human touch within stores. The use of technology contributes to facilitate a purchase or to develop preference towards certain products. "I really depend on which brand and how is the match of technology with the brand. If it is really like a traditional brand then maybe you are expecting more one to one service than technology, whereby for premium brands, its ok because there would be people helping you but also you would be exploring something entertaining and functional in your purchase journey" (I6).

11.5 Discussion, Implications and Conclusion

In-store innovation has become an obvious retail phenomenon as retailers are adopting cutting edge technological advancements into their stores (Kristinnsson 2014; Grewal et al., 2017). Technological advancements, such as VR headsets, AR, digital signage, smart shelves, beacon technologies, self-service technologies, window shops, magic/smart mirrors, digital fitting rooms or interactive store windows are working towards the purpose of improving channel performance and customer-brand relationships (Thamm et al. 2016). Results from this research provide evidence for both. In terms of channel performance, respondents support the fact that the introduction of technologies helps them to make better decisions and improves the perceived performance of the physical store while at the same time has an effect on brand satisfaction.

Literature supports that the introduction of in-store technologies has a positive effect on enhancing the in-store involvement of customers. However, most of the interviewees mentioned that the technologies they have encountered do not work properly or are not very accurate with the exception of the ones implemented for pure hedonic purposes. Many customers did not notice technologies or found them obstructive or located in unsuitable locations. Contrary to Kim et al. (2017), who found that perceived enjoyment is considered more important than perceived usefulness to develop a positive attitude among customers to use technology, premium fashion customers seem to prioritise utilitarian aspects as they consider enjoyment as a secondary factor over functionality. But it is important to note that both aspects, functional and emotional, improve customers' relationship with the brand (Mosley 2007). Results show that the interaction with technologies enhances the emotional relationship with the brand and makes customers feel more satisfied about the service received.

Among premium brands, trust is a very important factor (Euromonitor 2017). However, many respondents were not able to trust brands as they do not want them to interfere in their privacy. In terms of the different dimensions of trust developed by Clark et al. (2010), respondents expect technologies to be accurate and provide a superior experience which fits with the competence dimension. They also rely on the suggestions provided by technology, which enhances the integrity associated with the brand. Last, benevolence relates to a brand's willingness to help customers, which should improve through the implementation of technologies and in turn contribute to help customers and retailers to construct their own competitive differentiation. The customers' trust towards the brands can provide the basis to transform a cognitive connection to a more emotional connection between brands and customers, hence enhancing the attachment (Hess and Story 2006).

Regarding brand satisfaction, according to the results, the perceived performance of technology affects the satisfaction felt by customers (Anderson and Sullivan 1993). Brand satisfaction contributes to developing a positive perception towards the brand which along with brand experience and trust produces brand loyalty (Şahin et al. 2011). Previous research found that attitudinal and behavioural loyalty has an influence on repatronage intention as well (Morgan and Hunt 1994; Anderson and Mittal 2000).

The specific characteristics of premium fashion brands make some technologies specially relevant in the physical space. In terms of brand positioning premium brands needs to communicate their heritage and what the brand stands for. Hence, in-store technologies can be used effectively as a platform to provide information about brand heritage, craftsmanship and values, differentiating themselves from the other brands. On the other side, technology should not be implemented to keep up with the competition, if it cannot be applied properly. The result of a faulty technology or a not relevant one will affect trust and satisfaction (Anderson and Sullivan 1993), which in turns affect brand loyalty. Technology should be used to optimise customers' experience and retailers need to find the right balance between technology and personal interaction with sales assistants. Findings show that in-store technology lead to repeated purchases which might lead to behavioural loyalty as a result of the satisfaction gained through the service and trust on the technology implemented by the brands (Kumar and Reinartz 2006).

Customers develop purchase intentions and repatronage decisions based on their holistic experience as a result of cumulative satisfaction (Ha and Perks 2005). However, current usage of advanced in-store technologies do not completely satisfy customer expectations (Pantano and Viassone 2014) as retailers find it difficult to understand what customers expect in order to develop proper services to fit these expectations. Interviewees provided suggestions regarding their ideal in-store technological experience and how the retailers can improve already existing technologies within premium fashion stores to maximise their relationship with customers. Based on their perceptions, in-store technologies should eliminate all friction points in the purchase journey and be innovative and engaging at the same time. Technologies should be implemented within all the stores of the brands as customers would expect a similar experience in different locations. A positive encounter with the technology would influence customers' purchase behaviour and relationship with the brand if they get the service they were expecting. They suggest to combine the concept of third place with technology within premium fashion stores to increase the time customers spend in stores and provide a superior experience, thus improving the relationship. Also, they consider technology as key to increase brands' customer base as it would be a way to engage younger customers and would position the brand as more creative and innovative. Regarding the use of specific technologies, respondents suggest the following (Table 11.3):

Table 11.3 In-store technologies in premium fashion retailers (authors' own)

Technology	Recommendations
Digital fitting rooms	Should not require carrying clothes to the fitting rooms/ order different clothes without stepping out/payment through the fitting room itself
Magic/smart mirrors	Ensuring it works and responds fast and accurately/ payment through the mirror
Digital signage	Powerful source of information and brand awareness/ should be useful, attractive and non-obstructive
Beacon technology	Product search/provide information at customers' will/ should not be daunting
Smart shelves	Provide style advice, effortless and informative, e.g. maintenance, outfit suggestions and price
Interactive store windows	Customer engagement before entering the store/attract potential customers
Window shops	Very effective when its 24 hours as customers could shop even after the store closes
Virtual reality headsets	Lighter headsets would create a better experience and would create engagement/useful to promote brand awareness in pop-up stores/if used for gaming, it would encourage more customers to try the technology
Augmented reality	Should be accurate and not distracting/increase convenience for customers

11.6 Implications for Theory and Practice

Previous research has observed customers' attitudinal and behavioural responses towards in-store technologies in general settings, while this research is focused on fashion-oriented in-store technologies within premium fashion context. Also, the role of in-store technologies to enhance a multi-sensory consumer experience has been already addressed, but not in relation to its impact on customer-brand relationship in a premium fashion retail context. This research has applied the TAM in a new context, customer-brand relationship. In terms of methodology, previous research related to technology and customer-brand relationships is either mixed methods or quantitative, whereas this research is built on qualitative research techniques.

This study provides practical recommendations for retailers from the viewpoint of the customers; it helps retailers to understand the impact of technology in customers' relationship with the brands. It contributes to the literature on customer-brand relationship and extends the in-store technology literature, which is a relatively new field of academic research. Also it provides broad understanding of advanced in-store technology and its current implementation by premium fashion retailers and prospects for future incorporation (Ki and Kim 2016). Through this study, in-store technology has been defined as an effective relationship-marketing tool to enhance brand satisfaction and brand trust and as a facilitator of brand loyalty.

11.6.1 Limitations and Areas for Further Research

This study contributes to an emerging field of study but has some limitations, which will need to be addressed in future research. Further retail formats and retail contexts such as fast-fashion or luxury fashion could be considered in order to offer a more complete consumer perspective. Also, looking at the role of demographic variables would expand research and provide relevant insights for industry.

This research has been conducted over a cross-sectional time horizon, which does not completely explore the dynamics of customer-brand relationship. Therefore a longitudinal study could be developed in order to consider the complexity, dynamics and causality effects.

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12

Opening New Opportunities to Close the Loop: How Technology Influences the Circular Economy

Nina Bürklin and Jasmien Wynants

12.1 Circular Economy: An Introduction

Did you know that every second, the equivalent of one garbage truck of textiles is landfilled or burned? Moreover, did you know that clothes release half a million ton of microfibre into the ocean every year, which is equivalent to more than 50 billion plastic bottles (Ellen MacArthur Foundation 2017)?

Over the past couple of years, the textile industry has become one of the most resource-intensive industries in the world, especially during production and usage, as well as in the disposal of clothing. One potential solution lies in the concept of a circular economy which can provide more sustainable ways of using resources in the fashion industry. Advancements in modern technology have served to develop innovative

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solutions to enhance a circular economy that can lead to waste reduction, longevity and new service offerings. This chapter seeks to shed light on technology-based opportunities that will foster sustainability in the fashion industry. This study is based on a multiple case study research approach done within the Close The Loop (CTL) framework that was established in 2015 and includes the phases of resourcing, design, production, retail, consumption and end of life. Thus, each phase in the cyclical process is discussed conceptually and further illustrated through best-practices. Finally, we derive concrete managerial implications for hands-on strategies to be implemented in the fashion industry.

12.1.1 General Principles

Moving towards a circular economy takes far more than traditional measures to reduce the negative impact of the current linear system. It entails shifting to an entirely new system and cannot be achieved merely through incremental improvements (Ellen MacArthur Foundation 2017). While the current economy is largely characterized by the principle *take-make-waste* in the sense of a linear economy, the main focus in a circular economy is not to destroy resources unnecessarily (van Buren et al. 2016). A systems perspective lays the foundation for a circular economy and it takes the preventive 3Rs approach, namely to recycle, reduce and reuse (Kirchherr et al. 2017). Broadly speaking, a circular economy 'aims for the creation of economic value (the economic value of materials or products increases), the creation of social value (minimization of social value destruction throughout the entire system, such as the prevention of unhealthy working conditions in the extraction of raw materials and reuse) as well as value creation in terms of the environment (resilience of natural resources)' (van Buren et al. 2016, p. 3). Current research shows that there are multiple understandings of the 'circular economy'. For example, Kirchherr et al. (2017) identified and analysed 114 definitions which could be linked to 17 different dimensions. Nevertheless, they report that the concept is mostly expressed as a combination of the 3Rs. They also find that the substantial need for a systemic shift is often neglected. In addition, neither business models nor consumers are frequently mentioned as enablers of the circular economy approach (Kirchherr et al. 2017).

A variety of different circumstances emphasize the need for shifting towards a circular economy (van Buren et al. 2016). A country or region that manages to implement a circular economy becomes less dependent on imported raw materials from other areas of the world. Further, such an economy has the potential to create new job opportunities. Moreover, there is a major advantage in how significantly reducing environmental deterioration is enabled. Through enhancing closing-the-loop-production patterns as part of a circular economy, resource use efficiency can be increased, especially regarding urban and industrial waste being used to achieve a greater balance between economy, environment and society (Ghisellini et al. 2016). A study of greenhouse gas emissions in seven European countries found that a shift to a circular economy would reduce each nation's carbon dioxide levels by up to 70% and grow its workforce by about 4%, thus achieving the ultimate low carbon economy (Stahel 2016).

The successful implementation of a circular economy will require cleaner production patterns at the company level, increased producers' and consumers' responsibility, and the application of innovative technologies and renewable materials wherever possible (Ghisellini et al. 2016). Best-practices show that the transition from a linear towards a circular economy stems from the 'involvement of all actors of the society and their capacity to link and create suitable collaboration and exchange patterns' (Ghisellini et al. 2016, p. 11). Yet, not being familiar with the concept and fear of the unknown have meant that the circular economy idea has been slow to gain traction. As a holistic concept, it collides with the established silo structures of academia, companies and administrations (Stahel 2016).

Circular economy business models fall into two groups: those that foster reuse and extend service life through repair, remanufacture, upgrades and retrofits; and those that turn old goods into as-new resources by recycling the materials. People, regardless of their ages and skills, are central to the model. Ownership gives way to stewardship, and consumers become users and creators (Stahel 2016). Innovation in the fashion industry could include, for example, searching for material flow opportunities from other industries as input into clothing manufacturing; developing patterns from which no leftover fabric remains after manufacture; innovative collecting and sorting technologies; textile-to-textile chemical recycling technologies that are able to separate and extract polyester and cotton; or developing garments that last but are adaptable to changing styles (Ellen MacArthur Foundation 2017).

12.1.2 The Need for a Circular Economy in the Fashion Industry

While a general shift in economic thinking towards a circular economy is needed, this urge becomes especially visible in the fashion industry as the profitability of the sector is at risk. The *Pulse of the Fashion Industry Report* projects that by 2030, fashion brands, if they were to continue business as usual, will register a decline of more than three percentage points in earnings before interest and tax (EBIT) margins (Eder-Hansen et al. 2017).

Until today, the textiles system, especially regarding apparel, operates in an almost linear way. Large volumes of non-renewable resources are extracted to produce clothes that are often used for only a short time, after which the materials are mostly sent to landfill or are incinerated. Less than 20% (18%) of all clothing is recycled or reused across the 27 EU countries, and in the US, this percentage is even worse (Eder-Hansen et al. 2017). If the current trend continues, the negative impact of the industry will potentially be catastrophic. If the industry continues on its current path, by 2050, it is likely to use more than 26% of the carbon budget associated with a 2 °C pathway. Moving away from the current linear and wasteful textiles system is therefore crucial to stay within reach of the 2 °C average global warming limit (Ellen MacArthur Foundation 2017).

These developments not only have tremendously negative effects on our environment, causing water pollution, for example, they also pose tremendous economic challenges. An estimated value of $500 billion is lost every year due to clothing that is barely worn and rarely recycled (Ellen MacArthur Foundation 2017). Estimates suggest that as much as 95% of all discarded clothing is thrown out with domestic waste while it could've been worn for longer, reused or recycled, depending on the state of the textile wastes (Lu and Hamouda 2014).

Sustainability will evolve from being a menu of marketing-focused CSR initiatives to an integral part of the planning system where circular economy principles are embedded in every part of the value chain. More fashion brands will plan to be recyclable from the fibre stage through all of the supply chain, and many will harness sustainability through technological innovation in order to unlock efficiency, transparency, mission orientation and genuine ethical upgrades (McKinsey 2017). Fashion brands with targeted initiatives will be best placed to improve their environmental and social footprint and counteract the rising cost of apparel production. They will pull ahead of their competitors with innovative ways of doing business and efficient production techniques that minimize the use of water, energy and land as well as hazardous chemicals (Eder-Hansen et al. 2017).

12.2 Close The Loop Framework

12.2.1 Introduction to the Framework

In a circular fashion industry, designers, producers, retailers and consumers are challenged to take the whole life cycle of a garment into account. Flanders DC and Circular Flanders developed an online guide for companies in which they encourage the industry to move away from a linear system (*take-make-waste*) and instead to embrace a more circular approach that focuses on durability and avoiding waste. The Close The Loop (CTL) platform was launched in December 2015 by two Belgian organizations, the former Flanders Fashion Institute (now merged into Flanders DC) and Circular Flanders, who started collaborating.

Flanders DC is an independent not-for-profit organization, which supports creative entrepreneurs in building and growing their businesses. One of its focal points is 'future-oriented entrepreneurship' related to sustainability and new technologies. Circular Flanders's aim is to facilitate transition from a linear to a circular economy, focusing strongly on circular cities, circular business strategies and circular purchases.

In order to accelerate the shift to a circular economy, including companies and other stakeholders, the CTL platform was created as a framework that included five strategies for each phase in the lifecycle of a garment, starting from resources, through design, production, retail and consumption up to the end of life of a product. The framework for CTL was created following a three-step method. First, platform developers did research in the domain of circular fashion, drawing on academic literature and on experience within the founding organizations. Second, a rough framework was created with several strategies defined for each phase in the lifecycle of a garment. Finally, these strategies were discussed in expert round tables until agreement was reached and the framework could be finalized. The CTL framework consists of 30 strategies (six phases in the lifecycle with five strategies each). Its aim is to encourage entrepreneurs' selection of the strategies that are most effective for the business model each has in place.

In the following sections, we will describe the challenges per phase, giving an indication of the technological innovations that could contribute to a transformation towards a circular industry. In each case, we give a case study to illustrate the applicability of the theoretical framework we have developed (Fig. 12.1).

12.2.2 Resources

The selection of resources in the fashion industry clearly has important implications, not only for the look of an item, its lifespan and quality but also for its environmental impact. When it comes to implementing strategies in the sourcing phase, the first and foremost frequently used traditional materials need to be replaced with materials that have a lower impact on the environment. Further, it is important from the very beginning to think about the end of the product's life, considering what will become of these clothes after they have served their purpose. For instance, questions need to be answered about what recycling options are available and which resources are the easiest to reuse at the end.

Also, the consequences of using certain coatings, accessories and finishing must be taken into account. Often these additions become barriers to a thorough recycling process, also due to the polluting elements they

Fig. 12.1 The Close The Loop framework

contain. To illustrate, 20% of all industrial water pollution globally is attributable to the dyeing and treatment of textiles (Ellen MacArthur Foundation 2017). For example, current technological progress is improving the finishing and dyeing processes, as in the use of Vetex solvent free coatings and Organotex® for water and dirt repellent treatments.

Some techniques reduce the environmental impact, others focus on making the garment more recyclable and another category aims to prolong the lifecycle of a garment by adding features such as anti-odour, anti-stain and anti-wrinkle elements to reduce the environmental impact in the consumer phase.

Additionally, there are experiments underway with non-traditional textiles, developing a growing group of innovative, new textiles. On the one hand, there are materials that resemble conventional textile processes but with a lower environmental impact, such as Tencel™ or Refibra™. On the other hand, there are bio-designed materials inspired by nature in which, for example, algae, bacteria and mushrooms form the basis, while bio-waste from, for example, pineapples, coffee, milk or oranges serves as resources. A last option is to work with leftover textiles as less than 1% of the materials used to produce clothing is recycled into new clothing. This represents a loss of more than $100 billion worth of materials every year (Ellen MacArthur Foundation 2017).

New opportunities further emerge with advancements in recycling technologies on different levels. The main difficulties that arise are related to the fact that the vast majority of all clothing is made of a blend of fibres and a mix of textiles, often combined with different materials in the form of yarns or buttons. Technological innovations are required on different levels, such as at the 'end of life' phase of garments, which makes use of new methodologies that improve textile collection, fibre/material recognition, sorting, disassembling and fibre to fibre recycling (see 'end of life').

Case: Orange Fiber

Orange Fiber is an Italian company that was founded in 2014 and that makes sustainable fabrics based on orange fibres. Specifically, the material is based on citrus juice's by-products that are generated during the process of juice production and that would otherwise be thrown away. According to the company, the food industry in Italy produces more than 700,000 tons of citrus waste per year. Thus, Orange Fiber started developing a disruptive technology that creates new materials out of this industrial by-product. In 2017, the first collaboration with an internationally renowned fashion house was established when Salvatore Ferragamo launched his collection made of Orange Fiber fabrics.

12.2.3 Design

In the process of transformation towards sustainable businesses, design plays a crucial role in the fashion industry. Studies show that almost 80% of the costs of product development, manufacture and use are determined in the design stage (Mascle and Zhao 2008). Thus, the earlier environmental and social factors are considered in the design process, the greater the potential savings and increase in product performance (Bhamra et al. 2013).

Selecting textiles and materials that match a certain strategy (e.g. prolonging garments' life, improving recyclability and enabling biodegradation) is one of the most crucial decisions in the process. Designers and fashion companies are responsible for what they create in general, which includes responsibility for materials, styles, colours and shapes. However, companies' design approach should take into account the entire life cycle of a product from resources to design, production, retail, consumption and end of life.

In contemporary (post-war) society, 'planned obsolescence' has become an important strategy to ensure sufficient consumption. Consumers have been conditioned to think that they always need something a little newer, a little better and a little sooner than is absolutely necessary. This concept is directly opposite to the core principles of sustainability. In the circular economy design phase, it is therefore crucial to consider different ways in which this 'planned obsolescence' can be avoided and instead to 'design for longevity'.

One of the strategies in 'design to last' is built on quality and timelessness, attempting to create designs that outlive trends and hypes. Assuming that not all business models are reconcilable with this strategy, it is important to keep in mind the 'end of life' of the design and to ensure that in one way or other the garment gets a second life. Design for rebirth is done by contemplating every possibility in terms of reuse, repair, redesign, recycling or even biodegradation. In any case and for every design, the golden rule is to avoid waste or surplus, for example, through smart production solutions, reuse of someone else's waste or multifunctional designs.

On a more abstract level, there is ultimately one goal, namely to avoid fast consumption and overconsumption. This also can be achieved by focusing on the services that are offered to the consumer. By devoting attention to the experience and involvement of the customer, the relationship between a user and his/her piece of clothing can be strengthened. This can be achieved by innovative service models, as well as interactive/cooperative design, customization, timeless aesthetics and emotional design, to name just a few. Finally, it remains important to design with the right techniques in mind. There are several techniques that generate much less waste than some that until recently have standardly been used. Even if these technologies will have the greatest impact during the production phase, the decision to work with (fly) knitting, 3D-printing, 3D-weaving or digital printing, for example, are made during the design and prototyping phase.

Design-phase technological advancements planned for use in different areas can contribute to a lower impact on different levels. In pattern cutting, for example, very few companies in the industry do not focus on minimizing waste, especially given the direct economic advantage it holds. Having said that, only a few companies will succeed in achieving 'zero waste pattern cutting' (ZWPC). So far, this method seems to be best suited to small studios and design experimenting, even though it should be possible to adapt the system to larger scale and industrial scale production (Niinimäki 2013). Other areas worth researching in the quest for more sustainable design through new technologies are based on the complexity and non-uniformity of sizing and grading, and on new methods aimed at a more efficient way of enhancing modularity. The latter refers to the multi-functionality of a garment that a wearer can alter in a way that brings variety into his/her wardrobe (Niinimäki 2013).

Case: Nike

Nike's Flyknit shoe is sustainable in different ways. Firstly, it is based on a design that radically minimizes waste. The upper part of the shoe is knitted in one whole piece so that the shoe is practically seamless. This considerably reduces waste during the process of pattern cutting. According to Nike the Flyknit technology lessens the amount of waste that would otherwise end in the landfill by millions of pounds. They calculate that on average they create 60% less waste in the production process than in traditional cut-and-sew shoe manufacturing. Secondly, Nike offers its clients the possibility of designing their own shoes online. This customization feature brings stronger engagement and includes the idea of long-term design that will specifically suit the individual customer's needs.

12.2.4 Production

In a traditional process, after the design phase, a small sample collection is produced containing prototypes of new designs. The samples items that gain significant approval and are apparently interesting will enter full production. This means manufacturers switch to high-number commercial entities with varying sizes, colours and patterns. It now becomes important to incorporate zero waste thinking into the production process. Zero waste production is a holistic approach aimed at avoiding textile waste throughout the production process, which means that they regard design as part and parcel of the process. Throughout the whole production process, two kinds of waste are generated, namely waste of resources, e.g. water, energy and chemicals, and waste of fabric in production. 'Apparel industry professionals say that about 15 to 20 percent of the fabric used to produce clothing winds up in the nation's landfills because it's cheaper to dump the scraps than to recycle them' (Rosenbloom 2010).

When producing in-house or selecting a manufacturer, several aspects related to the circumstances of production should be taken into account. This includes checking whether the manufacturer puts in suitable effort to contain energy and water consumption, whether the process is compliant with environmental legislation, and what the manufacturer's position is on the use of chemicals.

Producing locally obviously has several advantages which include logistic ones as in shorter distances, communicative ones as in increased efficiency and fewer misunderstandings, and ones that 'close the loop' as in reusing clothes that find their way back to reproduction in the same country. Moreover, rapidly developing new technologies are likely to replace or complement traditional production processes, thereby helping to reduce the ecological footprint. Such new technologies will probably need less energy, water or chemicals, or allow us to skip certain harmful steps, like transportation, altogether. They can facilitate local production, for example, by digital designing, printing or even 3D-knitting and weaving, the digital technologies can enable smaller editions. Perhaps it could even be possible to work on demand, which is the golden route to avoiding surplus.

Some new business models are built on the idea of local 'maker spaces' with laser cutters or even consumers owning 3D-printers so that items can be designed anywhere in the world but produced at home. In the prototyping phase, new technologies are being developed, of which 3D-virtual prototyping is one of the most well-known examples, to minimize the number of prototypes (and, thus, the amount of textile and energy) needed to finalize a design.

Having noted this, one still has to remember that the fashion industry, which is one of the biggest industries in the world, is also one of the very few industries where almost everything is still made by hand. There is hardly any automation in production, which creates opportunities, for example in the field of robotics as with SoftWear's Sewbot Automation's clothes-making robot.

Case: Post-Couture Collective

The Post-Couture Collective, a project by Dutch designer Martijn van Strien, offers an alternative to today's fashion system. His clothing is designed on the principles of open source and is developed for production on a laser cutter and assembly by the end user. Consumers can use a laser cutter in a local maker space in combination with patterns that can be digitally downloaded from the website. Van Strien's innovative way of producing clothes makes it possible to stop centralizing production in low-wage countries and to spread it over the entire world instead. In the local production spaces, the clothes aren't made until someone makes an offer to buy them (production on demand), which drastically reduces the waste stream. The aim is to gather a 'collective' of designers and maker spaces worldwide that offer different designs and patterns according to these principles.

12.2.5 Retail

At a rate of 30–50 collections a year, the life expectation fast fashion offers to a piece of clothing is just a couple of weeks. A traditional business model can be summarized as follows: resources are extracted, transformed into a product, which is then sold, and after use (or sometimes even before), the item is thrown away. This process, which reflects the *take-make-waste* model, is undergoing a slow shift towards circular business models that add a sustainable spin to the traditional linear model and challenge conventional ways of clothing production.

A rising number of fashion retailers are already following this approach in that they install a take-back model. The possibility of returning garments to the retailer, who gives clothes a second life as resources for new items, is gaining popularity. In this story, retailer and manufacturer are often one and the same company.

A second big movement is taking place within the peer economy or the sharing economy (see Chapter 4 by Bürklin & Risom). This type of economy allows a consumption mode in which consumers pay for using clothes rather than owning them. The rise in clothing libraries, where customers can rent clothes for a specified period of time, is one such an example. Initiatives like swishing or swapping clothes where consumers exchange clothes on a non-transactional basis are also becoming more and more common. In the meantime, there are also plenty of online possibilities to give clothes a second life. Many platforms allow people to sell or swap their clothes peer-to-peer. Further, clients currently want to be involved in the design process, attaching special importance to the experience. Focusing on this as a retailer could enhance the bond with the customer and create ambassadors for the brand. Seemingly trivial services like repairing, giving styling advice, producing made-to-measure clothing and letting the customer pick his/her own print or pattern, are significant in this process.

Technological innovations that work towards more sustainable new or existing retail models, could, for example, aim to improve current take-back systems and the logistics that support such opportunities, or they could focus on facilitating the sharing economy via apps and online platforms. Concerning in-store experiences and omni-channel approaches, companies are experimenting with, for example, intelligent fitting rooms, smart mirrors, virtual avatars, 3D-bodyscans, new payment methods and optimization of logistics in e-commerce. These strategies and devices all focus on a better shopping experience that can easily be combined with sustainability targets like reducing the environmental impact of e-commerce logistics or reducing the number of 'bad buys' in fit as well as size (e.g. by ordering the right size based on a 3D-bodyscan).

Case: Filippa K

The Swedish brand Filippa K has done much to enhance sustainable consumption and design. On the one hand, Filippa K wants to help its clients make the right, thus responsible, choices. On the other hand, the company is trying to set an example through circular designs that reduce the waste stream. These efforts have resulted in various specific projects. Besides striving towards the target of having a 100% sustainably produced offer by 2030, the retailer focuses on making particular adaptations to the retail model as well. In 2008, the second-hand store chain 'Filippa K Second Hand' was opened. The 'Filippa K Lease' (online) shop saw the light in 2015. The latter allows clients to rent clothes instead of purchasing them and thus helps to avoid overconsumption. Moreover, after the season's fashion shows, several catwalk looks are offered for rent online. In addition, the brand collects customers' old Filippa K clothes via *the 'Filippa K Collect' project. Customers get a coupon in return for their old items, while their clothes get a second/third life, or are recycled and used to make new clothes.*

12.2.6 Consumption

In all retail sectors, consumers are becoming more conscious and more outspoken, asking questions about certification labels, resources, production circumstances and so on. Nowadays, retailers, designers and manufacturers are obliged to provide adequate answers to these questions. Especially in times where social media and the internet have shifted the power to the consumer, transparency has become a requirement (Snoeck and Neerman 2017).

Besides being answerable to customers, companies in the circular economy can take responsibility to inform and educate consumers regarding the maintenance of clothing. The right treatment of clothing will prolong the life of the garment but at the same time will assure that owners cherish and use the items for longer. About 60% of the energy used in the life cycle of a cotton T-shirt is related to post-purchase washing and drying at high temperatures (Claudio 2007). The educative role of brands can also be harnessed to communicate about sustainability in general, informing clients on why certain design decisions are made, where and in which circumstances an item was manufactured, what the best way is to keep the particular fabric as good as new, and what one can do with a garment after you're done with it.

Brands and retailers are looking for ways to communicate this kind of information not only via customary channels like their websites. For example, the Dutch brand *Studio Jux* attaches a number code to each garment they sell. Customers can look up the number on the brand's website and then get information on who made the item. Similar examples include QR codes in clothing labels that show videos of workers or factories producing the garment or smart labels that warn consumers when and how they should wash an item to avoid washing it too often.

Information on product and company level is provided not only by the brand itself but also by third parties that have developed more and more tools for consumers to participate. Smartphone apps make it easy not only to compare prices but also to provide information and guidance on sustainability levels. '*Rank a Brand*', for example, awards a score to brands based on how they communicate information about their efforts towards people and the planet. Experiments going beyond apps are investigating how radiofrequency identification (RFID) can be integrated in fabrics or threads to capture data along the way. Another example refers to block chain technology to track transparency all along the mostly complex supply chain of a garment.

Case: Provenance x Martine Jarlgaard

Provenance refers to a platform that contains and displays publicly available and secure supply chain information. Through their app, the information is presented in a way that customers can easily access and understand. In 2017, the block chain technology provider collaborated with Martine Jarlgaard to track the world's first garment with a unique digital token. This specific type of ID contains data that map location, content and timestamps along the whole value chain, thus representing the complete production process. This information is made accessible to the consumer via *the garment's smart label. As such, this collaboration illustrates block chain technology's potential for increasing transparency.*

12.2.7 End of Life

Depending on choices made when designing and producing garments, different strategies can be implemented to avoid or postpone the 'end of life' of an item. A basic principle of nature is one of growth and decay, according to which things consisting of natural materials spring to life, grow, mature and then end by slowly disappearing back into the earth. It can be referred to as the most advanced closed-loop system ever. One way to close the loop in fashion, then, is to assure our clothes are biodegradable. At the moment this is not a widely used strategy as it still requires a lot of research. Influencing elements like the exact circumstances in which clothes will decompose or the time this would take are crucial. Adding to that, clothes are often made from a blend of fabrics (e.g. polyesters), materials are heavily coated or they contain other extras like buttons and zippers that would complicate the degradation process. On the other side of the spectrum, rather than end-of-life disintegration, there is recycling and reusing, which at present appear to be more difficult and therefore not widely applied. This is referred to as 'upcycling' and 'redesigning'. Reusing, redesigning or upcycling is regarded as an eco-efficient strategy, even though this approach does not address the real problem, namely the increase in both production and consumption.

Beyond reusing a discarded garment's fabric itself, one could reuse its fibres. Recycling is still an option here, but it needs to be taken into account from the beginning, i.e. from the design phase (see below). Finally, it is important to keep in mind that perhaps the most sustainable option of all is 'prolonging' the lifecycle of a garment. This can be done by strategies discussed earlier, such as focusing on quality and timelessness, involving the customer to increase attachment to an item, educating on maintenance, stimulating second-hand use and creating new business models like leasing systems.

Since the ultimate goal of a circular economy is to avoid waste, it is not surprising that the development of new technologies is often focused on the 'end of life' phase. Three waves in innovation can be distinguished based on the processes of recycling as we know them. In the first step, collected clothing or textiles are sorted out, often still by hand, which is quite time consuming. New projects like 'Fibersort', a technology that automatically sorts large volumes of garments and finished products by their fibre composition, are looking for ways to improve recognition and sorting techniques. The second wave is one that focuses on improving disassembly techniques, developing ways to easily remove buttons and zippers or even seams from clothing. Wear2, a company focusing on disassembly technology, illustrates this in using microwaves to easily remove labels and branding from corporate clothing. The process allows large volumes of clothing to be disassembled swiftly to prepare the textile for fabric recycling processes.

A final cluster of technological innovations is aimed at improving the recycling of the textile itself. Turning to existing yarn and textile would reduce the need to make fabrics from virgin (raw) materials like cotton, wool and synthetic yarn. This will save energy and avoid the pollution that takes place during traditional harvesting, dyeing and washing processes. Natural materials and synthetic materials are recycled in a different way. Recycling natural materials like cotton and wool happens mechanically as it is a process of stripping and shredding fabrics into smaller particles, the fibres. For synthetic fabrics, there are more options. They can be recycled both mechanically and chemically. Polyester that consists mainly of industrial waste and 'post-consumer' plastics (like bottles) is pulverized, melted and then spun into new fibres. Keeping in mind that there is an impact during the 'use phase' as well, the use of plastics in recycling processing is criticized due to the 'micro plastics' that are released in the washing process.

Sorting and recycling is of course the easiest when garments are made of only one kind of material. Unfortunately, most pieces consist of a blend of different materials, which of course complicate the process. This means the first step is a costly sorting process, which raises recycled textile prices to a point at which they cannot compete with raw material. RFID-tags could be a possible solution. Such a tag would contain all the necessary information to facilitate the sorting process. Several organizations like Worn Again believe in the possibility of chemically recycling fabrics that contain at least 80% of the same material, thus supporting the idea of recycling some kinds of blended fabric. The partnership between the H&M Foundation and The Hong Kong Research Institute of Textiles and Apparel provide another example of working towards solutions to recycle blend textiles into new fabrics and yarns without any quality loss using a chemical process.

Case: H&M Global Change Award Winners

In 2015 the H&M Foundation introduced their annual Global Change Award as a challenge for inventors to come up with game changing ideas that can make the fashion industry circular. Every year, five Global Change Award entries are selected from a pool of applicants, to the extent that in 2018 over 2600 entries from 151 countries were registered. In the winning projects the 'end-of-life' topic was represented often enough to indicate the importance of this matter. In 2016 there was an online market for textile remnants, a project focusing on making new textile out of cotton waste, and the 'Polyester Digester', which investigated how microbes could recycle polyester textile. In 2017 the 'Content Thread' facilitated the sorting and recycling process using a digital thread, and in 2018 'The Regenerator' tried to separate cotton and polyester blends, turning them into new textile fibre, while 'Resortecs' introduced a dissolvable thread to improve repairing and recycling processes.

12.3 Implications and Future Perspective

To be able to make the shift towards a circular fashion industry, research, innovation and technological enhancement are needed on several levels. The CTL framework identifies different challenges throughout the value chain that require innovation at social, technological and commercial levels (Stahel 2016) while illustrating ways to increase sustainability in the fashion industry through innovations. Some of these are related to technological innovations such as 3D-printing, RFID and block chain; others relate to new business models such as renting or second-hand shops.

On a product level as well as on a business model level, we find that organizations should put serious effort into their contribution to a sustainable future. Strategies for a product design that is aligned to environmental efficiency provide a great opportunity to benefit from developments towards sustainability in the fashion industry and a community that prefers toxic-free, recyclable and high-quality garments to ones that depend on an end-of-pipe technology (Greenpeace 2017). Producers in the fashion industry who integrate these innovations will contribute to environmental protection through the avoidance of toxic substances and reduction of raw materials, especially during the production phase. They will also benefit from these developments on an economic level, as they have opportunities to reduce their production cost on a long-term basis. This is enhanced through integrating the concept of zero waste, for example during the design and pattern cutting phase. Further, inter-industry co-operation as in the case of Orange Fiber can make use of by-products from one industry and create value through material production in another industry.

In addition to innovations in design and reuse, businesses can contribute to a circular economy by focusing on solutions instead of mere products. New innovations like production on demand allow them to react quickly to customers' wishes and preferences without risking high investment costs in having to create samples during the production process. Moreover, the technological development through Web 2.0, along with consumers developing a new ecological consciousness, spaces for innovative business models are opening up. Thus, entrepreneurs in the fashion industry can make use of new technologies to meet contemporary customer needs while establishing their position in the market. On the business model level, services such as repairing, recycling, lending and sharing should be taken into account (Greenpeace 2017) as ways of getting all stakeholders to take greater responsibility for sustainable fashion production and consumption. New business models, for example, allow them to integrate new services that are platform based and can be accessed through mobile apps. These not only respond to alternative consumption modes such as swapping or renting, but also reduce material use and, thus, textile waste. A further example is a strategic approach to 'leasing' where the manufacturer retains ownership of the product and, hence, takes responsibility for the costs of risk and waste (Stahel 2016). Still, more effort needs to go into explaining these new services and making them more accessible too.

Marketers can benefit from the aforementioned innovations throughout all six phases of the CTL. First, they can better respond to growing customers' needs for customized and strongly individualized products, such as through the integration of virtual prototyping or 3D-printing.

Further, they can increase customer satisfaction through better consultation during the purchasing process, such as by using smart mirrors in-store. Additionally, marketing professionals can react to the demand for corporate responsibility and improve the brand's reputation by positioning their fashion brands as highly sustainable. This can be reached through transparent communication regarding their raw materials and supply chain as is demonstrated in the case of Martine Jarlgaard. Nevertheless, one of the main challenges in this industry relates to strategies for open communication and information dissemination. On the one hand, these are needed in order to raise awareness about the responsibility for products throughout their service lives on the levels of manufacturer as well as consumer (Stahel 2016). On the other hand, producers carry the perceived risk of presenting too much information to the competitor and thus decreasing their own stable position in the market. Yet, more transparent communication and special attention to proactive knowledge sharing within the industry (and cross-industries) can push this movement forward.

Lastly, research institutes and independent technological innovators can contribute greatly to progress related to innovation in the fashion industry. While fashion brands have to cover moderate to high investment costs, market developments will further increase the pressure on those companies to invest in sustainability. Additionally, retailers should build close relationships to those stakeholders that are directly involved in the production process (e.g. through choosing innovative materials or pattern-making) in order to understand their needs and wants from an early stage. Through close collaboration and constant exchanging of new ideas, overhead costs can be reduced, while benefits for all parties involved can be increased.

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