Sustainable Textiles: Production, Processing, Manufacturing & Chemistry

Subramanian Senthilkannan Muthu
Miguel Angel Gardetti *Editors*

Sustainable Design in Textiles and Fashion

Springer

Sustainable Textiles: Production, Processing, Manufacturing & Chemistry

Series Editor

Subramanian Senthilkannan Muthu, Head of Sustainability, SgT and API, Kowloon, Hong Kong

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Editors
Subramanian Senthilkannan Muthu
SgT Group and API
Kowloon, Hong Kong

Miguel Angel Gardetti
Center for Studies on Sustainable Luxury
Buenos Aires, Argentina

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Preface

Based on the complexity that sustainability implies in the fashion industry, it was identified by researchers that the best way to afford sustainable practices is to introduce aspects directly related to sustainability, since the beginning, already during the first part of the design process. Through handmade products and sustainable fashion garments, the consumers can have a sensorial experience that enables a different relation with the product and were emotional attachment is possible. The‘ consumer will feel the purchase as an investment that will transcend seasons and make them feel satisfied for its attractiveness and functional longevity. Design is the only way out of this unsustainable situation, to this harmful pattern of consumption and social behavior. Almost always, the design process brings together needs and functions for its client only. Esty and Winston [1] criticize design process for the environmental impact a product has that could be estimated and avoided if took into consideration during the first part of this process.

This volume gives a comprehensive outlook about this subject and begins with the work titled “Fashion Design for Holistic Systems” by Jennifer Whitty. This exploratory design paper incorporates a multidisciplinary mixed methods approach and a systems lens to the fashion system to examine the boundaries of conventional fashion practice to encourage more complex interrelationships between and around garments. The theoretical framework is informed by systems thinking and a critique of the paradigm of growth, in conjunction with the “four orders of design.` It invites us to ask, through design research, what a holistic, flourishing, responsible fashion and textiles system for the twenty-first century might look like, by widening the parameters of the fashion system in order to critically examine the tension between analytical and systematic thinking for fashion.

The following chapter, “Composite Material Design for Aircrafts from Sustainable Lignocellulosic Fibers—A Review” written by Çiğdem Gül and Emine Dilara Kocak, shows that the use of composite materials in aircraft design is gradually increasing. For example, Airbus, the world's largest aircraft manufacturer, is working on the use of hemp, linen, kenaf and sisal fibers for manufacturing of the sidewall and ceiling panels, the insulation covers and the other aircraft interior components. It is considered to use natural fibers as a reinforcement element in

composite materials to increase fire resistance and reduce the smoke level and toxicity. In this study, information will be given about the latest developments in composite design from lignocellulosic fibers in aircrafts.

Then P. Senthil Kumar, P. R. Yaashikaa and C. Femina Carolin develop the chapter titled "Sustainability in Textile Design." Since designers are in the main positions for handling, this chapter focuses on the qualities that constitute designing practices. This chapter also identifies the environmental design techniques so that designers may creatively develop performance strategies based on life-cycle analysis methods.

Subsequently, Sophia N. Njeru presents "Junior Sportspersons Living with Physical Disabilities' [Dis]Satisfaction Level with Selected Active Sportswear Attributes: Implications for Sustainable Apparel Design for Social Inclusion in Kenya." The junior sportspersons living with physical disabilities—JSLWPDs' dissatisfaction level in Kenya is significantly higher than the satisfaction level concerning selected active sportswear attributes: function/usability, fit, freedom of movement and sportswear weight. Chi-square test revealed a significant difference in the [dis]satisfaction level among the attributes. The dissatisfaction level is at par for both genders. Accordingly, dissatisfaction inhibits their social inclusion and enjoyment of sports. Evidently, active sportswear fashion actors' product development is unsustainable because they disregard the JSLWPDs' special apparel needs. The research is envisaged to inform the co-design of JSLWPDs' intelligent adaptive active sportswear that shall empower them academically and within the bio-psychosocial continuum for social inclusion.

Finally, Jo Cramer in the chapter entitled "Use Forecasting: Designing Fashion Garments for Extended Use" introduces the concept of "use forecasting" to describe how designers might anticipate and design for the extended use of fashion clothing. Garment design that supports extended use is one strategy with the potential to mitigate the harmful environmental consequences of disposable fashion. Life-cycle assessment studies of clothing conducted in the UK have shown that even a modest extension to the use phase of clothing can significantly reduce the carbon, water and waste footprint.

Kowloon, Hong Kong — Subramanian Senthilkannan Muthu
Buenos Aires, Argentina — Miguel Angel Gardetti

Reference

1. Esty D, Winston A (2009) Green to gold. How smart companies use environmental strategy to innovate, create value, and build competitive advantage. Wiley, New Jersey

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About the Editors

Dr. Subramanian Senthilkannan Muthu currently works for SgT Group as Head of Sustainability and is based out of Hong Kong. He earned his PhD from the Hong Kong Polytechnic University and is a renowned expert in the areas of Environmental Sustainability in Textiles and Clothing Supply Chain, Product Life-Cycle Assessment (LCA) and Product Carbon Footprint Assessment (PCF) in various industrial sectors. He has five years of industrial experience in textile manufacturing, research and development and textile testing and twelve years of experience in life-cycle assessment (LCA), carbon and ecological footprints assessment of various consumer products. He has published more than 100 research publications, written numerous book chapters and authored/edited around 100 scientific books in the areas of carbon footprint, recycling, environmental assessment and environmental sustainability.

Miguel Angel Gardetti (PhD) founded the Center for Study of Sustainable Luxury, first initiative of its kind in the world with an academic/research profile. He is also the founder and director of the "Award for Sustainable Luxury in Latin America." For his contributions in this field, he was granted the "Sustainable Leadership Award (academic category)," in February, 2015, in Mumbai (India). He is an active member of the Global Compact in Argentina—which is a United Nations initiative—and was a member of its governance body—the Board of The Global Compact, Argentine Chapter—for two terms. He was also part of the task force that developed the "Management Responsible Education Principles" of the United Nations Global Compact. This task force was made up of over 55 renowned academics worldwide pertaining to top Business Schools. He has several publications in the sustainable luxury arena.

Fashion Design for Holistic Systems

Jennifer Whitty

Abstract Fashion, like all ecosystems, is complex and dynamic. The fashion system comprises intangible, and tangible aspects, all of which have significant consequences. The linear structure of this system, used throughout the twentieth century—referred to as 'take, make and waste'—has set artificial boundaries and driven a wedge between players in this system. This has led to the global fashion, and textiles industry being one of the world's most polluting industries, and overshadows the potential of the fashion system as a powerful vehicle for social and environmental change. Design can be key to reorienting the fashion system and bringing the disparate parts together. Design research, and practice can generate new ways of understanding, being, and doing 'fashion' that acknowledges the complexities and the varieties of fashion(s) in an authentic twenty-first-century context. This exploratory design paper incorporates a multidisciplinary mixed methods approach, and a systems lens to the fashion system to examine the boundaries of conventional fashion practice, to encourage more complex interrelationships between, and around garments. The theoretical framework is informed by systems thinking, and a critique of the paradigm of growth, in conjunction with the 'four orders of design'. It invites us to ask, through design research, what a holistic, flourishing, responsible fashion and textiles system for the twenty-first century might look like, by widening the parameters of the fashion system in order to critically examine the tension between analytical and systematic thinking for fashion. This study acts as a catalyst for a conceptual model showing how the fashion system can reconnect, and fashion design can engage with a higher order of design to encompass sustainable practices.

Keywords Sustainable · Service · Fashion systems · Orders of design · Transition design · Fashion experience · Systems · Design systems

J. Whitty (✉)
Parsons School of Design, New York, USA
e-mail: whittym@newschool.edu
URL: https://www.linkedin.com/in/jennifer-whitty-5909231b

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1 Introduction

1.1 Situating the Research

The definition of a system, according to the key systems theorist Meadows [41, p. 2], is 'a set of things—people, cells, molecules, or whatever—interconnected in such a way that they produce their own pattern of behaviour over time'. The fashion system is one of the most complicated global supply chains, involving more than 60 million people, and moving tonnes of chemicals, water, crops, and oil across the planet [49, 57]. We have adopted the predominant method of reasoning of the 20th—analysis over synthesis—to understand and operate in this complex system. Analysis involves breaking the system down into its constituent elements through a process of reductionism, so it is simply a sum of these constituent elements.

In fashion terms, the constituent elements, and boundaries are exemplified by the reduced, linear, compartmentalised, 'take, make and waste' supply chain model [21]. This analytical model isolates, and spreads the three stages of the system across the globe. The first stage, 'take', involves the sourcing of fibre and raw materials in one place, before being transported to another place for the second 'make' stage for processing and manufacture. The elements are then taken to another place for finishing and sale before the final, third 'waste' stage where a garment reaches the end of its useful life.

Applying analytical thinking to break down a complex dynamic system such as fashion into a linear, compartmentalised model has led to disconnection across all stages of the fashion system. It also veils activities such as subcontracting to the point of disruption and disorder, as human rights and working conditions can operate below global standards, without visibility or penalty. This reduced model doesn't encompass the broad spectrum and diversity of activities that are the reality of the fashion system, such as the use phase, post-purchase phase, or alternatives to a garment becoming waste. Moreover, it suppresses everything this system could be—one of flourishing interconnectedness, transparency, feedback loops and harmony. In the words of Indigenous knowledge academic Yunkaporta [56, p. 4], 'viewing the world through a lens of simplicity always seems to make things more complicated, but simultaneously less complex'. Yunkaporta sees the desire to reduce things through analytical reasoning as part of the legacy of colonisation. As complex indigenous knowledge systems of nature were controlled, an impossible and unrealistic expectation of simplicity was chosen over wisdom and complexity.

1.2 Synthesis and Analysis

Synthesis and analysis both form part of a well-developed reasoning approach, but on the whole, highly interconnected dynamic systems are best suited to synthesis or systems thinking, rather than a reductive, analytic approach. An analytical approach

has been highly successful for the fashion industry in financial and production terms. It has accelerated mass manufacturing and growth at all costs, 'chasing the needle' across the globe for the lowest production costs in a race to the bottom, driven by hyperconsumption. This segmented approach has contributed to the brokenness of this system as a whole and an absence of values and ethics. Prioritising financial and manufactured capital in isolation, blatantly ignores the interrelationships and impacts on other forms of capital, such as human and cultural capital (Fig. 1) [48]. The effects of cost-cutting decisions include rampant low wages below living standards, unhealthy and dangerous working conditions, and forced child labour akin to modern-day slavery throughout these disconnected supply chains [32, 37].

This approach has enabled some key players in the industry to divide and conquer—to sequester parts in isolation without consequence or without motivation to build a dynamic, thriving system for all. These key players have neglected to ask what is right for each place, and each community, and understand all the outputs, inputs, and throughputs of this entire interconnected ecosystem. The reductionist paradigm systematically and inherently de-promotes the relationships between these components, and instead accelerates competitiveness across developing countries. Production swiftly moves on from place to place as wages, workers' rights and conditions improve, leaving behind a trail of social, human, and natural instability and devastation. A recent BBC investigation noted that low-cost clothing production had moved from Bangladesh to Ethiopia, where wages are a third of the previous rate [19] (Fig. 2).

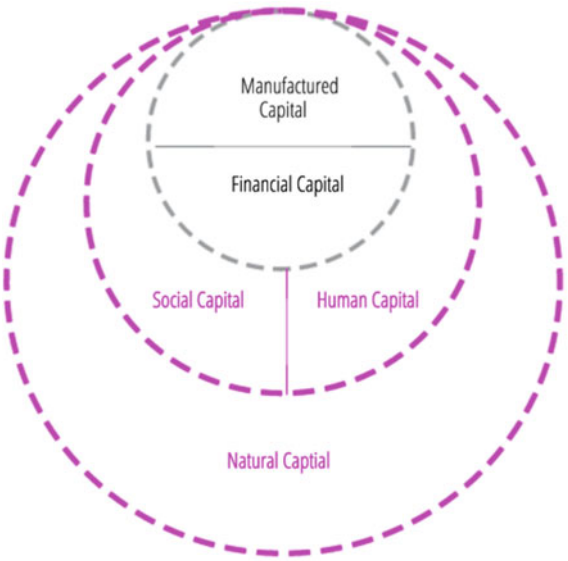

Fig. 1 Five capital model [48]

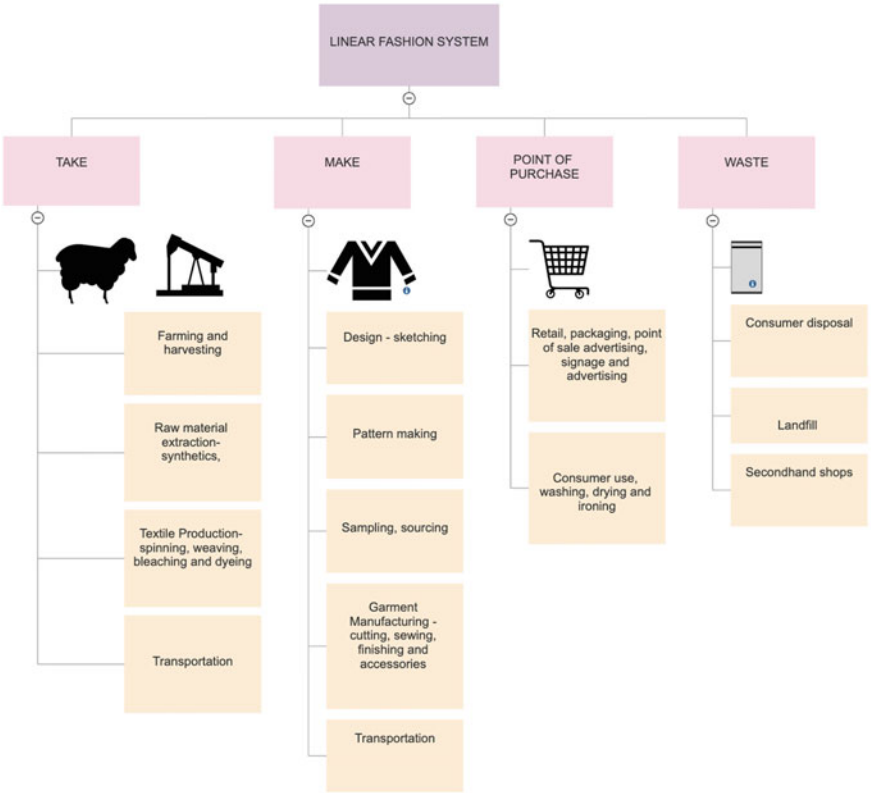

Fig. 2 A linear fashion system

1.3 A System Broken into Constituent Parts: A Contextual Review

The general process from clothing design to production follows discrete divisions of activities, and specialist skills from design, pattern-making, construction, production, and retail. The hierarchy, and separation of these processes has led to a cut-and-sew fashion system which is inherently wasteful, and ignorant of the context in which garments are created and used [51]. The act of garment cutting results in an average of 85% effective textile use, leaving the other 15% on the cutting-room floor [1, 51]. This waste is a production problem, seen as outside the narrow remit of design, and designers. Each stage of this hierarchical system is segregated, which leads to much virgin fabric being wasted while adhering to the growth paradigm's perpetual hunger for the new. We now have a global clothing production system that produces over 150 billion garments annually, which could provide 20 new items to every person on the planet, every year [15].

The division of labour has meant that designer responsibility typically begins, and ends with drawing a design for the garments to be crafted from new fabric [52]. Making the patterns, making the maker, cutting the fabric, and sewing the garment is all done by a series of discrete specialists, who are responsible for these stages in the fashion system, before the garment is ultimately sold. While designers' roles can vary depending on the scale of their organisation, on the whole designers rarely factor environmental or social parameters into their work. The garment is generally not designed in the micro-context of fabric dimensions or in the macro-context of limited natural resources, and clothing-driven pollution in our air and water [13]. This broken system supports an impulsive 'act now, think later' approach to design where surplus overproduction is accepted, as what doesn't get sold is secretly burned or buried. A report by the Ellen McArthur Foundation [22] estimates that one trunkful of clothing and textile materials is landfilled or incinerated every second. This mindset has led to a reduced sense of designer responsibility and integrity—responsibility that ends at the point of purchase, as garment lifespan is beyond their remit. The material waste, and negative impacts could be minimised or eliminated if the system for design and production was redesigned to become more integrated with the processes of nature. Wood (in Chapman and Gant [12], p. 111) writes that the use of resources in a holistic, circular, systems-based production-to-consumption system, could follow zero-waste systems that are found in nature (Fig. 3).

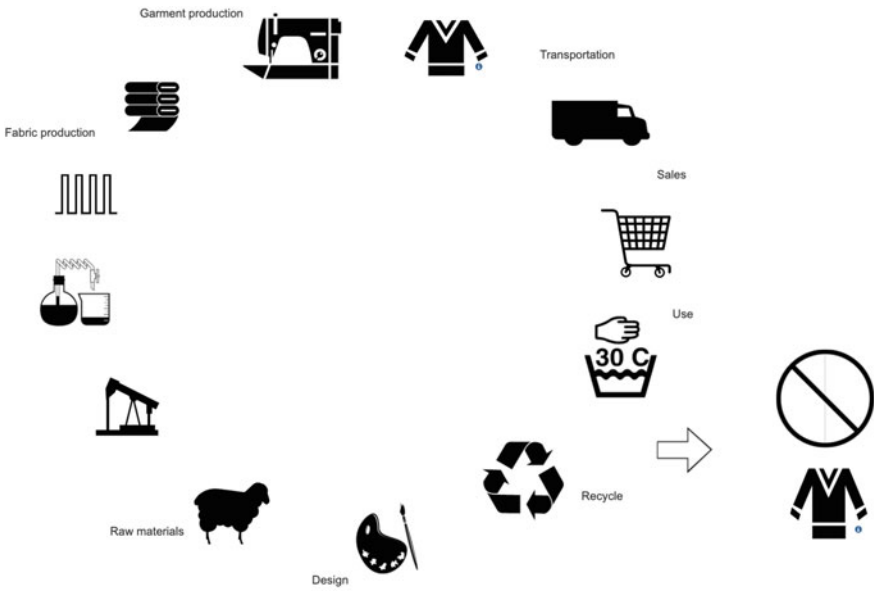

Fig. 3 Circular Systems [55]

2 Methodology

In keeping with its open interdisciplinary approach, this exploratory research incorporates a multidisciplinary mixed methods approach. Drawing upon multiple theories, philosophies, and knowledge from varied fields from across the fields of environmental studies, politics, science, history, philosophy [53], and economics [35] in addition to design research from across the field of design [39]—design thinking [10, 17, 44], fashion [51] and textiles in order to gain a comprehensive look at this topic on multiple levels. It follows a qualitative approach: historical and content analysis.

The theoretical framework for the research is informed by systems thinking [2, 21, 41] and a critique of the paradigm of growth, in conjunction with a Transition Design-led [34] exploration of sustainable fashion design (Fig. 4). The application of a systems lens to the fashion industry is in opposition to the mainstream reductionist view with the aim of replacing reductionism with expansionism—the view that everything is part of a larger whole and that the connections between all elements are integral.

The conceptual framework is informed by design thinking research [8, 17] in conjunction with the 'our orders of design' (Fig. 5) as posited by Buchanan [9, 10]. According to Buchanan [9], the orders of design are:

1. Signs and symbols: communication, graphic design, editorial, etc.
2. Objects and artifacts: product design, fashion design, industrial design, etc.
3. Interactions and experiences: UX-UI (user experience, user interface design), service design, etc.
4. Systems: policy design, system design, industrial ecology, etc.

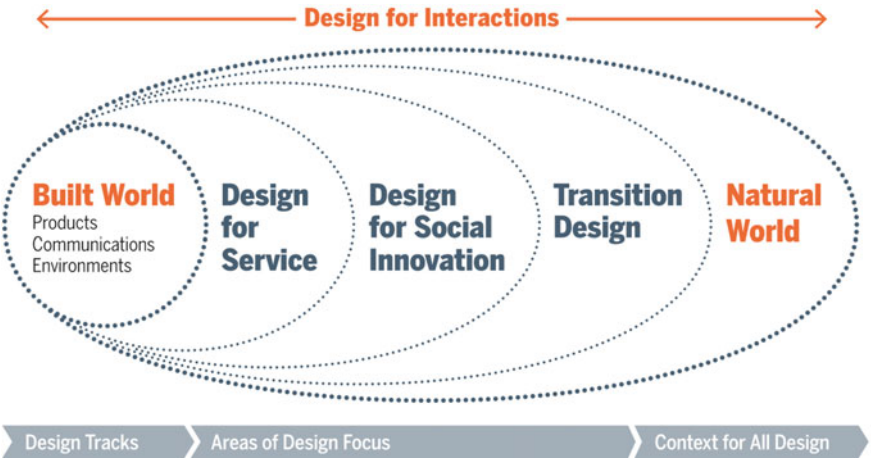

Fig. 4 Diagram of transition design [34]

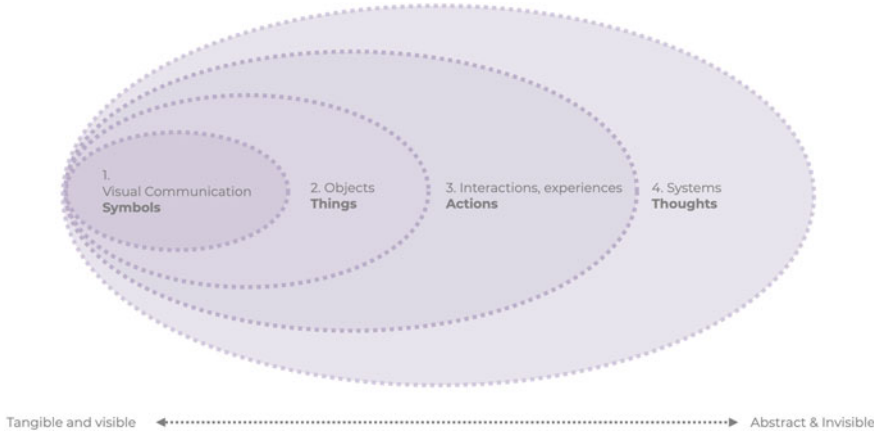

Fig. 5 Model of the four orders of design [10]

This research consists of three predominant methods: a literature review, a contextual review, comparative analysis and recommendations. A review of literature was undertaken pertaining to the entire context in which fashion exists while examining the roles of the fashion designer in industry and education. A contextual review was developed via a method of critique whereby the ethos and fashion practices undertaken are compared and contrasted according to criteria developed in the literature review.

3 The Limits to Growth: The Fashion System as a Subsystem of Our Ecosystem

An ecosystem is defined by Encyclopædia Britannica [23] as 'the complex of living organisms, their physical environment, and all their interrelationships in a particular unit of space'. The current fashion system was developed in the context of the socioeconomic system of Western consumer capitalism and globalisation of the late twentieth century/early twenty-first century where the default position has been overwhelmingly pro-growth, as it has been for over 200 years [42]. The 2018 UN climate report [31] states that we have approximately 12 years to make significant systemic and social changes to all aspects of human activity; or we risk catastrophic climate change. Growth can be beneficial for society but it can also create problems, particularly if it is not conscious or respectful of its context. This growth is exponential rather than linear, and the failings of applying an analytical approach to these dynamic systems are exemplified by our current environmental and social issues as the full context of our ecosystem and its subsystems—in which the fashion system and economy exist—are not acknowledged. The result is that the boundaries

of industries such as fashion have been largely ungoverned by ecological thresholds. In 2013 the world was confronted with the statistic that fashion is one of the most destructive industries in contemporary society [5, 15]. While the accuracy of this claim has since been disputed, it is difficult to be specific about data on an industry so globalised, complex and vast, connected as it is to the oil, petrochemical, agriculture, manufacturing, retail and shipping industries. This information provides us with an opportunity to be more vigilant regarding this seemingly harmless industry, and for the industry itself to begin to ask questions about its reliance on growth.

If we accept and understand the concept of systems thinking, that is, the idea that all human activity is interconnected and interdependent, we understand that there are limits or boundaries to growth in our finite ecosystem [18, 40]. The ability of this system to absorb waste and replenish raw materials is compromised by fashion overproduction and consumption. According to Meadows et al. [42] we have several options: to ignore and continue as usual; to create eco-efficient solutions that will solve problems in the short term; or to adopt a more strategic approach, addressing the underlying causes and changing the structure of the system. Yet despite the magnitude of these warnings, the fashion industry has opted for the second choice, continuing to operate with a twentieth-century reductive, anthropocentric, and technocentric mindset in a belief that scientific and technological advancements will create the required solutions—in other words, upholding the status quo by tweaking around the edges, amending things in isolation, and treating the symptoms, not the causes. For example, the Pulse Report from the Global Fashion Agenda [6, 7] attempts to improve the industry but neglects to accept the full context and the realities of the biophysical limits of our ecosystem. The report continues to advocate for a logic of growth with 'The Roadmap to Scale' of continued consumption, while not addressing the tensions and contradictions inherent in this approach in our bounded system (Fig. 6).

3.1 Disengaged and Disconnected Consumers

The dominant industry model is one of mass production of low-quality, cheap clothing that is disposable and lacks transparency. Fashion designers have created a distance and a barrier between themselves and their users. Positioned apart, as 'experts' or gatekeepers of taste and style, they design on behalf of their wearers who rely on and trust their authority [36] and their design integrity. Fashion users are conditioned by this system to be passive, often kept in the dark about the impacts and true cost of these products on people and the planet. Consumers are buying more clothes than ever before, but the use time for wear and depth of engagement with these items is decreasing as almost half of what is purchased is thrown out every year [29]. The world is drowning in clothes that appear to have no meaning or sustained purpose beyond a few wears by their users. A UK study of almost 2,000 women over 16 years of age [3] found that the average garment is

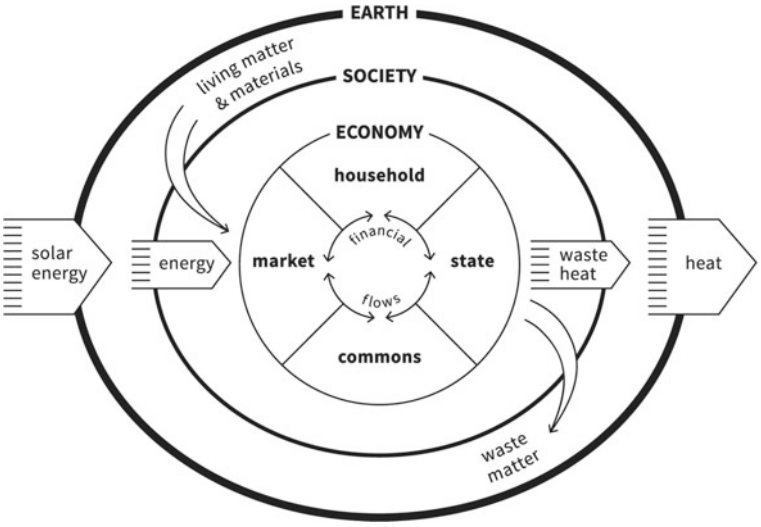

Fig. 6 Embedded fashion economy in our ecosystem. Diagram by Marcia Mihotich. Copyright © Raworth [50]

only worn seven times. Designers need to concede that the clothing produced in this system is failing people, as it is of little value or meaning to them. Fashion users/wearers demonstrate concern about ethical practices and environmental issues [46, 47], but this concern and awareness does not always follow through to action [47]. After experiencing decades of price conditioning, consumers cannot understand the higher cost of a sustainable garment, signalling a lack of awareness of the complexity of the fashion system. For Western consumers, the impacts of this industry are complex and difficult to comprehend, as these happen somewhere else, to someone else. Consumers have become detached, confused, and disengaged. As Fashion Revolution [25] proclaimed in its global campaign for transparency across the supply chain, 'Purchasing a garment means purchasing a whole chain of value and relationships'. Buchanan [10, p. 11] states that unless products—in this case, clothing—become part of one's life experience, they have little value or meaning. Activating consumer empathy and understanding of the people engaged in making their clothes or getting them involved as a fashion experience may indeed be a powerful method of connecting and interacting across this disconnected system.

An oft-quoted statistic in relation to product development is '80% of environmental impacts are determined in the design stage' [45] of a product. From a system thinking perspective, this raises many questions about the causality of decision-making in the design process. How much agency does the fashion designer have in making decisions about ethical practices, labour standards, material choice, and transportation? What if designers began to open up dialogue and communicate their actions with fashion wearers to create feedback loops for participation in environmental decision-making? Could designers extend their responsibility to

helping consumers understand the indirect implications of their actions within the system, and deepen the connection and relationships among designers, products, and fashion users?

3.2 *Limits to Design: Inward Practice*

According to Muratovski [44] there are essentially two approaches to design: the first as inward-looking practice for oneself, or the second as an externally driven approach—design for others. The majority of fashion designers, particularly at the high end of the market, approach fashion in the former manner. While the work is for an intended audience, it is essentially a form of personal self-expression and decisions are driven by the fashion designers' aesthetic choices [30]. This approach has restricted designers from applying their skills and knowledge across a wider range of activities or on systemic solutions, including services and systems that could address environmental or human rights issues [9, 43]. It has meant that the remit for design activities is narrow as fashion designers are not taught, encouraged, or empowered to explore the boundaries of their discipline. The majority of their work is spent on investigating form and/or technical application led by principles of aesthetic and economic factors. The standard method is often one based on intuition, practical knowledge, assumptions, and creative expression driven primarily by personal aesthetics [20].

Fashion designers are primarily concerned with 'designing'—often in the form of a drawing—discrete physical products that look 'good' within an infinite growth paradigm; that is, giving life to form with little consideration of where the material comes from, how it behaves in use, and what will happen to it after it is no longer desired. The designers' sphere of concern is primarily centred on what they are designing—the product and material—and not on whom they are designing for or with—the wearers and makers [39]. While the knowledge of creating physical artifacts is undeniably important, these garments are often made in isolation, without a connection to the end-users or the ecosystem of which they are a part [30].

The external approach as posited by Muratovski [44] positions design as a form of problem-solving, where the needs of others are at the forefront of the design intention and the outcome is driven by enquiry-led research rather than by taste or style. A research-driven, user-centred, problem-solving approach in terms understood by design thinking research [8, 17] is rarely part of fashion design. Instead, fashion designers stay within the narrow confines of the status quo for fashion, where they have been given permission for innovation to occur. For many fashion designers, their role consists of rehashing older styles, following the same well-worn linear path from idea to production/make to retail/consumption and, eventually, to waste [16].

As observed in my many years (2007–2019) of teaching design students across disciplines in interdisciplinary projects, there is a notable difference between

fashion designers and designers from other disciplines in their ability to engage their strategic mindset, question existing solutions, or understand and solve complex problems that have not been 'solved' already. Design students from other disciplines are attuned to and adept in this territory, engaging in 'solving' or 'seeking' practices, in contrast to fashion designers who are unfamiliar with this approach and rarely consider design in this way. Important shifts in design are taking place around the world, from 'product creation' to 'process creation' and from a 'field of practice' to a 'field of thinking and research'. As the approach for design shifts from problem-finding to problem-predicting, this raises concerns for the future of the fashion industry if its designers are not prepared or able to work in this way. It also raises questions regarding the relationship and responsibility of education on the current situation. If, as [44] asserts, the internal approach to design favoured by fashion designers limits their skills and ability to take a more strategic role in the formation of outcomes, one might well question how much this approach plays a role in current problems inherent in the fashion industry. The need for fashion designers to expand their problem-solving toolkit to incorporate design research and practice in the pursuit of better outcomes for all has never been so urgent and important.

4 Discussion

4.1 The Need for New Ways of Designing

Fashion design is as powerful as it is pervasive. It is everywhere, as everyone wears clothes. It has the potential to tap into the richness and complexity of its system to have real power and meaning, but it has lost its way. It has been forgotten that what is interesting is the interaction between 'things' and not the 'things' (in this case, clothing) in and of themselves.

The challenges facing humanity in the twenty-first century involve complex systems for which there are incentives from a sociotechnical systems perspective to transform all industries within parameters set by the United Nations' 17 Sustainable Development Goals [54]. Fashion designers must change the way they design so that they can reconnect fashion to its purpose and context—its interaction with people as both a social process and a material practice in our ecosystem.

The framework for design has expanded in the twenty-first century, as all designers will need to learn to operate in a cross-disciplinary way to collaborate with non-designers, conduct research, and make informed decisions in a systematic manner. As Muratovski [44, p. xxii] declares, 'In the twenty-first century, design involves a wider range of challenges than typical of design in the twentieth century, and a wider range of goals. Design also involves a broader context and greater complexity'. In this complex environment, the boundaries, expectations and audience for 'creative outcomes' are blurred, reimagined, and redefined [28]. An

examination of the fashion industry reveals that it meets the definition of a 'wicked problem' [9], as a series of interconnected problems, with significant economic and environmental responsibility, multiple opinions, and incomplete or conflicting knowledge.

This leads us to ask: is it time to examine the boundaries and context for fashion to reconsider its 'outcomes' and purpose? Irwin [33, 41] posits that 'the transition to sustainable futures calls for new ways of designing that are based upon a deep understanding of how to design for change and transition within complex systems'. Theories of Transition Design are essential for designers to build the necessary skills, literacies and mindsets required to confront twenty-first-century global challenges. According to Buchanan [10, p. 12], 'The idea or thought that organises a system or environment is the focus of fourth-order design.'

This research asks, in this time of transition: Can we apply a systems approach to fashion design toward a more expansive view of fashion (Fig. 7)? Can we move towards a higher order of design such as action and experience, environment and systems, oriented for and with engaged wearers and users? Can this be done with the aim of creating, as Fletcher [27] describes, a new narrative for a more open, diverse, resourceful, emancipatory, and holistic fashion and clothing system that helps wearers understand the true cost of clothing?

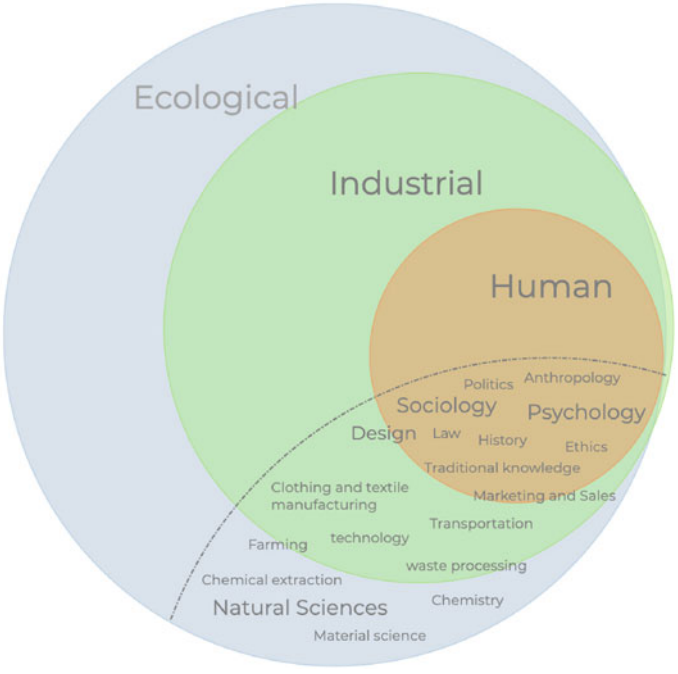

Fig. 7 An expansive view of fashion [55]

4.2 *Fashion Design as Action and Interaction, Forging Empathy and Engagement*

Philosopher Soper [53] claims that humans do not have an innate impulse to consume, but instead have an urge to connect, to relate to one another, to be creative and to be productive. Tapping into these values and drivers rather than ones of novelty could provide an impetus to engage consumers in alternatives to contemporary resource-intensive consumption systems. Chapman [11] sees garment waste as a symptom of expired empathy.

Bengtsson [4, p. 89] asserts that a product designer is at his or her best when they perform like a 'behavioural scientist' winning our trust and love as 'they focus on what is to be human'. He identifies two different schools of design: those who choose to focus on the noun, that is, 'the glass' or 'the garment', the second-order of design [9]; and those who prefer the verb, that is, to drink' or 'to wear'—the third order—as a driver for design. This aligns with contemporary fashion theorists such as Entwistle's [24] interest in 'new materialism' as a tool to address specific sociocultural concerns as a philosophical framework on embodiment, and the materiality of the human body. This framework helps to understand fashion and dress as a situated bodily practice. It provides another way of considering it beyond the noun, the object, or the dress in isolation, by reasserting the importance of the bodily 'experience': how clothing enables us to move, feel, interact and perceive the world.

Fashion designers have predominantly adopted the first school of design, focusing on the noun and designing the product in isolation based on aesthetic values, with little insight or empathy for human behaviour and interaction with clothing. Fashion designers do not deeply consider the 'craft of use' [27]—the lived, real experience of fashion, the act of wearing and 'being in a garment'. When human behaviour has been examined for fashion, it is normally directed towards exploiting our ability to buy the next item, not to keep it, wear it, and have a fulfilling fashion experience.

At a time when consumers are wearing their clothing for less time than ever before, we must acknowledge that the lack of consideration of the use phase contributes to this situation. If we consider fashion from the more complex, higher orders of design from the perspective of interactions, experiences, and systems to address what makes a product/garment useful, usable and desirable, and then engaged user-centred methods, fashion designers could become more attuned, empathic designers, and discover an integrated new understanding of what fashion could be. This may be able to deliver prosperity for all.

Through design, people can align their actions with their values, and see the bigger picture [14] to encourage more complex interrelationships with and around their garments. Kate Fletcher's research project, 'Local Wisdom' [26] sought to flatten the hierarchy of the current system by examining the role of 'non-professional' user-makers and how they can contribute to the fashion system without relying on the professional skills of designer/producers.

Changes in function or purpose can be profound. If the purpose of fashion and the mindset of fashion designers can be shifted towards behaviour, and the action of wearing, this could lead to fresh thinking around sustainability, to an expanded view of fashion that really fulfills us and equips us for living.

5 Recommendations

This study is meant to act as a catalyst for a conceptual model that aims to reconnect the fashion system, and engage fashion design with a higher order of design to align with sustainable practices. In order to shift the fashion system, we must acknowledge it as part of an ecology of sustainable practices that are evolving and dynamic.

The following recommendations follow an approach as posited by key systems theorists such as [2] in order to develop a systems mindset for the fashion industry:

1. Interconnectedness (Fig. 8): This requires a shift from the 'mechanical worldview' of the fashion system as being linear in order to confront its reality as a dynamic, chaotic, interconnected array of relationships and feedback loops that occur before, during, and after a garment is created. Levelling the inherent hierarchies and discrete skill sets that restrict innovation, creativity, and responsibility across the entire fashion system and beyond will provide opportunities for investigation and for new modes of practice.

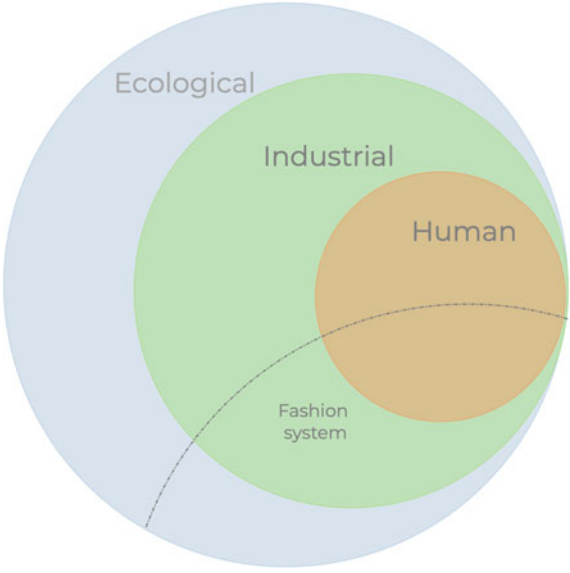

Fig. 8 Interconnectedness [55]

2. Synthesis (Fig. 9): Synthesis means being able to see the relationships and the connections of the entire fashion system as a whole, not as a discrete set of activities that become myopic, losing perspective on the ultimate goal of the lived, real experience of fashion in our ecosystem. The fashion designer as a key player can advocate for change and synthesis throughout a garment's life cycle, and can also challenge conventional ideas about the work of a designer as not simply designing clothing, but rather arranging entities/textiles into sets of relations [38].
3. Emergence (Fig. 10): Emergence refers to the outcome of the synergies of the parts; of things interacting together. This could mean many things in fashion, such as broadening the education and remit for designers to understand the interlocking complexities of human and social behaviour, from behavioural sciences, technology, and business. It could also refer to the new synergies that could occur if environmental or ethical issues form a part of the design and production process or fashion design brief. Challenging conventional ideas is not so much concerned with designing clothing, but rather on arranging entities/textiles into sets of relations [38].

Fig. 9 Synthesis of fashion system and roles [55]

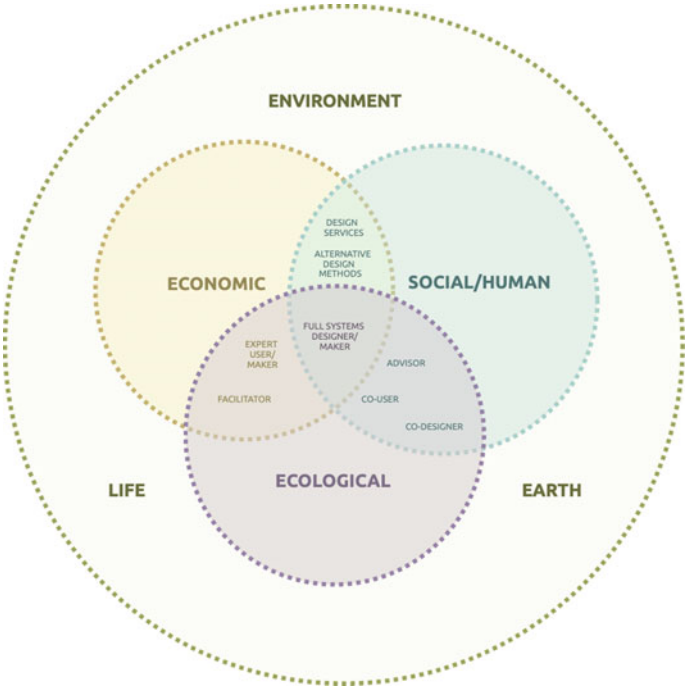

Fig. 10 Emergence [55]

4. Feedback loops (Fig. 11): Much rich engagement and connections across the fashion system have gone unnoticed and are not harnessed for the value they have for the system as a whole. First, the system needs to observe and understand this information and then intervene in feedback loops that recognise when they are *reinforcing* and *balancing*. An alternative fashion system could ignite higher levels of design such as action and experience, environment and systems, if it created stronger feedback loops which could result in greater collaboration of individuals and designer/makers in conjunction with fashion users. Designers could learn from people via 'local wisdom' [26], reflecting and reconceptualizing the role of the designer in a future fashion industry.

Causality (Fig. 12): With the perspective of causality, fashion will start to consider its agency and impacts. Consider the entire lifespan of a garment, traditionally designed with a built-in obsolescence, instead designed to last beyond a season for a deeper, longer engagement. This would be a major rethinking of how the fashion industry works and would shift the general public's expectations of and engagement with fashion. This could also shift industry concerns from purely monetary to other forms of capital, such as human, cultural, and environmental.

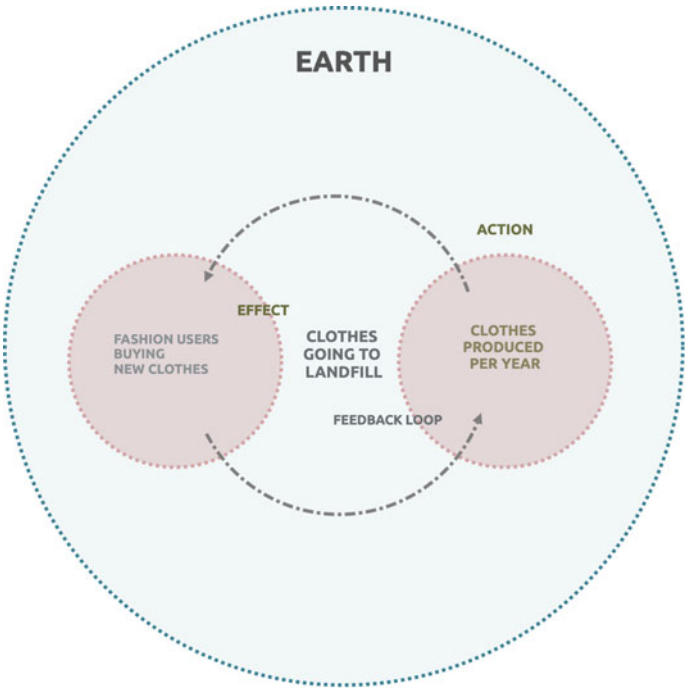

Fig. 11 Feedback loops [55]

Systems Mapping (Fig. 13): If fashion designers can identify and map the elements of 'things' within its system, they can understand how these interconnect and interrelate. This will lead to unique insights and discoveries that can be used to develop interventions, shifts, or policy decisions that will dramatically change the system. An example of this is the zero-waste fashion movement. Designers have examined and mapped part of the production process to develop a fusion of approaches between three-dimensional forms, virtual avatars, and two-dimensional pattern-making until fabric waste is minimised. This is a point of reference from which to consider how designers, working at all levels of the industry, can rethink their role and behaviour in the context of the system and sustainable design strategies.

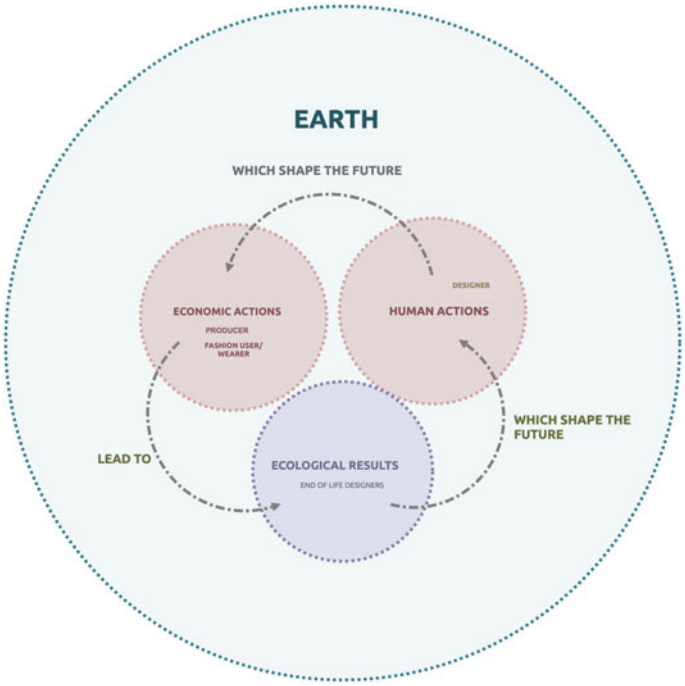

Fig. 12 Causality [55]

6 Conclusion

Systems thinking, while not a new concept for design, has significantly changed its focus in the twenty-first century from one of material systems—systems of 'things'—towards human systems and the integration of information, physical artifacts, and interactions in environments of living, working, playing, and learning [10]. It is the distinction between our traditional method of analytical reasoning and the alternative method of synthesis that forms the foundations of system thinking. We have made significant breakthroughs and leaps in progress by applying analytical thinking to human endeavours, looking through a microscope at the world, but we need to remember to shift that view to the perspective that a telescope brings to observe all the infinite possibilities of space and the universe. As Manzini [39] notes, in this time of profound change we are compelled to look at our context and consider how we, as individuals and collectives, can use our creative capacities. Fashion needs a period of self-reflection and radical change that systems thinking

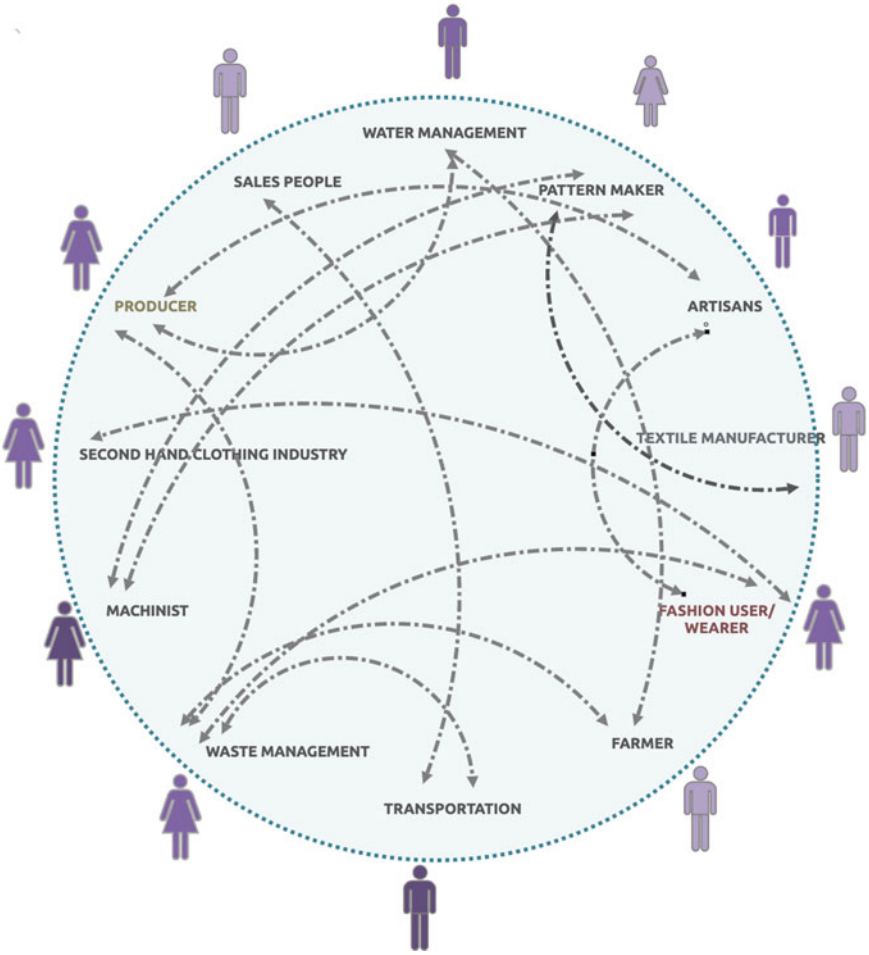

Fig. 13 Systems Mapping [55]

can bring, in order to remain relevant in the twenty-first century and to move away from a linear economy towards a circular, regenerative economy based on feedback-rich flows. The future of the fashion system is ripe for new modes of practice that challenge the dominant logic and the relationships among the designer, producer, and consumer.

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Jennifer Whitty is an Assistant Professor of Fashion Systems and Materiality, at Parsons School of Design, New York, where she is also the Coordinator of the BFA Fashion Systems and Society Pathway, and the Coordinator and Course Lead for a new certificate in 'Sustainable Fashion' for continuing education. As an educator, researcher, designer, facilitator, and writer with over a decade of global experience in the field of sustainable fashion design. Her work aims to usher in a new era of deep systemic change for fashion in mindsets, models, and systems that is expansive and diverse, rooted in social and environmental justice.

Composite Material Design for Aircrafts from Sustainable Lignocellulosic Fibers—A Review

Çiğdem Gül and Emine Dilara Kocak

Abstract Transportation vehicles include aircraft, automobiles, motorcycles, trucks, buses, trains, boats, ships, trams, etc. Composite materials are used extensively in this industry. Required properties for composite materials are good mechanical properties, biodegradability, renewability, abundance and low cost. Composites, which are the most important component of the aerospace industry, began to be used in aircraft in the 1950s. A lot of aircraft parts are made of synthetic fiber reinforced composites. The most commonly used fibers in synthetic fiber reinforced composites for aircrafts are glass, carbon and Kevlar. However, leading aircraft manufacturers have goals such as reducing aircraft weight, increasing fuel efficiency and minimizing the impact of manufactured products on climate change. Therefore, the composites produced for the cabinet are desired to be recyclable, flame retardant, strong, flexible, biodegradable and lightweight. Natural fibers are preferred as reinforced material instead of synthetic fibers because of low density, biodegradable, recyclable, non-abrasive, low cost and easy availability. For example, Airbus, the world's largest aircraft manufacturer, is working on the use of hemp, linen, kenaf and sisal fibers for manufacturing of the sidewall and ceiling panels, the insulation covers and the other aircraft interior components. It is considered to use natural fibers as a reinforcement element in composite materials to increase fire resistance, reduce smoke level and toxicity. In this study, information will be given about the latest developments in composite design from lignocellulosic fibers in aircrafts will be given.

Keywords Sustainability · Composites · Lignocellulosic fibers · Carbon footprint · Aircraft

Ç. Gül (✉)
Institute of Pure and Applied Sciences, Marmara University, Istanbul, Turkey
e-mail: cigdem.gul@marmara.edu.tr

E. D. Kocak
Department of Textile Engineering, Faculty of Technology, Marmara University, Istanbul, Turkey
e-mail: dkocak@marmara.edu.tr

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1 Introduction

The environmental issues are very serious for the future of human beings and the solution to those problems is one of the global goals. Synthetic production activities increase environmental problems. Greenhouse gases generated as a result of synthetic production activities absorb heat trapping it between the atmosphere and the earth and cause the temperature of the planet to rise. One of the most important reasons for the rapid increase of greenhouse gases for 150 years is human activities. The most important reason for greenhouse gas emissions in the United States; is the use of fossil fuels in electricity, heating and transportation. According to 2018 data, the largest part of greenhouse gases is generated by transportation sector. This sector involves 28.2% of all greenhouse gas emissions. In the transportation sector, greenhouse gases actually result from the use of fossil fuels in land (car, bus, truck, etc.), air (plane, helicopter, etc.) and sea (ship, etc.) vehicles [1]. According to the International Air Transport Association (IATA) and Air Transport Action Group data, all of the flights constituted 915 million tons of CO_2 gas in 2019, which is equivalent to 2% of CO_2 gas from human activities worldwide. All over the world, people have produced more than 43 billion tons of CO_2 gas [2]. The rapid rise of carbon dioxide gas in the atmosphere causes major disasters such as global climate change. In addition, excessively use of petroleum-based materials and the inability to dispose of non-degradable solid waste are other important problems. This has raised awareness of producing new biodegradable materials. Materials science has begun to follow a sustainable path since the end of the twentieth century due to growing environmental concerns. Sustainable, renewable, environmentally friendly materials are called "green materials, green chemistry." Green chemistry is the design of chemical products and processes that reduce or eliminate the use or production of hazardous substances [3]. Green composites have attracted great attention from both academia and industrial sectors due to the need for new environmentally friendly products [4]. There is a growing research interest in bio-based products due to the rapid consumption of natural sources and synthetic production activities that are responsible for environmental pollution. The Food and Agriculture Organization (FAO) of United Nations, or the Common Fund for Commodities (CFC), has foreseen the use of plant-based materials for leaving a clean environment to future generations and disposing of harmful chemicals; thus, the legislation on the use of natural materials and wastes has been adopted by governments in this context [5].

The decision of which material to choose must be taken during product design and this material must comply with the demands of the market, the legislation, cost and a sustainable environment [6]. Composites are the most promising material of this age. Composite materials are among those that play an important role in current and future aviation components. The composite is a new material that is formed by the combination of at least two or more different materials and is stronger than its components when combined. A great deal of aircraft parts is made of polymer composites that are reinforced with man-made fibers such as glass, carbon and

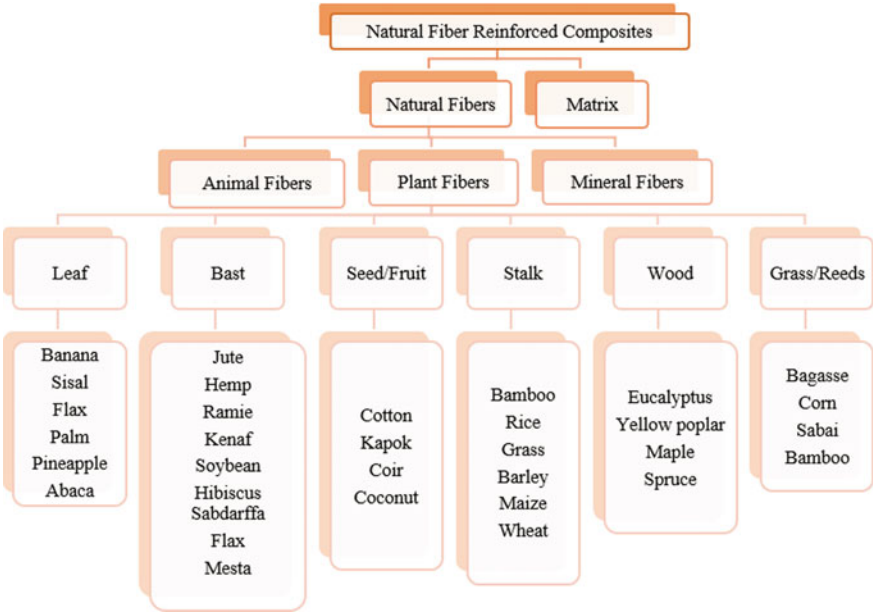

Fig. 1 Plant fibers types [7, 8]

kevlar. Composites consist of two parts as matrix and reinforcement element. Natural fibers are divided into three parts: animal fibers, vegetable fibers and mineral fibers. The diagram below shows the subcategories of plant fibers. In recent years, researches on plant fiber reinforced composites have been at the forefront of aviation (Fig. 1).

Synthetic fibers, which are reinforcement elements, are generally more resistant and harder than matrix materials [9]. The basic purpose of designing aircraft parts from composites is to minimize the aircraft weight as much as possible. Composites allow the design of more strength aircraft parts. Aircraft parts are subjected to too much compression and tensile rough out the distance from take-off to landing. Therefore, it is an advantage to have both strength and light parts and that stress enhances the safety rate [10]. Carbon fiber reinforced composites are an ideal material for manufacturing many parts of an aircraft, thanks to their lightness, strength and smooth surfaces. Using carbon fiber reinforced composite in the airframe allows it to be produced with less fuel saving, more aerodynamic and lighter parts [11]. Carbon fiber reinforced composites provide a better strength/weight ratio than metals and are more resistant to fatigue and corrosion [12]. Although synthetic fiber reinforced composites show good mechanical properties, thermal stability, corrosion and fatigue resistance, are not completely biodegradable in nature [13]. Figure 2 shows the proportion of composites used in the Airbus A350 XWB type aircraft.

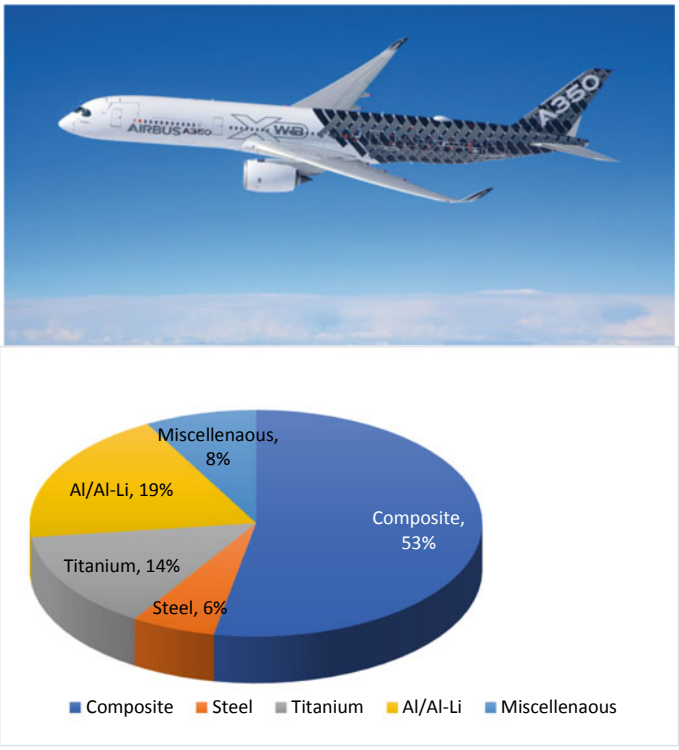

Fig. 2 Airbus A350 XWB (https://www.airbus.com/aircraft.html)

The use of composite materials in aircraft design is gradually increasing. The A350 XWB is the latest example of this upward slope. While aluminum material was used in aircraft in the early 70s, composites developed by the designers to reduce fuel costs facilitated the transition. Because composites weigh 20% less than aluminum and the reduction in weight also reduces fuel consumption. Composites consist of reinforcing elements and matrix parts. Using fibers or fabrics as reinforcement elements will provide strength and stiffness to composites [14].

Composites are widely used in some parts of modern aircraft such as rudder spoilers, air brakes, elevators, LG doors, engine covers, keel beam, rear bulkhead, wing beams, main wings, turbine engine fan blades, propeller and aircraft interior components [15]. These parts consist of glass fiber or carbon fiber reinforced composites. Aircraft parts are manufactured from carbon or glass fiber reinforced composites due to their superior strength-to-weight ratio and aerodynamic efficiency [14]. Although composites obtained with synthetic fibers show superior mechanical properties, they are disadvantageous due to some properties. Some toxic residues are formed during the production process of synthetic fibers. The fact that these wastes are not completely degraded in nature causes great environmental problems. To solve this problem, economical and environmentally friendly natural

material with good mechanical properties is needed [16]. Natural fibers consist of cellulose, hemicellulose, lignin, pectin, wax. Although natural fibers have excellent properties compared to synthetic fibers such as biodegradability in nature, cheap, readily available and low density, the main limits of using natural fibers are low flame resistance and moisture absorption [6].

In this chapter, information will be given about the research on natural fibers in the design of aircraft components, the manufacturing processes of their components and their efficiency compared to synthetic fiber reinforced composites. Firstly, information will be given about the advantages and limitations of natural fiber reinforced composites, then the selection of the materials used in aircraft will be mentioned. In the next part, the applications of sustainable lignocellulosic fiber reinforced aircraft components will be explained, and in the last part, suggestions for contributing to future studies will be presented.

2 Advantages and Limits of Natural Fibers

2.1 Advantages

Specific properties: Cellulose-based natural fibers have a relatively low density, stiffness and strength.

Cost: Because many natural fibers are cheaper than synthetic fibers, natural fiber reinforced composites are also cheaper than synthetic fiber reinforced composites. In addition, due to the low density of natural fibers, the transportation cost of these fibers is lower than synthetic fibers [17].

Health: People who produce natural fiber reinforced composites have fewer health problems. Natural fibers do not cause skin irritation or lung cancer.

Biodegradability and environment: While natural fiber reinforced composites can be converted into environmentally harmless (biodegradable) and recyclable products, synthetic fiber reinforced composites cannot. Materials that cannot degrade in nature cause great environmental pollution. Non-degradable and accumulated wastes threaten the future of our planet and humanity. From an environmental point of view, natural biodegradable materials are more advantageous than synthetic materials.

2.2 Limits [18, 19]

Natural fibers are highly affected by the environmental conditions and these conditions determine the fiber properties. The environmental conditions that determine the fiber properties are the region and time of harvest, the nutrient and mineral properties of the soil, the amount of sunlight and rain.

Natural fibers have a strong affinity for water. So they have hydrophilic structures. However, synthetic fibers have a reverse situation, they have hydrophobic structures. The disadvantage of using plant fibers is that the fibers are not distributed homogeneously in the matrix, resulting in poor interfacial bonding.

When natural fibers are exposed to high humidity, their mechanical properties decrease.

Another disadvantage is that the processing temperature is below 200 °C. Above 200 °C, the fibers begin to degrade.

Lower strength, especially impact strength compared to synthetic fiber composites,

Less durability than synthetic fiber reinforced composites.

3 Sustainable Aircraft Interior: Material Selection

The aviation industry has focused on the development of sustainable, environmentally friendly aircraft interiors based on natural fibers. The use of natural fiber polymer composites in aircraft interiors increases fuel efficiency while reducing carbon footprint and weight. C.V. dos Santos et al. [20] prepared a guide for selecting and designing materials for use in executive aircraft interiors. According to Santosa material selection decision is usually taken stage product design. The chosen material should meet demands, cost reduction, legal regulations and sustainability of the environment. They emphasized that sustainable materials for the existing honeycomb panels are biopolymer composites reinforced with natural fibers and solid cores [20]. The aviation industry has taken a step forward in revolutionizing natural fiber aircraft panels. Linen, ramie, and hemp are used to create interior parts, especially for cabin services [21].

4 Sustainable Lignocellulosic Fiber Reinforced Aircraft Components

4.1 Radome Applications for Aircraft

Aircraft radomes are dome-formed structures that defend the radar antennas from aerodynamic loading (definition of how much weight the wing must lift per unit area), rigors of the weather and effects of bird strikes [13]. It is made of composite materials, usually from glass fiber (Fig. 3).

Glass fiber is widely used in composite material making for the aerospace industry due to its high strength, just like carbon fiber and Kevlar. However, these fibers are not biodegradable, so scientists started working on natural fibers. They have some superior properties compared to synthetic fibers, such as low density,

Fig. 3 Aircraft radome structure (https://www.aeronewstv.com/en/lifestyle/in-your-opinion/2985-what-is-a-radome.html)

Table 1 Mechanical properties of some fibers that are used in radomes [22]

Fiber	Tensile strength (MPa)	Tensile modulus (GPa)	Elongation at break (%)	Ref.
Kenaf	930	53	9.8	[25, 26]
Banana	392–677	20–24	5.9	[13, 27]
Bamboo	615–862	35.45	1.4	[13, 28]
Oil palm	50–400	1–9	8–18	[29]
Pineapple	170	34.5–82.5	1–3	[30]
E-glass	2,000–3,500	70	2.5–3	[13]
S-glass	4,570	86	2.8	[13]

low cost, renewable, abundant in nature and biodegradable. Because of these properties, the material has attracted the attention of scientists. Haris et al. [22] studied the properties of banana, bamboo, palm oil, kenaf and pineapple leaf fiber used in aircraft radome composites. At the end of the review, they mentioned that epoxy-hybrid kenaf (NaOH treated)-glass fibers can be used as potential materials for aircraft radome. Dielectric is crucial for aircraft radome selection. The dielectric constants of natural fibers range is between 2.8 and 3.2 [23]. Composites used for light aircraft radome have materials with low dielectric constant and high strength [24].

It is clear from Table 1 that the kenaf fiber has the best mechanical properties among other fibers. Kenaf fiber has similar hardness as glass fiber and low dielectric constant. As a result, kenaf fiber is suitable for radome in aircraft.

4.2 Natural Fiber Reinforced Composites for Aircraft Wings and Wing Boxes

The wing box is a major part of aircraft engineering to provide support and hardness to the wings. It can contain some supportive spars and chambers designed to isolate impacts. Spars are the main bearing element of the wings. There are one

or two spars on the wing and join the body perpendicularly or with an angle. While in flight, intense shear stresses occur on the wings of the aircraft. Without sufficient support, the wings would fold up toward the side of the plane. The wing box absorbs some of this stress and distributes to the framework, preventing the wing of the aircraft from swinging or bending. It also helps to absorb the blows experienced during events such as turbulence.

The use of high-performance carbon fibers in aircraft reduces structural weight, but causes environmental problems as carbon fiber reinforced composites are non-renewable. Boegler et al. (2015) have designed a model of civil transport aircraft from natural fiber composites (Airbus A320-200). In this study, the potential of NFC in aircraft wings is emphasized. They compared the weight of the wing box made of ramie fiber reinforced composites with a reference wing box made of aluminum alloy. When using ramie fiber reinforced composites, the weight reduction was found to be around 12–14% [31].

The use of natural fibers in the production of the wing can reduce greenhouse gas production considering the CO_2 footprint. The carbon footprint of the natural fiber reinforced composite wing made of ramie fiber is 12,600–22,600 kg. Table 2 shows the airplane wing masses produced from various natural fiber reinforced composites. Hemp and flax fiber reinforced composites significantly increase the weight of aircraft wing box, while Ramie fiber reinforced composites reduce the wing box weight [31].

Kumar et al. (2018) analyzed the bending, buckling and vibration behavior of an airplane wing made of natural fiber reinforced composites. Compared to synthetic fibers, natural fiber reinforced composites are low cost, low density and weight, easily biodegradable and environmentally friendly. In this study, two different combinations have been investigated, the first is two layers of graphite epoxy at the top and bottom and between 16 layers are sisal, flax, or aloe Vera epoxy; and the other is the top and bottom 2 of the glass epoxy and 16 layers are sisal, flax, or aloe Vera epoxy. The composites used in aircraft wings are required to have less displacement value, high natural frequency and high buckling factor. When the results

Table 2 The effect of composites made of different materials on wingmass in comparison to aluminum reference [31]

Material	Mass m (kg)
Epoxy/Flax	11,355
Epoxy/Hemp	10,503
Epoxy/Sisal	–
Epoxy/Ramie	*7,576*
PLA/Flax	11,784
PLA/Hemp	10,815
PLA/Sisal	–
PLA/Ramie	7,758
Aluminum 7,000 (reference)	*8,829*

are examined, it can be seen that the flax-epoxy composite fulfils all the above conditions in both cases. Therefore, flax can be used as a reinforcement material in the structural design of small robotic aircraft [32].

4.3 Natural Fiber Reinforced Composites for Aircraft Cabin Interior

Nowadays, sustainability and "green" interiors are of increasing importance in the aviation industry, just as in the automotive and construction sector. A European project called "Cayley" brought together Boeing Research and Technology Europe, Invent GmbH, Aimplas and Lineo. The main goal of this project was to industrialize environmentally friendly interior panels made with renewable polymers or recyclable thermoplastic sheets and natural fibers, namely flax. Boeing Research and Technology Europe announced that it aims to develop a bio composite sandwich panel that can be used for sidewalls inside its aircraft. Throughout the project, Boeing manufactured a sidewall panel for a Boeing 737 aircraft made with the flax-thermoset composite. Lineo reports that the linen uni tape called FlaxTape and FlaxPreg linen/epoxy prepregs designed for transport interiors (cars, trains and aircraft interiors) are 35% lighter than carbon fiber/epoxy prepreg tapes [33, 34]. FlaxPreg T-UD consists of a series of prepreg materials based on thermosetting resin and a unidirectional flax fiber reinforcements (FlaxTape™) system. This material is suitable for many applications in aviation. FlaxPreg T-UD prepregs can be used in combination with glass or carbon prepreg to optimize the strength, comfort and mechanical and anti-vibration performance of composite parts [35] (Fig. 4).

It is thought that natural fiber reinforced composites, which are widely used in construction and automotive industry applications, can play an important role in the secondary structures of new-generation aircraft. The biggest advantages of using

Fig. 4 Long flax fibers in thermoset reinforced sandwich panel (https://www.castrocompositesshop.com/en/156-flax-epoxy)

natural fiber composites are environmental benefits, low energy consumption, lightness, insulation and sound absorption properties. The South African Council for Scientific and Industrial Research (CSIR) and international commercial aircraft manufacturer Airbus have been working on developing composites from natural fibers and phenolic matrices for use as commercial panels for cabin interiors. The main purpose of this research is the use of natural fibers such as linen, hemp and hemp in the production of aircraft interior components such as ceiling and side wall panels and insulation covers. The Airbus team is looking for a strong, flame retardant, flexible, lightweight and biodegradable natural fiber for the cabin interior. Natural fibers such as kenaf and sisal caught the attention of the Airbus team due to their low cost, biodegradability, low density and recyclability [13, 36].

ECO-COMPASS, an important project, aims to evaluate the potential applications of ecologically optimized composite materials in the aviation industry in an international collaboration with Chinese and European partners. In this project, bio-sourced and recycled materials for aircraft that can be converted into environmentally friendly composites were identified. The hollow structure of the specified plant fibers can provide benefits such as structural damping, noise reduction and thermal insulation desired for the interior structure of the aircraft. In the future, the composite materials identified and developed in this project could be aircraft interior panels, gear doors, winglets and other secondary structures. Preliminary results have shown that bio-based composites made from flax and ramie plant fibers have the potential to be used in natural fiber reinforced plastics for aviation. However, in order to compete with the currently used glass fiber reinforced plastics, their tensile strength and fire-retardant properties need to be improved in particular [37, 38].

4.4 Latest Developments in Aircraft Industry

Natural fiber reinforced composites are also used in the outer structure of the aircraft. Scarponi (2015) designed a Naca cowling made of woven hemp-reinforced epoxy composite. Environmentally friendly Hemp/epoxy composites are used in the production of Naca cowling for ultra-light aircraft. Engine cover produced using hemp/epoxy composites shows that it would be effective to produce aviation components from natural fibers [39].

The manufacturing and use of aircraft cause places with big environmental cost. For this reason, studies are carried out to minimize the carbon footprint formed. Producing sustainable aircraft is just one of these studies. The hemp airplane prototype by the Canadian company Hempearth is the first in the world and will soon make its first test flight. So, for which features is it preferred? Hemp fibers are ideal for building durable structures. Hemp material is used as a reinforcement element in the production of composite materials. Hemp fiber is increasingly being used as an alternative to glass fiber polymers, especially in the automotive industry. It was inevitable to work on the use of this fiber in the aviation industry. The plane

Fig. 5 Perfect conversion from hemp fiber to airplane (https://www.theeducationmagazine.com/education-now/hemp-plane-develop-stronger-steel/)

that is made of hemp is capable of carrying one pilot and four passengers. The wingspan of the plane is 36 feet. Hemp/Cannabis is one of the healthiest and most versatile herbs in the world. It is ten times stronger than steel. This property means that it can withstand much more weight and can break and bend much more than metal. So it has a great feature for the aviation industry [40, 41] (Fig. 5).

Composites made from natural fibers can be 25–30% stronger than those made from glass fibers. The addition of hemp fibers to glass fiber reinforced composites increases the tensile and flexural strength of the material (up to 30–35%). For example, composites made from hemp fibers used in car parts reduce weight. In addition, hemp fiber composites provide greater comfort to users as they absorb sound very well [42]. If hemp works in the automotive industry, why not aviation researchers decided to use this fiber for aircraft construction. Today's aircrafts are usually made of metal alloys and composites reinforced with glass fibers. Aircraft made of hemp that is as strong as glass fiber but does not cause environmental problems has provided a great advantage. Unlike many materials commonly used in aviation, hemp is non-toxic.

Expleo, Arkema, Cobratex, Specific Polymers, Cirimat, Compositadour, Lisa Aeronautics and Mécano ID formed a consortium to develop bio-sourced composites using long bamboo fibers. It was announced that this new material, called BAMCO (Bamboo long fiber reinforced bio-based Matrix Composites), could help reduce the environmental footprint of aircraft. As the glass/phenolic polymer composites currently used in aircraft will soon be affected by the European REACH regulation, there is an urgent need to develop alternative solutions. Expleo and CIRIMAT are working together on a bio-composite concept created using bamboo fiber to reinforce a bio-sourced thermoplastic matrix. It is a material that will replace glass/phenolic composites due to their very low weight, thermal resistance and mechanical properties (Fig. 6).

In the aviation industry, Bamco biocomposites can be used in cabin furnishings and cover panels and fuselage cladding panels and aircraft kitchen panels. Cirimat is responsible for the design and lab-scale production of thermoplastic or thermoset composites reinforced with bamboo fibers. Expleo will design the prototype

Fig. 6 Bamboo fibers are being used for bio-sourced composites for aerospace

components in this project. Arkema and Specific Polymers are responsible for the formulation of bio-sourced polymers used in composite matrices. Cobratex will research and recommend bamboo species. Mécano ID is responsible for conducting vibration-damping tests and modeling the behavior of bi-composites. Aircraft manufacturer Lisa Aeronautics will participate in the development of the prototype part. The first prototype parts are planned to be produced in 2021 [43].

5 Conclusion

Increasing environmental problems and efforts to overcome this make it inevitable to use natural fibers in future aircraft designs. Results regarding the use of lignocellulosic fibers in aircraft are as follows:

1. In aircraft, material selection should be determined during product design. The selected material should be environmentally friendly and biodegradable.
2. Kenaf fiber has superior mechanical properties among natural fibers. Kenaf fiber has similar hardness like glass fiber and low dielectric constant. As a result, kenaf fiber is suitable for radome applications.
3. Rami fiber reinforced composites significantly reduce wing box weight.
4. Flax fiber reinforced composites can be used in aircraft cabin interiors.
5. The hemp airplane prototype by the Canadian company Hempearth is the firs in the world and will soon make its first test flight.
6. Major commercial aircraft manufacturers such as Airbus and Boeing have begun research about producing various components of the aircraft using natural fibers.

The use of natural fiber reinforced composites in various aircraft components is expected to increase in the near future.

7. Expleo, Arkema, Cobratex, Specific Polymers, Cirimat, Compositadour, Lisa Aeronautics and Mécano ID formed a consortium to develop bio-sourced composites using long bamboo fibers. Bamco bio composites can be used in cabin furnishings and cover panels and fuselage cladding panels and aircraft kitchen panels.
8. The natural fibers such as kenaf, bamboo, coir, sisal have proved to be some materials with the high strength in aerospace application.

6 Proposal for the Future

In this review study, it is seen that natural fiber reinforced composites have a promising future in the production of light and environment-friendly aircrafts. The performance of plant fiber reinforced composites depends on the chemical composition and structure of the fiber, the angle of the microfibrils, its physical and mechanical properties, and the interaction of the fiber with the polymer. While natural fibers are hydrophilic, problems arise in composite production with hydrophobic polyethylene and polypropylene. The hydrophilicity of natural fibers affects the mechanical properties. Because, due to the high moisture retention of natural fibers in hydrophilic structure, poor adhesion occurs between the fiber and matrix. Modifications made on the surface of the fiber with alkali and other chemical treatments provide the improvement of adhesion and mechanical properties. When evaluated in terms of sustainability, the use of lignocellulosic plant wastes in the production of composite materials will contribute to the production of environmentally friendly materials. Cellulosic fibers can easily burn due to their nature. Another one of the studies carried out today is aimed at providing natural fibers with a non-flammable feature to be used in aircraft. They are nitrogenous and phosphorus compounds that increase the flame retardancy of cellulosic fibers. The addition of these compounds to the structure of cellulose will give the material flame retardant properties. However, instead of using flame retardant chemicals, it would be appropriate to use naturally occurring phosphorus compounds in order to provide non-flammability to composites obtained from natural materials.

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Sustainability in Textile Design

P. Senthil Kumar, P. R. Yaashikaa, and C. Femina Carolin

Abstract Textile designing is the process of creating novel designs for knitted, printed fabrics, or woven. Sustainability is delivering things required by humans without causing disturbance to natural balance and future generation and also to reproduce in beneficial ways. Sustainability in textile designing considers environmental issues. It identifies the environmental concerns and also the responsibility of a designer in showing the required modifications in designing. Since designers are in the main positions for handling, this chapter focuses on the qualities that constitute designing practices. This chapter also identifies the environmental design techniques so that designers may creatively develop performance strategies based on life cycle analysis methods. Natural return is the major aim of sustainability to produce eco-friendly products. The innovative designing results in the development of new designs with more variety of products than humans require. This results in damage to the ecosystem and humans. Thus, the products produced through sustainable design must possess better characteristics with improved quality. Designs must be created for the necessary need rather than to fashion.

Keywords Sustainability · Textile design · Eco-design · Circular economy · Life cycle analysis · Eco-friendly products

P. Senthil Kumar (✉) · P. R. Yaashikaa · C. Femina Carolin
Department of Chemical Engineering, Sri Sivasubramaniya Nadar College of Engineering, Chennai 603110, India
e-mail: senthilkumarp@ssn.edu.in

P. Senthil Kumar · C. Femina Carolin
Centre of Excellence in Water Research (CEWAR), Sri Sivasubramaniya Nadar College of Engineering, Chennai 603110, India

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1 Introduction

The primary objective in sustainability is to leave a sustainable world to the next generation, to rebalance the social, biological, and financial support, to make however many regular returns as feasible, to oversee assets appropriately, to sort out and to secure the biological equalization of the Earth. Sustainability is the only way in the current situation with modern creation today. Sustainability is stood up by the capacity in a focused creation condition, to work in a resource-restricted environment, to lessen natural effects, to diminish costs for a reasonable generation, and to continue their advantages by gathering client desires and concerns all zones including the administration area. The utilization of the idea of sustainability in the assembling area is the environmental change that is the outcome of the high carbon level in the air [9]. The start is the Industrial Revolution, which prompts the improvement and fast development of creation advancements. A definitive point in the life cycle of humans is a worldwide temperature alteration, environmental change, ozone layer exhaustion, acid rain, weakening of air quality, and corruption of ecological balance.

The premise of the Industrial Revolution is textile items. The improvement of automation, turning, and dyeing innovation, and other textile-related advancements in the modern transformation has additionally prompted the improvement of textile items. This improvement has changed the regular balance and harmed the maintainability of life. This improvement configuration factor also added to a wide scope of items, for example, product variety, customized structures with the main impetus of changing living conditions, and the impact of the design factor. Then again; the design is being turned to again rebuilding the characteristic equalization that has been crumbled by the quick improvement of innovation and to leave an economical world that can be experienced in the future. Various reactions, for example, feasible plan, biological structure, green plan, plan for economical living, eco-friendly design and also appears to reflect the complex nature of the concern [15]. Figure 1 represented the roadmap of this chapter and gives details about the sections explained in the chapter.

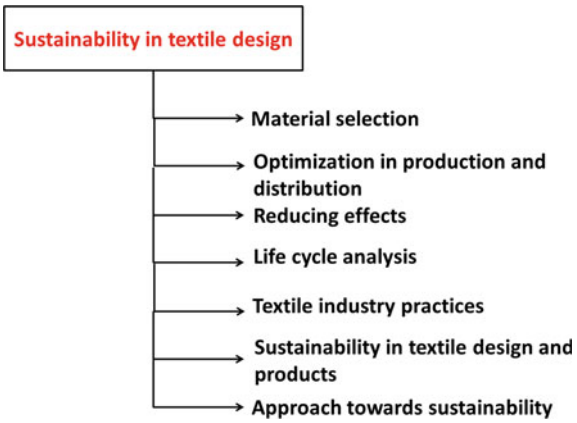

Fig. 1 Roadmap of this chapter

2 Sustainability and Sustainable Development

Sustainability is a fundamental idea, identifying with the coherence of social, financial, institutional, and ecological parts of human culture. It is proposed to be a method for designing progress and human movement with the goal that society, its individuals, and its economies can address their issues and express their most prominent potential in the present while safeguarding biodiversity and common environments, arranging and representing the capacity to keep up these beliefs unspecifically [5]. Sustainability influences each degree of association, from the nearby neighborhood to the whole planet. Sustainability might be depicted as our duty which will enable the following generations to live easily in a clean and friendly world:

- respect individual rights and network obligations;
- recognize social, ecological, financial, and political frameworks to be associated;
- weigh expenses and advantages of choices completely, including long-term expenses and advantages to future generations; recognize that assets are limited and that there are points of confinement to development;
- assume control of their predeterminations;
- recognize that our capacity to see the necessities of things to come is constrained, and any endeavor to characterize sustainability ought to stay as open and adaptable as could reasonably be expected.

Sustainability is addressing the requirements of the things considered, having the option to do on a limited planet, for generations to come while guaranteeing some level of receptiveness and adaptability to adjust to evolving conditions. Sustainability depends on a basic guideline: everything that one requires for our survival and prosperity depends, either straightforwardly or by implication, on one's indigenous habitat. Sustainability makes and keeps up the conditions under which people and nature can exist in beneficial congruity, that grant satisfying the social, financial, and different prerequisites of present and future generations. Sustainability is critical to guarantee that one has and will keep on having the water, materials, and assets to ensure both human wellbeing and ecological condition [6].

Sustainable development is a difficult statement. It is an idea that constantly drives to change destinations and needs since it is an open procedure and it cannot become conclusively. Sustainable development is the improvement model that enables us to address present issues, without trading off the capacity of future generations to address their issues. The fundamental target of this advancement model is to raise personal satisfaction by long haul expansion of the beneficial capability of biological systems [1]. While accomplishing manageability is the objective of sustainable development, the word sustainability has a few implications and is decreased by connecting it with the ecosystem. Sustainable development is not just another idea, yet also, another worldview, and this expects to take a view at things in an unexpected way. It is a thought of the world unique about the one that

commands our present reasoning and incorporates fulfilling essential human needs, for example, equity, opportunity, and dignity. Sustainable improvement contains two key ideas:

- The basic needs of the world poor to which replacing need ought to be given;
- The confinements are forced by the condition of innovation and social association on the capacity of the earth to meet present and upcoming requirements.

Currently, the most significant investigations in sustainability are carbon footprint computation, biological footprint, LCA (life cycle analysis) for maintainable generation/life cycle evaluation considers. A carbon footprint is a proportion of the ecological effect of human exercises as far as the measure of ozone harming substance created, estimated in units of carbon dioxide. The environmental footprint is a technique for ascertaining the weight of a given populace of nature. It figures the zone that is expected to give sustainable assets to individuals, naturally prolific and watery. Simultaneously, the biological footprint is a method for a healthy life, more advantageous, sustainable textile items, creating characteristic crude materials for textiles, and leaving a bearable world for present and future generations [17].

3 Sustainability Design

There are the sustainability design rules that recognize the earth must be a basic thought alongside the customary measurements around financial matters and execution. These general and subjective rules are intended to be pursued during new item improvement and depend on learnings from the lifecycle analysis and other sustainability tools. The rules are obliged by-product execution prerequisites and end-user needs. The basic guidelines for sustainable design are shown in Fig. 2.

3.1 Selection of Materials

Choosing low-effect materials and diminishing the measure of materials utilized is a very powerful approach to lessen an item's ecological effects. Removing parts are not required and enhance the structure to lessen material utilization, which diminishes transportation impacts. Additionally, increment the measure of reused materials utilized in the item, and use materials that can be promptly reused at the end of life or product transfer.

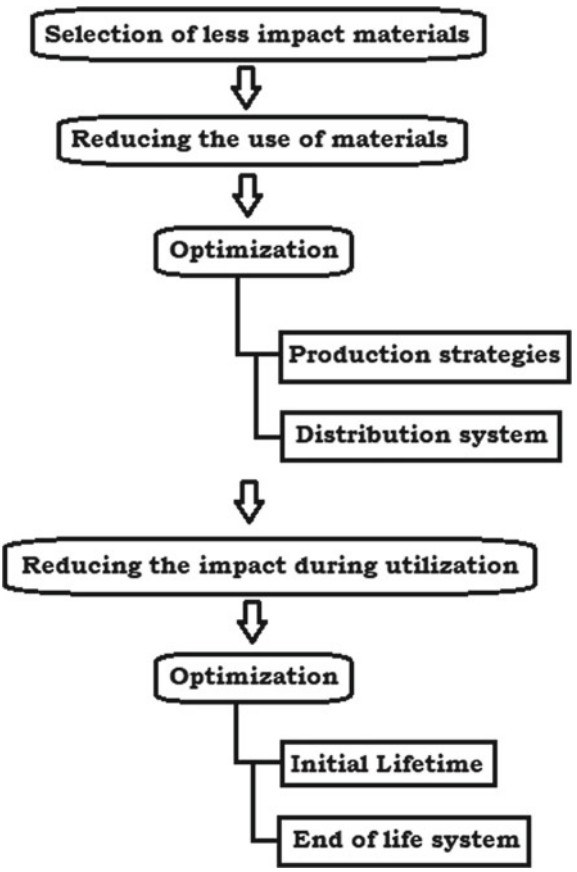

Fig. 2 Sustainability design guidelines [11]

3.2 Optimization of Production and Distribution Techniques

There are numerous approaches to upgrade creation procedures including joining the design for assembly standards to decrease generation steps, enhancing the structure to diminish the energy utilized during assembling, dispensing with or lessening surface medicines, for example, powder coatings, and limiting assembling waste and item scrap reusing. There is an unmistakable chain of command about the ecological effects of various transportation modes. Moving by compartment ship and the train is ecologically recommended over the truck, which is desirable over airship cargo. Different approaches to advance the dispersion framework incorporate the utilization of reusable mass bundling, for example, beds, limiting volumes and weight of bundling, and guaranteeing that all bundling is basic to work. Also, at every possible opportunity, items can be delivered to decrease transportation volume.

3.3 Reducing Its Impact Using the Utilization

Approaches to lessen effects during use incorporate diminishing energy utilization, making the default express the most alluring from an ecological angle, ensuring utilizing the product does not bring about covered up and destructive outflows and wastes, limiting consumables required, and decreasing generation of scrap.

3.4 Optimization of Initial and End of Life System

Initial lifetime product optimization incorporates keeping away from feeble connections that lead to a decreased life expectancy and require continuity; structuring so that the item can be fixed and redesigned, just as meet end-client requirements for quite a while; expanding the usefulness of the item and planning the item's appearance to build tasteful life. End of life system optimization incorporates planning considering reusing—through material determination and structures that can be dismantled—just as reuse of item and maintaining a strategic distance from untimely out of date quality. Different alternatives to optimize the end of life incorporate surveying the likelihood of reclaim programs and minimizing dangerous components to lessen air contamination when burned.

4 Life Cycle Analysis (LCA)

Life cycle assessment/life cycle analysis is a framework that surveys every single ecological measurement, from the crude material of a produced item to its normal origin, from all loss to return to the earth. The Life Cycle Analysis is utilized to decide and quantify both direct i.e., discharges created during generation and vitality use, etc., and indirect i.e., crude material disposal, product transfer, buyer use, and transfer, etc. In the life cycle assessment, the producer is relied upon to assume liability for the contamination that emerges from the procedure of configuration to fabricate and to deliver so that it will not make any damage to the earth in any event. Also, deterioration of biological balance ought to be controlled and eco-awareness ought to be created on the planet. Sustainable designs ought to be made to evacuate expanding ecological and medical issues. Sustainable design and generation must be made a social obligation. For feasible design, it is important to concentrate on life cycle investigation to deliver and create suitable designs. During the design and generation period of the item, the effect on the earth should be examined and recognized in detail [2].

5 Textile Industry

The textile industry is a differing and heterogeneous industry covering a huge scope of practices from the change of strands to yarns and textures and from these to dress, which might be either design or non-style garments. The textile sector has high-esteem included sections where configuration, innovative work are significant focused components. Textiles give a significant contribution to the dress industry, making vertical linkages between the two. At the small-scale level, the two segments are progressively incorporated through vertical supply chains that likewise include the circulation and deals practices. The retailers in the clothing section progressively deal with the inventory network of the textile industry [4].

The textile industry incorporates:

- Obtaining and handling crude materials, for example, the planning and generation of fiber materials.

  Natural fibers—cotton, fleece, silk, flax, and hemp.
  Manufactured fibers—cellulosic filaments, modular, Lyocell.
  Engineered polymers—polyester, nylon, acrylic, polypropylene.
  Inorganic materials fibers—glass.

- Production of yarns and fabrics
- Finishing practices that give materials visual, physical, and aesthetic properties that buyers request, for example, fading, printing, dyeing, and covering.
- Transformation of materials into pieces of clothing that can be either design or non-style clothing so-called the clothing or apparel industry.

6 Demand for Far Vision in the Textile Sector

Sustainability concern in textile requires considering the impacts rising out of outside the limits of the ordinary textile industry. These ‘outside’ impacts—extending from rural practices to global vitality approaches, going through utilization examples and levels of environmental ideas of society—affect the sustainability of the part in general. Environmental and social frameworks reach out the limits of organizations and individual sectors; subsequently, to build up an increasingly reasonable textile industry one has to submit with these issues at the level they compare to and associate with different sectors, industries, and other groups, past their very own limits [3].

7 Sustainability in Textile Design

Sustainable design is legitimately influenced by ecological conditions. The creator serves direct sustainability for a healthy condition when planning from common sources. It is plan and generation produced using characteristic, inexhaustible and recyclable materials that come initially as far as sustainability through designing. The second is to plan and create ecologically agreeable items while keeping up the balance between ecological conditions, society, and economy. The third is to design and create durable solid items with natural materials, durable products with inexhaustible and recyclable materials, inventive multi-useful items by assessing waste materials.

Sustainable design empowers inventive and innovative design and preparations of products to live in a certified, reasonable condition. Inventive items that make increased worth and, in particular, sustainable products will develop [14]. In sustainable design, the material to be utilized gives the creation procedures that are helpful by making upgrades and developments in the generation procedure and less or no damage to the earth. Diminish or control item advancement costs by lessening danger and risk issues. It assesses the destructive consequences for the ecosystem and people and gives design and production toward this path. To this end, it energizes advancement, expands the proficiency of design and creation, diminishes costs, builds product productivity, expands the overall value of the industry by presenting high-worth included items from a commercial perspective. Plan through sustainability, recycling, sustainable materials, re-use, and customary generation can be cultivated by utilizing four unique strategies, individually [10].

8 Sustainable Design in Textile Products

The objective of the Sustainable textile study is the enthusiasm for fit and fine living, the improvement of awareness in the environment with social obligation, the designing, ensuring, and verifying of things to come deliberately, however much as could be expected to delete the carbon footprints in the planet. Sustainable design, additionally called ecological style or eco-fashion, is the new pattern of the design with the broadest meaning of eco-friendly, recyclable and products with high quality [12]. The focus of sustainable fashion is to make reasonable frameworks, to secure the earth, to build social obligation, to make cognizant buyers, to lessen the cash spent for the textiles, to slow the design patterns expanded rapidly, to recover the regard for nature and earth. Sustainable fashion is rapidly reaching consumers and is found to be critical for competitive success in the future. Sustainability in fashion is one of the major themes in the textile industries but it is complex and multifaceted. The fashion industry adopts sustainable materials, practices throughout the designs and developments which represents a sizable portion of the market. Various tools and benchmarks were developed in the fashion industries to

eliminate the environmental impacts of materials and processes. The success of the fashion industry depends on cultivating and producing textile fibres like cotton and polyester fibre types. The manufacture of cotton and polyester fibres cause environmental effects and also give its ubiquity in apparel manufacture. Fashion industries depicted that sustainability has many elements and issues based on society, environment and plays a major role in the ethics and standards of companies. The most common issues of fashion sustainability are production cost and consumption practices on a natural source like air and water.

The beginning stage and the most significant factor in the design and generation of sustainable textiles is the material. The fundamental reason for existing is to utilize biological equalization of entire natural material and to make the creation of characteristic materials sustainable. With this objective, the primary crude materials are cotton, cloth, silk, ramie, jute, rabbit hair, fleece, bamboo, goat hair, camel hair. The fibers that are on the motivation in the extent of creative common materials and analyzed inside the extent of the advancement of sustainable characteristic materials today are espresso fiber, soy fiber, pineapple fiber, banana fiber, coconut fiber. Expanding the decent variety of recently delivered fibers is an important work regarding sustainable textiles [16].

Recycled natural fibers were acknowledged in exchange fairs, industry magazines/segment magazines during the 1990s. In the mid-2000s, natural sustainable fibers have the spot as the creative thought in plan and have turned into the pioneer. Numerous organizations have utilized normal and sustainable, biological elective materials in their items. Natural fibers are eco-friendly fibers acceptable for reusing and recycling. They are low thickness, healthy and solid. Reusing makes the generation of natural materials perpetual and can change over the texture into reusable fibers and yarn. Reused fibers, yarns, materials from garments, or home materials can be utilized as secondary materials. Just as petroleum-based manufactured and cellulosic crude materials are utilized in the textile sector, a wide range of new advances have been grown, for example, glass fiber, steel, silver, and so on the crude materials can be made usable once more.

This procedure must be acknowledged by methods for synthetic compounds and generation techniques that won't damage nature. New results of the equivalent or distinctive usefulness can be created and delivered from unfashionable garments and textile products. Generating textile materials by reusing fiber, yarn and texture evacuate numerous performance dependent on energy utilization that is a wellspring of contamination. During generation, it doesn't have to work, for example, cleaning. There is no compelling reason to wash with huge amounts of water as in preparing crude yarn. Interest in finishes and fixatives are decreased. Another strategy for sustainability is the utilization of inexhaustible materials.

Rather than oil-based fibers, inexhaustible fibers that can be delivered persistently in nature, for example, soybean fibers, and banana fiber, wool-like reused filaments, materials produced using corn starch-like materials decrease reliance on oil. Another strategy is re-use. Day-to-day utilized materials such as bed covers, drapes, covers, etc. that are in a usable condition might be offered for reuse. Clothing that can't be worn and unused inside and outside home materials can be

utilized for various purposes, for example, vehicle filling material, sound protection, board covering. Non-reusable clothing and home material items can be structured and made for various purposes [7].

The fourth sustainability technique is the traditional generation. Traditional generation of characteristic materials, for example, cotton, cloth, jute, silk, wool will diminish chemical utilization and water utilization in huge amounts. The pattern in the present material and texture decisions is to present creative, assorted items with numerous highlights that are impervious to microscopic organisms, take out terrible odor, and upgrade the advantage of the item, for example, providing security to the sun's rays. These new items are delivered from fake material fibers got from petroleum. Such properties bring about an enormous number of substance utilizes, progressively waste, and more energy utilization. Nonetheless, all characteristic materials, for example, cotton, bamboo, silk, wool, cloth, natural fibers, for example, recently created soy fiber, banana fiber, pineapple leaf fiber, and coconut fiber, etc. have properties like resistance against microbes, assurance against sunrays, and obliteration of terrible odors.

One model for reusing is Soya fiber, a recently created common fiber, which is a protein-based inexhaustible natural lifting. It is 100% natural eco-friendly. Wastes that are discharged during fiber generation can be utilized as soybean oil and creature feed. Soya fiber has comparable properties to silk and is less expensive than they are. The soya fiber is antibacterial due to the presence of amino acids present in its structure. Amino groups empower the enactment of collagen proteins in human skin. Simultaneously, it elevates air take-up to its unrivaled air penetrability. Soybean fiber, which is a bioengineering outcome, has luxurious fineness, low thickness, and high quality and extension properties.

Another method for accomplishing sustainability through design is to design and create new items that will give sustainability by impersonating nature or motivating from nature inside the setting of biomimesis, biomimetic, and biomimicry ideas. Biomimicry is a way to deal with the advancement that looks for feasible answers for human difficulties by imitating nature's dependable examples and techniques. The objective is to make items, procedures, and strategies better approaches for a living that are very much adjusted to life on earth as time goes on. The outcome is bio-design. Designing and delivering by assessing waste materials is another design sustainability analysis. The reuse of unused wool cover as rug and carpet is a genuine case of sustainability design.

Generation of print configuration designs utilizing advanced and move printing strategies rather than traditional printing techniques, for example, rolls and formats is a genuine case of designing and creating ecologically beneficial practical items while keeping up a harmony between condition, society, and economy. Designing and delivering printed materials adds to sustainability as it implies less paint use, less contamination, less water utilization. With advanced printing, the designing of the materials brings about less contamination and less water utilization because less color is utilized and spray dyeing is finished. Since the computerized printing procedure is being developed stage, it is reasonable for fabric coloring and imprinting in lower amounts. Since characteristic stains just paint natural materials,

water-based fabric dyeing ought to be favored as they are both natural materials such as fiber, yarn, texture.

With an ecologically friendly methodology, reactive dyestuffs with the low salt substance have been created. In sustainability through design, during the time spent change from design to generation precise creation estimations must be made. The utilization of superfluous yarns that cause more yarn coloring or more balls coloring ought to be evaded. It is important to keep away from unnecessary fabric creation, which means unnecessary stock accumulation and energy utilization [13].

9 Sustainable Design Approaches

Sustainable design techniques in three phases: product engaged design, result-based design, and prerequisites driven design. The product engaged design is to design items that are multifunctional, enduring, out of style, and to make existing items progressively proficient with inventive thoughts and to diminish negative impacts to the earth. Result-based design is to put out designs for a particular reason. Prerequisite-driven design is to design items that invigorate utilization by distinguishing genuine needs to have any kind of effect.

Designing and designing of items by using designing techniques, as one continually notices, requires less energy utilization, less water utilization, less compound, less destructive gas, and so forth distributing. It is conceivable to decrease ecological toxins and wastes, to utilize eco-friendly natural filaments and materials and sources, to support moderate style rather than quick design, to energize the reuse of sustainability textile items, to design and deliver products through designing methodologies [8].

10 Case Study—The Borbonese Company

Borbonese Company is a historic Made-in-Italy rand company created in Turin, 1910 as a jewelry accessory label and soon becomes the leading name in Italian luxury with products. He used precious materials and refined methods for crafting purposes to explore the details and characteristics. This research has created new ways for the historic Occhio di Pernice texture. This company created sustainable bags and accessories using the available articles with different kinds of stored leather containing metal clasps and shoulder straps. These sustainable bags and accessories have been designed to reduce wastes. The utilization of waste materials in the production of original products showed the company's thought towards sustainability. The products created from the wastes have a special kind of appeal to the market place.

11 Conclusion

The diversity of products and complex processes are the barriers in the textile and apparel industries. Higher consumption of raw materials and disposal of fashion products creates environmental issues worldwide. Products created through economic design need to be delivered as eco-friendly products that do not harm nature. The subsequent items should have the highlights, for example, being multi-useful, improved items instead of the products created in a typical manner. The sustainable design intention is to decrease common asset utilization and limit the destruction to the earth during the time of production and utilization. In the design and generation stage, energy sources, for example, water, wind need to be favored rather than non-renewable sources. In textiles, materials that do not harm the environment ought to be utilized in the dyeing of the yarns and textures, in dyes to be utilized in printing design products, and in synthetic compounds to be utilized in completing operations. The balance among utilization and generation can be given by making upgrades in quality, cost, and product conveyance techniques. The items intended for the genuine needs of the buyer can be designed and made multifunctional, utilizing fewer resources in the generation stage and less harm to nature, by making quick and errorless creation in a shorter time. Accordingly, the fundamental highlights anticipated from design are manufacturability, usefulness, visual intrigue speaking to buyers preferring, and attractiveness, that is, acceptable and affordable for the customer. One of the basic highlights of design must be sustainable to design and secure the future deliberately. Future research should focus on managing sustainable methods to balance the socio, economic and environmental developments. A sustainable process should be based on the complete consultation with the consumers and products because sustainability develops from consumer's cooperation. Hence the textile industries need to seek new approaches in case of design conceptualization.

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Junior Sportspersons Living with Physical Disabilities' [Dis] Satisfaction Level with Selected Active Sportswear Attributes: Implications for Sustainable Apparel Design for Social Inclusion in Kenya

Sophia N. Njeru

Abstract Persons Living with Disabilities (PLWDs) constitute 15% and 2.2% of the total world and Kenyan population respectively. Learners with disabilities and special needs have been inactively involved in sporting activities, even though participation in sports endows them with academic and psycho-social benefits. Globally, there exists a dearth of research on active sportswear for PLWDs. Consequently, in Kenya active sportswear worn by junior sportspersons living with physical disabilities (JSLWPDs) is ill-fitting, oversize, unattractive and widely limits their desired mobility. Active sportswear is identical to that for able-bodied sportspersons. This essay explores the JSLWPDs' [dis]satisfaction level with selected active sportswear attributes through a study conducted in Masaku School for the Physically Challenged, employing mixed-method research design. The population comprised 60 JSLWPDs. Judgement sampling was adopted to select the respondents who filled semi-structured questionnaires. Focus group discussion, artefact analysis and fieldwork photography augmented data collection. Data analysis entailed quantitative and qualitative techniques. The JSLWPDs' dissatisfaction level is significantly higher than the satisfaction level concerning selected active sportswear attributes: function/usability, fit, freedom of movement and sportswear weight. Chi-square test revealed a significant difference in the [dis] satisfaction level among the attributes. The dissatisfaction level is at par for both genders. Consequently, dissatisfaction inhibits their social inclusion and enjoyment of sports. Evidently, active sportswear fashion actors' product development is unsustainable because they disregard the JSLWPDs' special apparel needs. The research is envisaged to inform the co-design of JSLWPDs' intelligent adaptive active sportswear that shall empower them academically and within the bio-psychosocial continuum for social inclusion.

S. N. Njeru (✉)
Department of Fashion Design and Textile Technology, Kirinyaga University, 143-10300, Kerugoya, Kenya
e-mail: snnjeru@kyu.ac.ke

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1 Introduction

Afrika is characterised by a predominantly youthful demographic aged 15–24 years that constitute slightly more than 20% of the total population [39] and includes those living with disabilities. Persons Living with Disabilities (PLWDs) constitute 15% (1 billion) of the total world population. Disability prevalence is higher for developing than developed countries [42]. In Kenya, PLWDs comprise 2.2% (0.9 million) of the total population with more females (523,883) than males (394,330) which pose implications on the social roles undertaken by women in the society [15]. PLWDs are the most disadvantaged and marginalized groups and experience adverse socio-economic outcomes and discrimination at all levels of society: participation in sports and access to education. Girls and women are double disadvantaged: by gender and disability [23]. The Government of Kenya undertook a countrywide mass registration of PLWDs from 3rd to 7th June 2019 through the National Council for Persons with Disabilities (NCPWD), though the results have not been released. According to Handicap International [8] PLWDs educational stakeholders spread throughout Kenya comprise: special schools for the physically challenged, blind, deaf, cerebral palsied, mentally challenged, post-secondary institutions and schools with integrated units totalling 125, of which schools for the physically challenged (some are primary, secondary and others not classified) total 13. Others are community-based organisations (CBOs) and non-governmental organisations (NGOs), government ministries and institution programmes, Kenya sign language interpreters and educational assessment and resource centres. Considering that junior sportspersons living with physical disabilities (JSLWPDs) are in school, it means they are no longer confined at home as in the past. Thus, apparel styles, more specifically active sportswear must meet their newly-defined expectations, those from their peers and the community at large, thereby afford them social inclusion.

Concerns related to PLWDs' participation in sports are skewed toward physical barriers such as inaccessible and or unsuitable sporting facilities while ignoring active sportswear. Consequently, there is a dearth of research on sustainable adaptive active sportswear for consumers with physical disabilities in Afrika because studies are predominantly skewed toward the temporarily able-bodied consumers. One questionnaire item posed to PLWDs participants by KNHCR [16] was if they had adequate access to clothing, food and water among other needs. However, no finding was presented on clothing, despite it being a basic human need and a right to all persons: living with and without disabilities. Probably the researcher(s) did not deem clothing important to PLWDs, thereby inhibiting their social inclusion thus contrary to the United Nations (UN) *Sustainable Development Goal* (SDG) 16: Promote peaceful and inclusive societies for sustainable

development, provide justice for all and build effective, accountable and inclusive institutions at all levels. Botswana's and Kenya's fashion houses' founders have a combination of markets varying from "high class, male and female, middle age" to "high class/middle class/female" but they do not cater to the needs of green and elderly consumers. The prevalence of non-fashion-related qualifications among the respondents could suggest a lack of background knowledge and skills in fashion design and technical dynamics in the industry [31] especially sustainable fashion for special apparel needs end-users who comprise JSLWDs. The elderly persons experience similar physical disabilities to the JSLWDs. None of the fashion houses' collections in Botswana and Kenya includes active sportswear which refers to clothing and accessories such as shoes, socks, gloves, watches and headbands worn by sportspersons during training, racing and official opening and closing of athletics competitions.

The academia in Kenya more so postgraduate research has to some extent failed to practically address sustainability issues. Njeru and M'Rithaa [27] posit that fashion stakeholders' increasingly complex conundrums persist for lack of practical solutions by doctoral candidates notwithstanding that, research outcomes in design-related disciplines such as fashion design need designing. For example, a doctoral research outcome could be a capsule wardrobe for a specific consumer group/stakeholder such as JSLWDs. The authors strongly recommend a paradigm shift to taught-doctorate programmes that incorporate practical/studio-oriented units and the alignment of doctoral research to national and international development goals and research agendas *inter alia* sustainability. Consequently, fashion design doctoral candidates should competently engage in emerging discipline-specific issues especially applied trans-disciplinary research in sustainability as well as human-centred approaches.

The Paralympic Games are the equivalent competition for athletes with disabilities. The Games classify disabled athletes into six categories: wheelchair athletes, amputees, athletes with cerebral palsy, visual impairment, intellectual impairment and "*les autres*" meaning others such as dwarfism, multiple sclerosis and arthritis of major joints among others [33]. Learners with disabilities and special needs have not been actively involved in sporting, cultural and recreational activities [23], thereby constraining the attainment of UN *SDG* 4: Ensure inclusive and equitable high-quality education and promote lifelong learning opportunities for all. However, participating in sports especially for PLWDs profoundly improves academic performance, self-esteem, solidarity and team building; creates a positive self-concept, self-actualisation and social adjustment; counters discrimination and inequality and; offers a chance for enjoyment and enhancement of good bodily health [40] (Bukala Personal Communication 2015). With proper training, Bukala (Personal Communication 2015) asserts that PLWDs have become renowned sports heroes and heroines, for instance, Henry Wanyoike a visually-impaired runner. In addition to training, adaptive active sportswear could enhance their participation in and enjoyment of competitive sports. In Kenya, annual national special-needs education sports competitions for primary school pupils are held in various parts of the country. Sportspersons engage with diverse actors such as dealers, agents,

coaches and managers who play a pivotal role in the acquisition of appropriate active sportswear and their logistics.

Sustainable participation in any sport requires suitable active sportswear. Sportswear has inspired fashion and research but no study has been conducted in Kenya on active sportswear for JSLWPDs. Sports-Inspired Fashion (SIF) refers to high fashion/designer clothes inspired by active sportswear in a collaboration between the sportswear industry and designers. SIF reflects the characteristics of many sports games in silhouettes, colours, and details. It is predicted that sport will continue to be an important source of inspiration for fashion designers [20] as this study envisions and enhances the social inclusion of JSLWPDs. Kinuthia et al. [17] studied factors that influence brand loyalty among Kenyan swimmers. From the study, it can be inferred that the swimmers select their own sportswear. The authors call for similar research with other sporting groups of consumers. Kinuthia et al. [17] focused on one sportswear attribute: brand loyalty. This essay presents findings of numerous active sportswear attributes for a marginalized sporting consumer namely JSLWPDs. Ko and Zhang [18] conducted a cross-cultural study using a self-administered questionnaire on the moderating effects of nationality and lifestyle on the relationship between brand equity and purchase intentions between Korean and Chinese sportswear consumers: college and graduate students of both genders. However, the study does not specify whether or not they were involved in active/competitive sport, or living with or without a disability. Schweinbenz [34] asserts that like other major sports movement in the twentieth century, the Olympic Games have been organised around gender lines. Clothing and fashion with the Games provided indicators of some of the barriers which female athletes faced, specifically sportswear. Fashion determines how female athletes experience the sport. For instance, Victorian fashion emphasised femininity through the use of the corset, the hoop skirt and bustle. Sports federations may enforce dress codes upon male and female athletes. Gender-based barriers to fashion consumption are unsustainable and in the case of the female gender, it inhibits the achievement of UN *SDG* 5: Achieve gender equality and empower/emancipate all women and girls, such as JSLWPDs. Emancipation may be social among other aspects.

1.1 Statement of the Problem

Sustainability implies a model encompassing social, economic, environmental and cultural aspects, be it in the apparel sector or any other sector. Sustainable fashion focuses on addressing challenges created by the production and consumption of fashion without discriminating against any consumer group such as PLWDs. A reconnaissance survey of leading sportswear distributors in Nairobi, Kenya revealed adaptive active sportswear for special-needs persons with unique and changing needs are lacking in the retail industry, especially as applies to JSLWPDs. Hence, active sportswear for JSLWPDs is often ill-fitting, oversize, unattractive and widely limits their experience and enjoyment of sports, desired mobility,

self-concept and social adjustment. Nonetheless, JSLWPDs seek fashionable, functional and comfortable apparel that addresses their specific special apparel needs. The special apparel needs emanate from their physiological and ergonomic demands, inhibited mobility and specific body shapes. Moreover, there is a dearth of research on active sportswear for consumers living with physical disabilities in Afrika because the focus of fashion design actors: educators, practitioners and the sportswear industry in their studies, apparel collections or lines and products respectively is predominantly skewed toward the temporarily able-bodied, young, middle-aged and middle to high-class fashion-conscious consumers. The skewedness occurs despite the fact that sports inspire fashion. Further, no attempt has been made to co-design intelligent adaptive active sportswear, more so for an underserved, under-identified, invisible and marginalized consumer group of JSLWPDs. This is the first study in Afrika to address JSLWPDs' [dis]satisfaction level with selected active sportswear attributes, whose implication is the enhancement of the end-users' social inclusion.

1.2 Objective and Hypothesis

This study explores JSLWPDs' [dis]satisfaction level with selected active sportswear attributes in Kenya. The active sportswear attributes were limited to clothing only and comprised form, function, aesthetics and experience. The study hypothesised an association existed between selected active sportswear attributes and [dis] satisfaction level of JSLWPDs.

2 Literature Review

2.1 Physical Disabilities and Participation in Competitive Sports

The proportion of PLWDs is slightly higher in rural than in urban areas accounting for 2.6% and 1.4%, respectively. The common types of disability include mobility (385,417), visual (333,520) and albinism (9.729) [15] as well as hearing impaired and mentally handicapped [35] mainly caused by diseases especially polio, congenital disorders and accidents [26]. The age bracket of adolescent and youth living with disabilities is on the increase due to the current lifestyle and the difficult unchanging economic conditions [28], an indication of the continuous existence of disability conditions in the country. Simmons [36] opines that this special group lives as an invisible minority. However, their highly developed alternative senses and training in daily living skills, mobility, use of aids and appliances and social skills among other concerns would help them to adjust to their disability and

perform at par with the able-bodied. The persons can grow up to lead contributing and satisfying lives in the community as adults. These individuals face numerous challenges such as lack of access to good quality education [36] and high school drop-out rate due to their disabilities, poverty, illness and lack of interest as well as the negative attitudes displayed by the people around them [26]. Other conundrums relate to lack of equal opportunities, barriers of the physical environment [3], diseases whereby PLWDs comprise 29% of all new HIV/AIDS infections in Kenya [10], unintended pregnancies, early marriages, unemployment [30], un-adaptive vocational training, lack of information in diverse formats and limited access to health care and suitable housing [11]. Gender disparity is significant at all levels of education with girls being more disadvantaged [15]. The result is PLWDs' unsustainable livelihoods caused by social, environmental, economic and cultural exclusion.

Physical disabilities affect the lower torso or lower limb [12]. The study was limited to physically handicapped adults aged 18–45 years focusing on their decision-making and fit of apparel and employed structured questionnaire and interview schedule. The research approach adopted lacks human-centred techniques: design sustainability, which is considered amenable to design-related studies.

Schlosser and Caroll [33] assert that athletes undergo bodily stresses brought on by the physical demands of competition and performance posing potential physical risks. In the sporting environment, athletes even with a disability push their bodies to the limit to meet the physical demands of the competition and to avoid injuries. Hence, there is often a high risk of overexertion. Active sportswear attributes essentially for JSLWPDs should address not only their special apparel needs but bodily stresses occasioned by the physical demands of participation in sports and prevent injuries. The effort would contribute to their social inclusion.

2.2 Active Sportswear Attributes

Active sportswear is hereby discussed in relation to the types, styles, functions and acquisition. Types of active sportswear are body enclosures which refer to the envelopment and covering of the body or some parts of the body. The items may be pre-shaped to fit a part of the body, wrapped around the body, suspended from a part of the body or combinations thereof [14]. Examples include tracksuits, breathable tops, warm-ups, shorts, socks and shoes [1] as well as sports bras, singlets, tights (long or short), dresses and tee-shirts, gloves, and headbands among others.

Schlosser and Caroll [33] posit that specialised apparel can be designed to perform two important tasks for athletes: monitoring and enhancement. Compression apparel is traditionally used to enhance athletic performance by providing muscle support and stability throughout training and competition. Proper fit of the specialised apparel designed to meet the demands of individual sports is

especially important in product development. For instance, athletics (track and field) require form-fitted/loose sportswear. Physiological performance benefits to the wearer are attributed to contact pressure in the garment provided by fit and fabrication [33].

Style is the visual appearance, which includes line, silhouette, colour and details which affect consumers' perception towards the garment [17]. The type of neckline and placement of closures/openings is of the utmost importance in athletic apparel. Athletes with a disability can experience loss of dexterity or poorly functioning joints and muscles, therefore product development of their apparel must be mindful of the position of closures and seams; ease of wear as well as the comfort and selection of fabrics used to adhere to specific body types. Design aesthetics of mainstream fashion help to promote the athletes' self-body image [33]. Imbuki [12] concluded that assistive devices used by PLWDs such as crutches, wheelchairs and callipers determine the kind of features to be attached to clothes, their positions and the fabric used to design/produce the clothes. The study's adult consumers were dissatisfied with clothing styles in the market and are willing to pay more for apparel specially-designed to improve their appearance positively. Some sportswear styles include sports tee-shirts with raglan sleeves and crewneck or V-neck, fabrics comprise polyester, nylon, elastane, cotton and blends as well as pockets, graphics, Afrikan prints and the colours of a nation's flag.

Athletes with a disability have specific functional needs that could be met through the development of specialised garments based on physiological and ergonomic demands [33]. Athletes' functional needs include mobility, cushioning, support, coverage, comfort, visibility, warmth, durability, traction, enhanced performance and identity. Comfort relates to keeping the wearer cool and dry when in action. Comfort is also related to the type of fabric, sportswear item's weight and fit (sportswear size). According to Kinuthia et al. [17], 95% of the respondents indicated that sportswear size influences their brand loyalty because it provides comfort during swimming. All apparel items are selected based on their fitting qualities (the relationship between the apparel and the body size) and the swimwear is no exception. Imbuki [12] study findings, notably, adult PLWDs' dissatisfaction with apparel fit presented an opportunity for the adoption of design sustainability more so adaptive apparel for the consumers. However, the chance was never exploited. Hence, the consumers' special apparel needs and social inclusion remain unmet.

Visibility, provided by reflective details such as a logo or a strip of fabric enables the wearer to be seen even in darkness. Mobility refers to freedom and naturalness of movement. For instance, a singlet (worn as outerwear) made of polyester/elastane blend of single jersey for stretch purposes and raglan sleeves on tee-shirts. The mobility of JSLWPDs is inhibited, thus adaptive active sportswear should be designed to counter the challenge. Warmth is provided by the type of fabric and technology used to manufacture sportswear. Cushioning protects from hard and rough surfaces in addition to injuries. Support refers to stabilizing the muscles as well as securing sportswear in place during moderate to intense physical activities. Sports bras are the most important sportswear for female athletes to protect their breasts from sports injuries.

Durability is offered by the quality of workmanship and materials used to produce active sportswear. Durability/longevity, be it emotional, physical or stylistic extends the use of apparel [2] thus promoting sustainability. Coverage refers to the enclosure which is offered by sports bras, tracksuits, vests and wrap-around skirts. For the JSLWPDs, coverage also relates to the concealment of assistive devices as well as their disabilities. Coverage may also concern modesty/immodesty in that the sportswear item conceals parts of the body to various extents. Therefore, a tee-shirt conceals the wearer from the neck to the hips, whereas a short sports bra covers the bust leaving the midriff and hands exposed.

Hassan et al. [9] established that sportswear made of 100% polyester fabric produced the best physiological responses and performance from the athletes compared to 100% cotton and 65/35 polyester/cotton blend. Despite the positive results of the former, sustainable fashion advocates for the use of environmentally-friendly end-of-life (EOL) fibres and fabrics such as bamboo and organic cotton among others.

From sustainability viewpoint, branding should utilize embroidery rather than printing unless eco-printing pastes are used. From the customer's perspective a brand can signify product quality, allows one to shop with confidence and have some expectations. In Kenya, Speedo is the most preferred brand among university students' swimmers [17]. Green active sportswear consumers would buy from brands that promote sustainability.

Sportspersons, including JSLWPDs, may acquire active sportswear from corporates, fellow sportspersons, charitable organisations or the government. Young female runners in Kenya acquire used shoes during the Shoe4Africa races in Kenya. Shoe4Africa is a charitable organisation founded by Lorna Kiplagat and Toby Tanser. The initiative is sustainable because rather than dispose of the shoes into landfills they are re-used. Apfeld [1] articulates that lack of training shoes is a great obstacle that forces the runners to wear shoes for over 1000 miles well above the 300 miles guidelines for the life of a running shoe. The Government of Kenya kits all the national teams that represent the country in international athletics competitions, including Paralympic Games.

2.3 A Spotlight on Sustainability Elements Applicable to Active Sportswear Product Development

Sustainability implies a model comprising several elements: social, consumer, design, economic, environmental, innovation, technological, business models, marketing, raw materials, transparency [5] as well as cultural [43], which are dynamic and interact with one another, each factor being influenced by the others. Sustainability also implies a multi-disciplinary approach integrating the short-term into the long-term [5]. Research on the slow fashion movement or sustainable fashion has gained momentum globally with increasing concerns about sustainability.

Consumer sustainability entails information access, care of clothes purchased and consumer's responsibility in their purchase decisions [5] which reflects a goal of the slow fashion movement in that clothing is enjoyed and savoured for an extended period [2]. Majority of PLWDs in Kenya are unaware of distributors of specialised/adaptive apparel, though they are willing to pay a premium price for fashionable functional apparel if available [12]. The PLWDs' willingness offers an opportunity for fashion designers to co-create apparel with the marginalized consumers that meet their special needs thereby foster sustainability and social inclusion. Customer-experience-driven strategies such as co-creation, customisation, emotional value and experience design lead to attachment to the product. Consumption-driven sustainable strategies include high-quality material and finishing, durability/"longevity" (provide extended garment lifetime) and timeless/classic/slow design [41]. Casto and DeLong [2] outline three types of durability: emotional, physical and stylistic which lead to sustainability/extended use. Gwilt and James [7] in terms of "longevity" posit that WRAP's "Love Your Clothes" campaign provides resource advice on garment care and repair, remanufacturing methods and recycling/reuse ideas. The campaign also educates consumers in making better purchasing choices by highlighting the durable attributes that are typically found in different apparel types. Active sportswear for JSLWPDs with care labels attached to them shall enhance durability through appropriate care thus sustainable.

Regarding environmental sustainability Casto and DeLong [2], highlight males' and females' concept of classic involved a sophisticated style that related to current trends with slavish adherence to current fashion or any specific period that could help to extend their wearing of apparel and slow fashion in the future. Thus, classic apparel such as an outerwear coat is not readily discarded to the landfill.

Design sustainability classifies designers as a determiner (creator of boundary objects), condition creator (creator of learning objects) and co-creator (facilitator) and they should design items that people need and not those that people want [5] hence meet the needs of consumers as well as the need for sustainability [2]. On 3rd September 2020 Adidas, the German sportswear company released its *Adizero Adios Pro* running shoe that was co-created with elite Kenyan and Ethiopian athletes [21]. Two Kenyans, Peres Jepchirchir and Kibiwott Kandie went on to win their races in the 'Prague Restart' Project wearing the freshly-launched shoe [22]. The win could partly be attributed to the shoe.

Innovation sustainability is disruption that requires brands or companies to "think very differently" [5]. Morgan et al. [24] demonstrate the potential for innovation across all of Stevels' four levels of sustainable innovation based on five principles of sustainability for textile design. The authors express industrial partners' outlook that the ability to add customised, direct-to-garment features as advantageous benefits of the laser textile techniques for sportswear. Jonk [13] highlights that Egyptian fashion designer Chant Avedissian moved the traditional to the contemporary in a sustainable way by interpreting specific Egyptian textile traditions through a series of clothing and textiles namely the Nubian *Girgar* and Bedouin Flat weave: colour theories, traditional pattern-cutting techniques, usage of

shape and textures and finishing. Palestinian designer Faisal El Malak's work embodies sustainability as his contemporary men's and women's wear incorporate traditionally hand-woven fabrics around the United Arab Emirates. Thus, the designers are creating clothing with meaning, consequently changing production techniques and influencing consumption and post-consumption attitudes: sustainability. The study sought to establish the JSLWPDs' opinion about the aesthetic appeal of active sportswear considering that they are young and fashion-conscious with special apparel needs.

Technological sustainability entails the process-related and product-related issues [5]. Wong and Leong [41] observe that sustainable production-driven strategies comprise sourcing, technology, up-cycling, recycling and reusing. Sustainable products stress on product quality and safety and promote the use of eco-materials, to include organic cotton, natural cellulose and natural-dyed fibres. Morgan et al. [24] state that advances in textile design and technology underpin innovation in fashion. The reason is partly that textiles are the fabric of fashion, and also the natural intersection of design and science that occurs through textile practice. The advantages of laser textile techniques are engagement with the customer in a transparent process, reduce over-supply and subsequent waste. Moreover, the double-sided colouration of fabric is ideal for producing reversible apparel: a sustainable product. The JSLWPDs would greatly benefit from reversible sportswear. Gwilt and James [7] point out factors that need to be considered when designing apparel and services for longevity. The factors are design aesthetics; size and fit; providing greater durability/"longevity" as a valuable clothing attribute and reposition "disposable" garments as undesirable. The seniors/elderly consumers have relatively similar special apparel needs to PLWDs, including, the JSPLWDs. Rousseau [32] and Starkey and Parsons [37] reveal that the assortment of clothing/apparel design solutions and footwear items for seniors/elderly consumers is insufficient in the retail industry because it is a market that is often neglected by both the apparel products industry and design educators. The fashion actors ignored their needs for fashionable, functional, comfortable and conservative apparel that addresses their specific changes in ability (especially physical abilities), attitudes and lifestyle due to their focus on the young/middle-aged clients. However, Rousseau [32] asserts that some elderly respondents mentioned "speciality stores", catering for mature customers but they were generally expensive and that elegant styles were available if one were willing to search around. According to Starkey and Parsons [37] apparel design categories pertaining directly to clothing preferences were identified as style, colour and print, fit and adjustability, comfort, fabric, ease of wear and versatility. There was a preference for printed garments to accent areas of their outfits and to liven up a neutral-coloured ensemble. Adjustability allows for a somewhat customised fit. Garments that are not too tight are preferred hence most of the prototypes were designed to be body skimming-fitted. Concerning comfort, fabric and ease of wear, the fabrics chosen were soft to the touch and included linen, cotton, cotton/rayon/spandex and cotton/polyester/rayon knits and silk organza and incorporated stretch. Pocket placement on corresponding garments avoided the creation of bulk. Due to dexterity limitations, the garments were predominantly

designed to be pulled on. Versatility is achievable through a capsule wardrobe to make dressing more manageable. The mini-collection thus comprised versatile and interchangeable pieces that colour coordinate [37].

Social sustainability relates to social inclusion, modelling, labour rights, human rights, human trafficking, anti-corruption and knowing and understanding the fast fashion [5]. Social inclusion of JSLWPDs may be promoted through apparel as well as other factors. du Preez et al. [4] assert that the population of older consumers is growing significantly in South Africa as well. Although they have been labelled as vulnerable consumers with less financial freedom, they have become an important, often overlooked market segment with the likelihood of increasingly more buying power. Changes that occur with ageing specifically body features (shape and fragile skin) and preferences lead to changes in their evaluation of clothing quality, which clothing manufacturers disregard. The elderly consumers were dissatisfied with current clothing quality (negative disconfirmation), especially in terms of the attributes of price, correct sizing, and fabric, which attracted the lowest performance ratings. Ill-fitting garments may be uncomfortable to wear, which may influence the comfort of clothing, thus confirming the importance of fabric, style and fit [4]. Wong and Leong [41] state that corporate social responsibility (CSR) practices adopted by all the Hong Kong and China-based manufacturers and retailers are ostensibly "half-hearted" and have engaged less with sustainability on the consumption side but have instead boosted consumption via seasonal sales, free gifts, and buy-one get one-free online campaigns.

Other than fibres, yarns, fabrics, dyes and printing pastes, raw materials sustainability includes issues related to water, energy and soil [5]. Gopura and Payne [6] state that House of Lonali, a sustainable brand in Sri Lanka uses the export business industry's textile waste as the basis of design, that is, up-cycling discarded fabrics and trims. Her collections cleverly transform the odd-shaped offcuts into fresh and youthful designs with intriguing panelling and drape as well as appliqué styles and shoes. Youthful designs incorporated in the active sportswear for JSPLWDs would enhance their social inclusion.

Regarding cultural sustainability involves explicitly empowering and recognising artisans' traditional skills and knowledge in any collaboration/project [43] such as textile heritage with designers. Wong and Leong [41] highlight culturally-driven strategies like tradition preservation and embedding cultural elements. The Fabrick Lab started 'UN/FOLD' to work with the Shui ethnic minority to employ batik textile techniques to make scarves, thus preserve traditional handicrafts and subsidise their livelihoods. This study addresses the JSPLWDs' perspectives on incorporating culturally-inspired prints in their active sportswear that would help identify with their different cultures.

Based on the discourse on sustainability and sustainable fashion, it is clear that globally fashion actors: fashion educators', practitioners' and industry's studies, apparel and accessories collections and products, respectively are predominantly skewed toward production and consumption of fashion, targeting young, middle-aged and middle-high class fashion-conscious temporarily able-bodied end-users. The actors neglect and overlook a relatively large market segment of

end-users living with disabilities and special apparel needs, specifically JSLWPDs. In addition, the co-design and production of adaptive active sportswear remain largely ignored by the fashion actors. In the limited fashion establishments, which cater to persons with special apparel needs more so the elderly consumers the merchandize assortment is generally costly and out of reach to many end-users.

3 Research Methodology

The study adopted a case study and mixed-method research design: descriptive survey and ethnography. The reason is that case studies are usually qualitative in nature and aim to provide an in-depth description of a small number of cases while surveys are quantitative in nature whose objective is to afford a broad overview of a representative sample of a large population [25]. The study was conducted in Masaku School for the Physically Challenged, a primary school in Machakos County, Kenya. The population comprised 60 JSLWPDs who engage in diverse competitive indoor and outdoor sports. Judgement sampling was employed to select 12 games captains: one for each competitive sport and who according to the sports teacher would ably fill the questionnaire. The games captains (respondents), one sports teacher (male, holds a diploma in Special Needs Education (SNE) with five years of coaching experience) and the Association of Persons with Physical Disabilities (APDK) Machakos County Coordinator (female, holds a diploma in occupational therapy and has served in the position for four years) filled semi-structured questionnaires. Two focus group discussions (FGDs) were held, one with six girls and another with seven boys. The data collection also entailed artefact analysis (active sportswear worn by the JSLWPDs) and fieldwork photography. The approach resulted in technique and data triangulation which provided a basis for checking and rechecking interpretations and revealed 'the whole picture' of the phenomenon. The data analysis comprised descriptive and inferential statistical techniques and thematic and qualitative content analyses. Consent to conduct the study was granted by the school's head teacher (refer to Appendix I).

4 Results

4.1 Demographic Characteristics

The results from the questionnaire reveal the female and male JSLWPDs totalled 5 (42%) and 7 (58%), respectively, aged between 12 and 20 years. The majority 9 (75%) were 13–16 years old, except a 20-year-old girl who could have started schooling very late in life. The respondents are between class/grade 5 and 8,

whereby one-half (50%) are in class/grade 8 who are due to write the primary school level final national examinations.

The most used assistive device is the manual wheelchair 4 (34%), in addition to crutches, prosthetic legs and callipers 1 (8%) each. Notably, 5 (42%) do not use any assistive device due to the nature of their disabilities which include dowager's hump, cerebral palsy and club foot. The sports teacher affirmed that crutches and wheelchairs are the most frequently used assistive devices and lower limb weaknesses and cerebral palsy are the most widespread physical disabilities among the JSLWPDs. The occupational therapist also alluded that wheelchairs are the most unexceptional assistive devices used by the JSLWPDs and the most widespread physical disabilities are lower limb weaknesses.

The JSLWPDs have been participating in both indoor and outdoor competitive sports for between 2 and 7 years. Specifically, 5 (42%) have five years' experience and the exceptional case of seven years' experience who plays scrabble started competing at the tender age of nine years.

Some of the JSLWPDs participate in more than one sport. It is evident from Table 1 that chess is the most preferred indoor sport. Other than the JSLWPDs being talented in chess, they like it because it is intellectually-engaging. Football is preferred because it is enjoyable, likeable and challenging. Para-volleyball players similarly are talented in the sport. Netball players consider the sport as the easiest to play, enjoyable and it strengthens them. Scrabble is preferred because it is intellectually-engaging and the JSLWPD is proficient in the English language. Wheelchair racers enjoy the game and are talented in it. The girls' FDG corroborates the finding in that they participate in competitive sports because they are talented, like the specific sport and it makes one strong. The boys vocalised in their FGD that they get to travel to different parts of the country namely Kisumu, Nyeri, Meru, Nakuru and Kakamega among others, sport can be pursued as a career, for adventure, exercise and fun, get to interact with counterparts from other schools, learn and have the ability to participate in a specific sport such as wheelchair racing. Competitive sports occasion physical and mental demands on the sportspersons. From the girls' FGD, netball players' hands must be strong to hold the ball well and be fit to run. Para-volleyball requires firm hand muscles to hit and block the ball in addition to proper sitting positions. Both chess and scrabble are mental thus the players exercise their minds. The boys' FGD added that wheelchair racers must have strong hand muscles and bend appropriately to move the manually-operated wheelchairs. Footballers both CP and PH must be attentive to the whereabouts of the ball and be fit to run. Handball requires strong hand muscles to bounce the ball.

The questionnaire and FGDs findings reveal that the JSLWPDs who participate in competitive chess and scrabble do not sustain any injuries. However, outdoor sports players are prone to various injuries. Common injuries associated with football for CP and PH and handball include bruised limbs caused by falls or knocking stones when running, painful collision with other players and slippery ground during the rainy season. Wheelchair racing injuries include fingers being hurt by the wheels of manually-operated wheelchairs, muscle pull and the wheelchair may overturn, thus hurt the player. For para-volleyball players broken fingers

Table 1 JSLWPDs by competitive sports they participate in

Sport	n	%
Chess	3	25
Football for cerebral palsy (CP) and physically handicapped (PH)	2	17
Para-volleyball	2	17
Netball	2	17
Scrabble	1	8
Wheelchair racing	1	8
Handball	1	8

are a common injury due to the impact of the ball, the surface may be rough thus hurt the buttocks and being hit by the ball on any part of the body. The game is played with the players seated on the ground. Netballers also experience broken fingers, painful collisions with other players and bruised limbs emanating from falls. The sports teacher confirmed that fractures and dislocation of joints as well as bruises among wheelchair racers are common injuries associated with participating in sports. The occupational therapist asserted that soft tissue injuries and fractures from falls are common injuries among the JSLWPDs.

4.2 Active Sportswear for JSLWDs

Sportspersons can acquire active sportswear from diverse sources and the JSLWPDs are no exception.

Table 2 depicts all (100%) respondents acquire active sportswear from the school, in addition to (50%) each who buy for themselves or receive donations from charitable organisations. Notably, no sportswear manufacturer donates active sportswear despite the Kenyan market hosting several local and international producers. The sports teacher also asserted that the school procures active sportswear for the JSLWPDs and receives donations from charitable organisations. Further, the occupational therapist reported that the school procures, the JSLWPDs buy for themselves and charitable organisations donate active sportswear.

Table 2 JSLWPDs by acquisition of active sportswear

Acquisition	n	%
The school provides	12	100
Philanthropists donate	0	0
Sportswear manufacturers donate	0	0
I buy for myself	6	50
Charitable organisations donate	6	50
Coaches provide	1	8

Multiple responses allowed

Slightly over one-half (58%) and (42%) of the JSLWPDs are consulted and not consulted, respectively on their preferences for active sportswear. The former comes about when the JSLWPDs' anthropometric measurements are taken by a tailor who is sometimes engaged by the school to produce some active sportswear items. The sports teacher affirmed that the JSLWPDs are not consulted on their active sportswear preferences while the occupational therapist reported the contrary.

The girls stated in the FGD that the active sportswear items issued have a poor fit, are torn and the fabric colour (green) shows dirt easily thus require thorough cleaning which they are sometimes unable to do due to their disabilities. The boys in a FGD opined that the active sportswear poses challenges due to tight elasticized track trouser waistband, sleeveless vests expose their disabilities, non-absorbent fabric, heavy items of wear and a poor fit.

Fieldwork photography and artefact analysis revealed the active sportswear items include tracksuits (jacket and trouser), pair of shorts, wrap-around skirts and vests. The track jacket is made of green 100% polyester heavy-weight knit/jersey fabric. Other attributes include a centre front heavy-duty separating zipper, stand collar, raglan sleeves with elastic hems and two white strips of fabric along the length of the sleeves, elasticized hem, school's name and logo printed on both back and front and shallow side seam pockets (Figs. 1, 2, 3, 4). The track trouser features elastic and drawstring on the waistband, elasticized hems and zipper opening on the inside leg seams, deep side seam pockets and green 100% polyester heavy-weight knit/jersey fabric (Figs. 5, 6, 7). The green wrap-around skirt has a white binding along the edges and is of 100% polyester lightweight knit/jersey fabric (Fig. 8). Green 100% polyester lightweight knit fabric is used to produce sleeveless vests which have a white binding around the armholes and neckline, and the school's name is printed in front and at the back (Fig. 9). The pair of shorts is made from green 100% polyester lightweight knit fabric and has a white strip of fabric sewn along the side seams (Fig. 10).

4.3 [Dis]Satisfaction Level with Selected Active Sportswear Attributes

The JSLWPDs' perceptions on the [dis]satisfaction level with the listed active sportswear attributes were solicited using a four Likert-scale: Highly Dissatisfied (HD), Dissatisfied (D), Satisfied (S) or Highly Satisfied (HS).

The results of Table 3 illustrate the JSLWPDs' high dissatisfaction levels with the following active sportswear attributes: function/usability (75%), size ranges (50%), culturally-inspired fabrics prints (50%), versatility (50%) as well as school logo printed on track jacket (58%) though artefact analysis shows the track jackets and vests are branded with the school's name and logo both at the front and back. The JSLWPDs' dissatisfaction level is caused by fit (67%), the weight of sportswear items (59%), freedom of movement (67%), aesthetically pleasing colours

Fig. 1 JSLWPD plays chess and scrabble

(50%), absorbent fabric (50%), track jacket sleeves are wide thus allow mobility (67%) and pockets attached (50%). However, the JSLWPDs are satisfied with various active sportswear attributes namely coverage of assistive devices (42%), endow school's identity (50%), provide support to body parts (50%), care labels attached (50%), easy to manipulate openings and fastenings (50%), easily reachable openings and fastenings (67%) and the necklines (50%). Among the active sportswear attributes that the JSLWPDs are highly satisfied with comprise reputable Kenyan brand names (58%), waistline finishes (58%) and track trouser hems are wide enough thus ease wear (50%).

The sports teacher highlighted satisfaction with various active sportswear attributes to include coverage of assistive devices, the weight of the clothing, enhancement of performance and adjustability. However, dissatisfaction was attributed to lack of the school logo on track jackets, culturally-inspired fabric prints, stretch fabric and the pockets attached. The occupational therapist's dissatisfaction with the active sportswear arose from lack of the school's identification,

Fig. 2 Wheelchair racing mixed

Fig. 3 Wheelchair racing boys

Fig. 4 JSLWPD plays netball

Fig. 5 Boys participating in para-volleyball

Fig. 6 Girls participating in para-volleyball

Fig. 7 From left to right JSLWPDs plays scrabble and chess

aesthetically pleasing colours, care labels attached, reputable Kenyan brands and the width of track trouser hems. Further, the respondent's general satisfaction was with function, fit, size ranges, coverage of assistive devices, thermal insulation,

Fig. 8 JSLWPDs plays chess

smooth fabric texture, stretch fabric, adjustability, versatility, logo printed on track jacket, high-quality workmanship, wide track jacket sleeves, neckline, pockets attached and well-set collars.

4.4 Chi-Square Test for Independence Results for [Dis] Satisfaction Level of Selected Active Sportswear Attributes

The results in Table 3 were further analysed using Chi-square test for independence at ($p \leq 0.05$) alpha level to explain whether or not the attributes are associated and judge the significance of such association or relationship [19]. The eight active sportswear attributes selected were deemed amenable to sustainability and the design of adaptive/specialised apparel for special-needs persons namely PLWDs

Fig. 9 Boys participating in handball

Fig. 10 Boys engaging in cerebral palsy football

Table 3 JSLWPD by [dis]satisfaction level of selected active sportswear attributes

Active sportswear attribute	HD	D	S	HS	No
responseTotaln%n%n%n%n%(i) Function/usability97521718——12100(ii) Fit18867—2171812100(iii) Size ranges650217217—21612100(iv) Coverage of assistive devices217—5421331812100(v) Weight of sportswear items18759217181812100(vi) Provide cushioning3253252173251812100(vii) Affords visibility325542—433—12100(viii) Offer sportsperson's identity32543343319—12100(ix) Endows school's identity/name217217650216—12100(x) Enhance performance19325433433—12100(xi) Provide support to body parts21718650325—12100(xxi) Offer freedom of movement1886721718—12100(xiii) Reversible track jacket433433434——12100(xiv) Fabric affords thermal insulation542433—325—12100(xv) Smooth fabric texture325433325217—12100(xvi) Stretch fabric325542433——12100(xvii) Culturally-inspired fabric prints650325325——12100(xviii) Aesthetically pleasing colours18650217325—12100(xix) Adjustability433—1854221712100(xx) Versatility6501818434—12100(xxi) Trimmings add aesthetic19325433433—12100(xxii) Logo printed on track jacket75818217217—12100(xxiii) Care labels attached217216650217—12100(xxiv) Absorbent fabric217650433——12100(xxv) High-quality workmanship43321718542—12100(xxvi) Reputable Kenyan brand names, "Made in Kenya"325217—758—12100(xxvii) Easy to manipulate openings and fastenings18325650217—12100(xxviii) Easily reachable openings and fastenings433—867——12100(xxix) Width of track jacket sleeves allows mobility1886721718—12100(xxx) Necklines43318650—1912100(xxxi) Waistline finishes—325187581812100(xxxii) Pockets attached—6503252171812100(xxxiii) Track trouser hems are wide enough thus ease wear217217186501812100(xxxiv) Properly-set collars21743221721721712100(xxxv) Generally affords ease of and independence in wear217—32543332512100					

and the elderly as articulated in studies by Starkey and Parsons [37], Schlosser and Caroll [33] and Imbuki [12].

It is evident from Table 4 that there is a significant difference in the dis[satisfaction] level among the selected active sportswear attributes. The JSLWPDs express high dissatisfaction level with active sportswear. The *Ho* hypothesis is therefore rejected.

4.5 *Gender Perspective on [Dis]Satisfaction Level of Selected Active Sportswear Attributes*

Further probing was conducted on the discoveries in Table 3 to uncover the gender perspectives of the JSLWPDs' [dis]satisfaction level with selected active sportswear attributes. This is because female athletes faced barriers, especially sportswear [34], they have a high involvement with fashion [29] and generally most fashion studies focus on the female and disregard the male perspective. The attributes were also deemed amenable to sustainability and design of specialised apparel as stressed upon by researchers *inter alia* Starkey and Parsons [37], Schlosser and Caroll [33] and Imbuki [12]. A four Likert-scale: Highly Dissatisfied (HD), Dissatisfied (D), Satisfied (S) or Highly Satisfied (HS) was adopted.

Table 4 Chi-square test for independence results for [dis]satisfaction level of selected active sportswear attributes

Active sportswear attribute	HD	D	S	HS	No response	Total
(i) Function/ usability	75 (27%)	17 (34.6%)	8 (25.1%)	0 (8.3%)	0 (5%)	100
(ii) Fit	8 (27%)	67 (34.6%)	0 (25.1%)	17 8.3%)	8 (5%)	100
(iii) Size ranges	50 (27%)	17 (34.6%)	17 (25.1%)	0 (8.3%)	16 (5%)	100
(iv) Coverage of assistive devices	17 (27%)	0 (34.6%)	42 (25.1%)	33 (8.3%)	8 (5%)	100
(v) Weight of sportswear items	8 (27%)	59 (34.6%)	17 (25.1%)	8 (8.3%)	8 (5%)	100
(vi) Offer freedom of movement	8 (27%)	67 (34.6%)	17 (25.1%)	8 (8.3%)	0 (5%)	100
(vii) Absorbent fabric	17 (27%)	50 (34.6%)	33 (25.1%)	0 (8.3%)	0 (5%)	100
(viii) Easily reachable openings and fastenings	33 (27%)	0 (34.6%)	67 (25.1%)	0 (8.3%)	0 (5%)	100

$\chi^2 = 357.6$, d$f = 28$, $p = 41.337$, $n = 800$

Taking levels above 50% and the higher of the genders' percentage level, a notable observation in Table 5 is that dissatisfaction level of both genders is equal (31%) concerning eight active sportswear attributes: function/usability, fit, size ranges, weight of sportswear items, offer freedom of movement, versatility, absorbent fabric and width of track jacket sleeves allows mobility. On the other hand, the satisfaction levels of the males (31%) surpass the females' (7%) in five attributes: coverage of assistive devices, care labels attached, easy to manipulate openings and fastenings and easily reachable openings and fastenings.

Table 5 Gender perspective of JSLWPDs on [dis]satisfaction level of selected active sportswear attributes

Active sportswear attribute	Gender	HD		D		S		HS		NR		Total	
		n	%	n	%	n	%	n	%	n	%	n	%
(i) Function/usability	Female	6	86	–	–	1	14	–	–	–	–	7	100
	Male	3	60	2	40	–	–	–	–	–	–	5	100
(ii) Fit	Female	–	–	5	72	–	–	1	14	1	14	7	100
	Male	1	20	3	60	–	–	1	20	–	–	5	100
(iii) Size ranges	Female	4	58	–	–	2	28	–	–	1	14	7	100
	Male	2	40	2	40	1	20	–	–	–	–	5	100
(iv) Coverage of assistive devices	Female	–	–	1	14	1	14	4	58	1	14	7	100
	Male	2	40	–	–	3	60	–	–	–	–	5	100
(v) Weight of sportswear items	Female	1	14	3	44	1	14	1	14	1	14	7	100
	Male	–	–	4	80	1	20	–	–	–	–	5	100
(vi) Offer freedom of movement	Female	1	14	4	58	1	14	1	14	–	–	7	100
	Male	–	–	4	80	1	20	–	–	–	–	5	100
(vii) Versatility	Female	2	28	1	14	1	14	3	44	–	–	7	100
	Male	4	80	–	–	–	–	1	20	–	–	5	100
(viii) Care labels attached	Female	1	14	1	14	3	43	2	29	–	–	7	100
	Male	1	20	1	20	1	60	–	–	–	–	5	100
(ix) Absorbent fabric	Female	1	14	3	43	3	43	–	–	–	–	7	100
	Male	1	20	3	60	1	20	–	–	–	–	5	100
(x) Easy to manipulate openings and fastenings	Female	1	13	2	29	2	29	2	29	–	–	7	100
	Male	–	–	1	20	1	80	–	–	–	–	5	100
(xi) Easily reachable openings and fastenings	Female	3	43	–	–	4	57	–	–	–	–	7	100
	Male	1	20	–	–	4	80	–	–	–	–	5	100
(xii) Width of track jacket sleeves allows mobility	Female	1	14	5	72	1	14	–	–	–	–	7	100
	Male	–	–	3	60	1	20	1	20	–	–	5	100
(xiii) Track trouser hems are wide enough to ease wear	Female	2	29	–	–	1	14	4	57	–	–	7	100
	Male	–	–	2	40	–	–	2	40	1	20	5	100

4.6 Proposed Design Details to Counter JSLWPDs' Dissatisfaction with Selected Active Sportswear Attributes

The questionnaire also sought to unravel active sportswear attributes that the JSLWPDs would like to be improved. The respondents recommended the following design details: attach deep pockets in track jackets, replace sleeveless vests with long-sleeved tee-shirts to camouflage their disabilities but without any elastic to allow free blood circulation, provide correct sizes, change the colour from green to blue and identify the sport on the track jacket. In addition, the JSLWPDs desire to

be provided with more active sportswear items so that each player has a set, as well as sports shoes and socks. In the FGDs the boys proposed that the sportspersons' anthropometric measurements be taken to provide the correct fit, medium-weight fabric used to manufacture active sportswear and gloves for goalkeepers while the girls advocated for identification of the sport on the track jacket. On the other hand, the sports teacher proposed adjustability, size ranges and cushioning. The pants hems can be widened, brand the active sportswear with the school's name and logo for identification and use absorbent and knit/jersey fabric to produce all the items as suggested by the occupational therapist.

5 Discussion

Persons living with disabilities (PLWDs) of all ages are an under-served, under-identified and a marginalized consumer group. The JSLWPDs voluntarily participate in diverse indoor and outdoor competitive sports for reasons such as enjoyment, challenge, talent, adventure and learning experience, leading to their social inclusion. The reasons for participating in sports concurs with Wanderi [40] and Bukala (Personal Communication 2015), thus facilitates the attainment of social sustainability. Globally fashion actors: educators, practitioners and the sportswear industry have neglected this special group of end-users, hence inhibiting the latter's social inclusion. Consequently, the extant active sportswear donned by JSLWPDs disregards the principles and ethos of sustainability *inter alia* the consumer, environmental, design, innovation, technological, social, raw materials and cultural. The ignorance has resulted in the JSLWPDs' high dissatisfaction level with numerous active sportswear attributes and further inhibits their full engagement and enjoyment of sport and social inclusion.

The JSLWPDs compete and perform exceptionally well in the annual Special Needs Education sports held countrywide in both indoor and outdoor categories namely chess, scrabble, football for CP and PH, netball, wheelchair racing and para-volleyball. Manually-operated wheelchairs are the most used assistive devices by the JSLWPDs due to the prevalence of lower limb weaknesses. Depending on the sport, it may have physical or mental demands and may occasion injuries- especially outdoor sports, to the sportsperson. However, the injuries can be reduced by the development of intelligent adaptive active sportswear, for instance, with cushioning.

The school is the major provider of ready-to-wear active sportswear which it procures from sportswear retailers. Though it occasionally gets the active sportswear tailored, it does not adopt co-creation with the JSLWPDs, resulting in poor fit and incorrect size among other conundrums. Due to scarce, worn out and ill-fitting active sportswear provided by the school, the JSLWPDs sometimes buy their own to look presentable and feel comfortable. Nevertheless, 58% of the JSLWPDs reported being consulted on their preferences for active sportswear though the results reveal that their dissatisfaction level is higher than the satisfaction level regarding numerous active sportswear attributes. Dissatisfaction arises because of the active sportswear's poor

functionality, the dearth of varied size ranges, fabric lacks culturally-inspired prints, no versatility, the track jacket is not branded with the school's logo (however, artefact analysis revealed the contrary) and poor fit (either too big or small or too long or short). Moreover, the sportswear items are heavy (especially the tracksuit), inhibits freedom of movement due to poor fit, the colour-green- is not aesthetically pleasing and favour blue instead, 100% polyester fabric used is non-absorbent despite the fact that they sweat a lot due to the high amount of energy expended in mobility (using wheelchairs, callipers and crutches and limbs for CPs), track jacket sleeves deter mobility and the pockets are shallow thus items like handkerchiefs easily fall off. Starkey and Parsons [37] reported that respondents favoured printed garments as a way to liven up a neutral-coloured ensemble. The JSLWPDs active sportswear fabric is solid/neutral green but they favour culturally-inspired fabric prints. Dissatisfaction with size ranges echoes Kinuthia et al. [17] that sportswear size is very critical in that it provides comfort during swimming. Further, correct clothing sizing was one of the three attributes which older consumers felt that clothing quality fell short and that ill-fitting garments may be uncomfortable to wear [4]. The dissatisfaction with fit, colours, fabric absorbency and pockets echoes Starkey and Parsons [37] findings that the mini-collection designed for elderly consumers incorporated pockets but avoided the creation of bulk, natural fibres with stretch and adjustability which ensured a customized fit. The dissatisfaction with colour resonates with Schlosser and Caroll [33] assertion that the design aesthetics of mainstream fashion help to promote athletes' self-body image. Dissatisfaction with the non-absorbent fabric contradicts Hassan et al. [9] claim that sportswear made of 100% polyester fabric produced the best physiological responses and performance from the athletes compared to 100% cotton and 65/35 polyester/cotton blend.

However, the JSLWPDs are satisfied with the active sportswear because of branding especially the vest which is inscribed with the school's name and logo though they would prefer it replaced with a long-sleeved regular fit tee-shirt to camouflage their disabilities, provides support to body parts, care labels are attached thus easy to clean and easy to manipulate and reach openings and fastenings including closed and separating zippers (though zippers easily get spoilt) and elastic. Further, the vests' round necklines are wide enough to allow ease in wear, the clothing is produced by reputable Kenyan brands, the track trousers' elastic and drawstring waistbands ensure they are firmly secured in place and the hems are wide enough due to the zipper opening. Chi-square test revealed a significant difference in the dis[satisfaction] level among the attributes. Thus it behoves fashion actors to address the JSLWPDs special apparel needs. From a gender perspective the dissatisfaction level of both genders is at par and it is higher than the satisfaction level on 13 selected active sportswear attributes. However, the fact that girls and women are double disadvantaged: by gender and disability [23] is worsened by the female JSLWPDs' dissatisfaction (31%) and satisfaction (7%) levels with several selected active sportswear attributes, thereby exacerbating their social exclusion. The result is consistent with Schweinbenz [34] that female athletes faced barriers, more so concerning sportswear. The results are contrary to Osmud [29] that females have greater sensitivity to clothing cues than males.

6 Conclusion

This study has provided insights into JSLWPDs' [dis]satisfaction level with selected active sportswear attributes. The significantly high dissatisfaction level is primarily caused by fashion actors disregarding the special apparel needs of this marginalized invisible young fashion-conscious consumer group. The school as the major provider of active sportswear to the JSLWPDs may adopt co-creation, a design sustainability approach. The approach would not only produce active sportswear with the correct size and fit but it would incorporate the JSLWPDs' preferences and special apparel needs.

Although this study has afforded an overview of active sportswear donned by JSLWPDs, further work needs to be undertaken through collaborative multi-disciplinary (fashion, textile and special-needs actors) action research to inform the co-design/user-oriented product development of intelligent adaptive active sportswear that factors the JSLWPDs' disabilities, preferences that come with their disabilities, gender, attitudes, age, lifestyles and the assistive devices that they use as well as the physical, physiological and ergonomic demands of a specific sport. The outcome of the study could spill over to related sectors such as apparel and textile manufacturing, retail, place-branding and entrepreneurship. It is also envisaged to inspire designer clothes in SIF conforming to the global trend. Fashion actors need to attend to and enhance the active sportswear attributes that the JSLWPDs are dissatisfied and satisfied with respectively to foster diverse sustainability aspects. For instance, *inter alia* a dash of brightly coloured culturally-inspired Afrikan patterns and trimmings would enhance aesthetics. Ease of wear may be promoted by incorporating easy to reach and manipulate openings and fastenings. Comfort could be achieved by the use of end-of-life, medium weight, stretch/knit/jersey, thermally insulating fabrics as well as enriched adjustability for a customised fit, freedom of movement, correct fit for specific body shapes from a wide range of sizes, support of body parts for example, sports bras and coverage of assistive devices as well as reversible items and cushioning. Longevity may be attained by attaching comprehensible care labels, superior quality items, abrasion-resistant fabrics and enhanced functioning while compression apparel boosts performance. Above all the active sportswear should be affordable. Other than clothing the active sportswear co-designed should include accessories essential for preventing injuries during sporting activities such as gloves and helmets. The initiative shall help the JSLWPDs to realise their full potential not only academically but also within the entire bio-psychosocial continuum especially social inclusion and enhance their active engagement in and enjoyment of diverse sports.

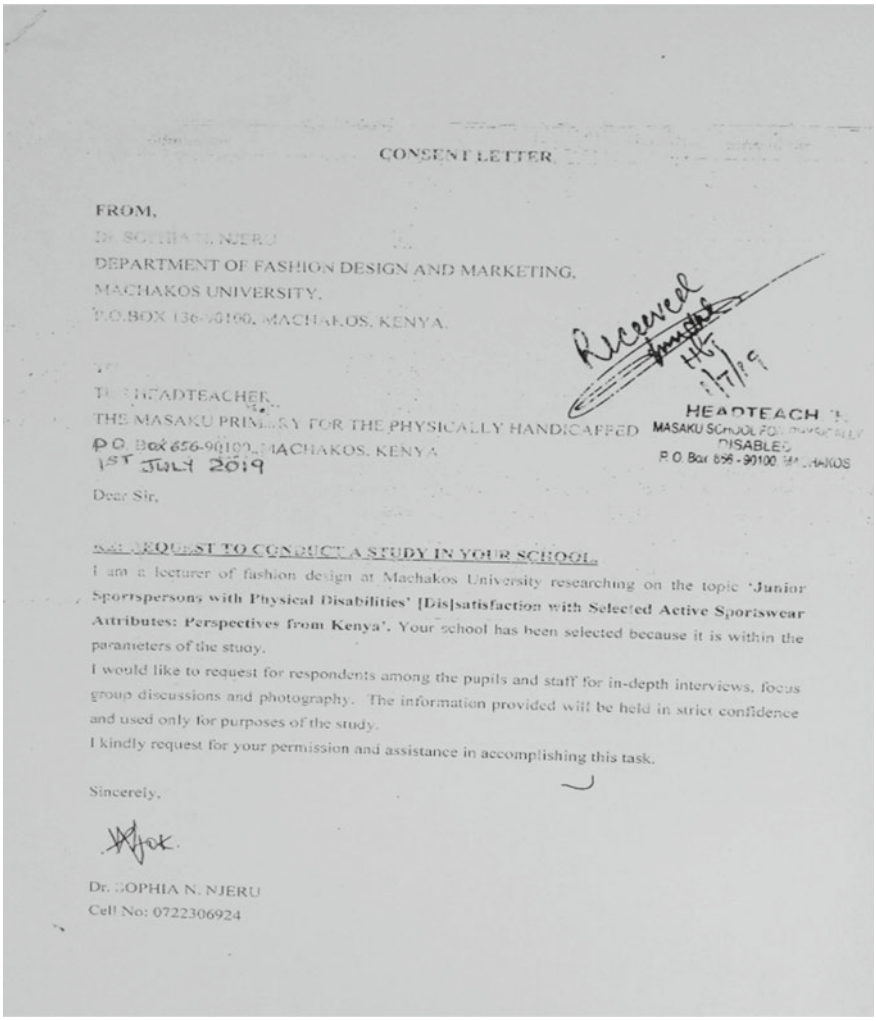
Significantly, the study takes up the challenge by Imbuki [12] to fashion designers to create attractive clothing styles that are functional to enhance and boost the self-esteem of consumers living with disabilities. The study also champions the implementation of United Nations *SDG* Goal 4 and 5 [38]. Further, it aims to support the implementation of Kenya's National Special Needs Education Policy Framework 2009, specifically the provision of research and documentation:

encourage research and dissemination of findings [23]. Evidently, active sportswear fashion actors' product development approach is unsustainable because they largely disregard the special apparel needs of JSLWPDs.

Appendix I

Consent Letter

Consent letter



CONSENT LETTER

FROM,

Dr. SOPHIA N. NJERU

DEPARTMENT OF FASHION DESIGN AND MARKETING,

MACHAKOS UNIVERSITY,

P.O.BOX 136-90100, MACHAKOS, KENYA.

Received
17/7/19

TO: HEADTEACHER,

THE MASAKU PRIMARY FOR THE PHYSICALLY HANDICAPPED

P.O. Box 656-90100, MACHAKOS, KENYA

1ST JULY 2019

HEADTEACH
MASAKU SCHOOL FOR PHYSICALLY DISABLED
P.O. Box 656 - 90100 MACHAKOS

Dear Sir,

RE: REQUEST TO CONDUCT A STUDY IN YOUR SCHOOL.

I am a lecturer of fashion design at Machakos University researching on the topic **'Junior Sportspersons with Physical Disabilities' [Dis]satisfaction with Selected Active Sportswear Attributes: Perspectives from Kenya'.** Your school has been selected because it is within the parameters of the study.

I would like to request for respondents among the pupils and staff for in-depth interviews, focus group discussions and photography. The information provided will be held in strict confidence and used only for purposes of the study.

I kindly request for your permission and assistance in accomplishing this task.

Sincerely,

Dr. SOPHIA N. NJERU

Cell No: 0722306924

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Use Forecasting: Designing Fashion Garments for Extended Use

Jo Cramer

Abstract This chapter introduces the concept of 'use forecasting' to describe how designers might anticipate and design for the extended use of fashionable clothing. Garment design that supports extended use is one strategy with the potential to mitigate the harmful environmental consequences of disposable fashion. Lifecycle assessment studies of clothing conducted in the UK, have shown that even a modest extension to the use phase of clothing can significantly reduce the carbon, water, and waste footprint [1]. Much like a fashion designer employs 'trend forecasting' to predict future tastes in colors, fabrics, and silhouettes, use forecasting anticipates how a garment will likely be worn and potentially repaired, refashioned, recirculated, and ultimately recycled. Thus, the capacity for future adaptations that may be necessary or desirable can be incorporated into the garment's design. The intention is not to predetermine a singular lifetime for all garments of one style, but rather to enable diverse, alternate futures for individual garments. Including within the garment's design a capacity for modification may help the garment keep pace with the changing needs of the wearer, therefore postponing obsolescence and disposal. Implementing use forecasting within a typical fashion design process is presented in a case study, The Living Wardrobe, within which a series of fashion garments for extended use was prototyped. Strategies for consumer engagement with enduring garments are also discussed.

Keywords Use forecasting · Garment lifetimes · Fashion design · Sustainable fashion · Design for longevity · Clothing practices

J. Cramer (✉)
RMIT University, Melbourne, Australia
e-mail: research@jocramer.com

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1 Too Much of a Good Thing

Fashion clothing is being produced in excess of consumption. In early 2018, H&M revealed they are carrying US$4.3 billion of unsold stock [2] and Burberry admitted to burning GB£150 million of unsold stock [3]. The fashion industry accounts for 2% of the world's Gross Domestic Product [4], achieving US$1.34 trillion in retail sales per year [5]. These sales figures are projected to grow significantly over the next few years, increasing by 13% in 2021, attributed largely to the growing middle classes in China and India [6]. Yet the value of the market is only anticipated to grow by 8%, indicating an increase in low-value goods, i.e., fast fashion [5]. Over-production directly relates to over-consumption; clothing is being produced in excess of consumption but also the rate of purchasing is being driven in line with the availability of new products. While researchers often recognize fast fashion as the problem, industry solutions focus on adjustments to current industry supply chain practices to meet compliance. A more enduring solution is instead to focus on developing sustainable solutions for implementation within the garment use phase.

Prolonging the use of garments is imperative to reducing the waste problem generated by unwanted clothing. In Australia—where I live—it is estimated that a total of 6000 kg of clothing is dumped into landfill every ten minutes [7]. The charity sector receives one million tons of donated clothing and household goods per year [8], including quantities of unworn overrun production fashion clothing. In the state of New South Wales alone, the Smith Family processes annually 13 million kg of clothing at just one facility. Of this, the highest quality garments (3–4%) are resold locally through their network of charity shops, a further 60% is baled and sold by the ton for export to developing countries [9], and 5–10% is sold for industrial rags. The remainder, estimated to be 30% comprising soiled and worn-out textiles too degraded for recycling, goes to landfill, at a cost to the charity of nearly one million dollars per year [7]. Both the Smith Family and the Salvation Army have noted the diminishing quality of donated fashion clothing, unsuitable for reuse [7, 10]. These "flimsy" garments are the product of the 'fast fashion' system that produces garments quickly and cheaply for short-term use: fashion-forward styles that are relevant to the prevalent tastes for a season or two, then discarded in favor of newer styles. This means that although the consumer behavior is commendable in donating them, the garments are unable to be reused.

Fast fashion is a recent phenomenon that has evolved since the 1970s through improvements to industrial supply chain management (just-in-time manufacturing), the reduction of global trade tariffs, and the rapidly expanding manufacturing capacity of China. The global dissemination of new fashion ideas and products has contracted from a six-monthly cycle of spring/summer and autumn/winter collections, to a continual drip feed of new products into store throughout the year. Trends still trickle down from the haute couture runways but are just as likely to bubble up from the street via social media. As production has increased and retail price points have dropped, the consumption of fashion garments has increased

significantly. The largest group of consumers of fast fashion are women of the 'millennial' generation (born between 1981 and 1996), for whom the definition of fashion 'value' has shifted from quality and durability to bargain pricing [11]. When garments are valued in economic terms over performative qualities, they are more readily discarded.

The negative environmental and social consequences of the fashion supply chain are well known to producers and consumers alike. The production of both natural and man-made textiles depletes natural resources and pollutes the environments in which they are made and into which they are disposed [12–15]. The manufacture of garments has long been associated with the exploitation of workers in developing countries who work long hours for sub-standard pay in poor conditions [16]. Efforts to improve the negative impacts of the fashion sector have primarily focused on the supply chain, for which less harmful substitutes have been sought for existing materials and processes [17]. Supply chain improvements are critical to meeting sustainability objectives as are improved recycling options for discarded products. However, patching the existing linear economic model of 'take, make, waste' is insufficient to solve the planetary impacts of a rapidly growing population with a lust for stuff.

In contrast with fast fashion is slow fashion. Emerging from the slow design movement of the mid-2000s, and with parallels to the slow food movement of the 1980s, 'slow fashion' describes fashion produced with alternative values and methods to those of fast fashion. Hazel Clark defines slow fashion as fashion that demonstrates: concern for local resources and distributed economies; transparent production systems with less intermediation between producer and consumer; and sustainable and sensorial products that have a longer usable life and are more highly valued than typical "consumables" [18]. Slow fashion endorses a rethink of fashion as a production system but also as a values system which over the last decade has led to an examination of how the desire for fashion might be satisfied in less materialistic ways [19]. These approaches emphasize the durability of emotional relationships between consumers and products as a means of reducing consumption whilst pointing out the elusiveness of designing products to bring about such relationships [20].

The conception of fashion as the on-going engagement with the garments of the wardrobe, describes fashion as a social practice of wearing clothing to present a fashionable appearance [21]. This is in contrast to the prevalent understanding of fashion as the constant acquisition of new garments (fast fashion). Through actions like buying second-hand fashion and making alterations to garments, participation in fashion extends beyond the adoption of the current trend to include fashion as the capacity of the wearer to create fashion looks [22]. Situating fashion within its social context of daily dressing, highlights the need to design sustainable garments for sustainable wearing: including in the design process anticipated modes of use and reuse and deliberately designing to enable a multitude of possible futures within which garments persist, or are remade as fashion. This too seems at odds with fashion understood as the insatiable thirst for novelty. Alternatively, it suggests a less resource-intensive way to satisfy the same needs by extending the circulation of

fewer garments. Might actions that extend the use of a garment for one wearer reanimate a discarded garment for another?

In line with existing research in fashion and textile sustainability both designers and consumers demonstrate a desire to engage with more sustainable practices. This has led to many and varied models of sustainable fashion practice from design methodologies to consumer-driven approaches. Changes to retail practices and new business opportunities include: up-cycling garments into new fashions [23], reselling/take back schemes for unwanted garments [24], transparency around end-of-life scenarios for returned garments [25], customization [26], clothing swap schemes [27], new sharing services [28], a renewed market for formal wear hire [29], and bespoke made-to-measure [30]. Widespread consumer-led approaches include buying secondhand, recycling and upcycling garments, a resurgence in 'mend and make do' practices of garment repair, home garment production, and clothes sharing and swapping. In turn, this has led to an increase in fashion activism through which consumers are demanding more information about the environmental impacts and labor conditions with which fashion is produced [31]. These initiatives are increasing social engagement with sustainable fashion practices to extend the garment use phase. However, currently garments are not designed for extended use and reuse. This particularly limits their suitability to the various consumer-led sustainable fashion practice strategies listed above. Alongside increasing the original quality of the garment (materials and manufacture), the real opportunity is to begin to design for these practices in the first instance: garment longevity in support of social engagement. This requires a redirection of the fashion design process to design in anticipation of how garments will be used, here presented as 'use forecasting'. Forecasting garment use requires a closer examination of the garment use phase than is usual within the fashion design process typically followed within the industry [32–34].

2 Clothing Use

The nature and duration of use have environmental impacts that might be mitigated through a design process that includes greater consideration of garment use. There is a lack of research into consumer use of garments, but that field is growing. The available data goes some way to detailing the use phase within the garment lifetime by explaining reasons that garments are either kept and worn or discarded [35, 36]. Different garment types, and garments for different occasions, are worn by people of different demographic profiles, are used with varying intensity, and have different life expectancies [37]. The duration of use can be alternatively measured as a number of wears, washes, users or years [38]. Where the latter is used, research indicates widely variable values between garment types, based partly on the different research methods used [1, 39]. In an analysis of why Norwegian women stop using clothing and wish to dispose of them, Klepp identifies that clothing use can be generalized as a series of phases [40]. Klepp describes a phase between acquisition

and first use when the garment is 'on hold'. During 'actual use' it may be rested for a period, then following last time use it remains in the wardrobe 'at mercy' until the decision is made to dispose of it. This model is significant because it highlights common patterns in use despite the complex differences between garment types and the occasions for wear. Klepp's model also enriches our understanding of the phases of the garment life cycle between retail, use, and the grave. Klepp further noted a difference between garments disposed of for reasons of fashion over reasons of wear: fashion garments had a longer use phase, not because they were worn more actively, but remained 'at mercy' for longer before discard [40]. These garments linger in the wardrobe unworn, not because they are physically flawed or no longer fit, but because of changes in taste. That garments are used and rested is important to design in relation to both function and fashion: Where garments are rested because they need dry-cleaning or ironing, might they be designed for less labor-intensive care practices? Where garments reflect the very latest fashion taste, might they be designed to be modular so that components can be removed and interchanged once their moment has passed? Particularly, when a garment is 'at mercy' of disposal, what design strategies might enable tired garments to become fashionable again and return to active use?

2.1 Extended Use

Extended use is most readily understood as continuing to use a product beyond the point that it might typically be discarded. For clothing, the decision to discard a garment can be motivated by a range of reasons. In 2015, Laitala and colleagues published the findings of a wardrobe study in which they analyzed why the women interviewed disposed of particular garments. In summary, the findings show that the longevity of the garments in the wardrobe and their active use is largely determined by physical garment attributes of material properties and fit, over fashionability [41]. These findings are in keeping with research conducted in the UK which found that the majority of clothing was disposed of because it did not fit anymore [1]. Emerging from this research is the importance of garments being kept in 'active' use. Active use describes garments that are being worn regularly or periodically, as distinct from garments stored in a wardrobe but unworn [38]. This is a critical distinction to draw since research also shows that while there has been a reduction in the discard of clothing in recent years, there has also been an increase in overall clothing sales, which points to increased storage of clothing in people's homes [1, 42]. High volumes of clothing in the home suggest that each garment is worn less frequently and/or garments are being stored unworn. Extended use can be further understood as more intensive use. Intensive use has environmental benefits where it mitigates, or at least reduces, the need for additional garments worn for the same occasion or function. For example, increasing the number of wears between washes. This might be achieved by changing the fabric of a garment design from one that is 'dry clean only' to one that is 'gentle hand wash', thus reducing the time

the garment rests, unworn, in the dry-cleaning pile. The cost and the effort required to take garments for dry cleaning are barriers to a garment's more frequent use. Incorporating consideration of the ease of cleaning within the design process when selecting fabrics, is an example of use forecasting.

The growing body of research into clothing use provides fashion designers with considerable information on clothing lifetimes and consumer practices that can be directly applied to the existing fashion design sector, enabling a reorientation of design from design for sustainable *products* to design for the *conditions of sustainability* [43]. It begins to show how designers can influence the use of garments, through a more holistic understanding of the garments' life cycle and the relationality of the design phase within that cycle. Through their design decisions, the designer can contribute to sustainable use practices. It is at the point of design that materials are gathered and manufactured into garment form, comprising decisions on which fabrics and trims to use and where and how to produce it. These decisions affect how the garment can be cared for (dry clean, machine, or hand wash), how long it will last (durability of components and construction), and what end-of-life scenarios are possible (reuse, recycling, and disposal).

3 Use Forecasting

So how might designers approach design for extended use within the typical fashion design process? This question underpinned my postgraduate research study, The Living Wardrobe [44], through which the concept of use forecasting emerged. Prior to the study, I had owned and designed for a boutique womenswear label. Within this commercial practice, I had become concerned with the environmental impact of the materials and production methods I was using, but also the environmental impacts of the model of business in which I was practicing fashion design, particularly the significant amounts of post-consumer waste generated by the seasonal fashion calendar that continually rendered my designs obsolete a few months after they were produced. My fondness for dressing in fashion garments acquired secondhand, suggested to me the potential of design for extended use to enable sustainable fashion by increasing the recirculation of fashion garments. This potential warranted exploration through practice, to investigate how current industry practices of fashion design might be expanded to give greater consideration to use.

3.1 The Living Wardrobe

Within the PhD, I employed creative practice to investigate how a typical fashion design process might be adapted to produce garments better suited to extended use. Research methods of object analysis and literature review were used to expand my

existing professional garment-making skills and develop a repertoire of technical design and construction techniques to use in garment design and specification for manufacture. These were trialed in a series of sample garment designs, framed within the notion of a 'living wardrobe'. A *living* wardrobe emphasizes the use phase of the garment's lifecycle and therefore the study looked beyond the production of the most sustainable fashion garments, to instead explore the potential of fashion design to enable sustainable ways of living with garments [45]. Animism in product design can contribute to stronger subject-object relationships between people and their possessions, potentially leading to more careful and long-term use of products [46–48]. Thus, practically, The Living Wardrobe describes a suite of womenswear garment types that comprise an essential everyday wardrobe, while conceptually, it defines the prototype garments as enduring entities with the capacity of long and active lifetimes.

The garment prototypes that comprised The Living Wardrobe were developed iteratively, each one contributing new knowledge to the research study by testing and refining practical approaches in designing fashion for extended use. In total, six different garment types were produced: dress, skirt, coat, top, culottes, and trousers; archetype garment forms considered to be typical womenswear 'wardrobe staples'. The transition from one garment type to another, necessitated changes to usual industrial pattern-making and construction methods in consideration of fit and fabric requirements typical to those garment types. The fashion design methods developed from prototyping these garments draw on techniques of professional dressmaking and tailoring and domestic practices of garment repair and reuse, where the former seeks to enable the latter. Forecasting likely use and possible use informed how these techniques were incorporated into new designs; directing the design development process to account for future use scenarios that enable sustainability, where sustainability is not located within the 'sustainable' object but instead is the outcome of the relationship between people and things, in their context of use. These prototypes revealed the critical role the garment artefact might play in the transition from fast, disposable fashion to enduring, slow fashion. A garment designed with provisions for extended use, might contribute to new habits of garment care in use by making sustainable clothing care practices available to wearers.

3.2 Use Forecasting as a Method

Use forecasting is a suitable descriptor for the activity of designing for use because it aligns new practices to familiar methods, echoing 'trend forecasting.' Trend forecasting is a typical stage of the fashion design process that comes early in the overall design process. By forecasting trends, a designer (or design team) seeks to preempt what styles will appeal to the target consumer at the time the collection being designed will be on sale. Trend forecasts predict favored silhouettes, colors, fabrics, textures, and details to inform garment design development. Because trends

emerge through collective cultural consciousness (the 'zeitgeist'), generalized trend forecasts for consumer markets are developed by trend forecasting agencies for sale to product developers who in turn adapt the forecasts to their target market.[1] Importantly, new trend forecasts build on previous trends and market behaviors, offering updates and alternatives to existing looks. Traditionally, trend forecasts were released bi-annually, in keeping with the fashion calendar of spring/summer and autumn/winter. However, given the collapse of seasons within the fast fashion system and the move from print publications to online subscription platforms, trend information is now produced and shared continually in support of time poor designers seeking aesthetic inspirations for the dozens of collections they produce per year. The easy accessibility of these mass trend directions (provided for download as technical drawings of garment design concepts, color and fabric palettes) contributes to the homogenization of mass market fashion because everyone is working from the same trend material. This begs the question whether trend forecasting preempts or predetermines future trends.

Use forecasting shares some similarities to the above description trend forecasting: generalized patterns of use can be applied to specific garment designs and target markets. Similar to trend forecasting, use forecasting is undertaken early in the design process, and the findings applied to the development of each garment's design, informing fabric choices, construction methods, garment styling (silhouette, fit, fashion features), and details (fastenings, trims, embellishments). The data required to inform use forecasting has some similarities to trend forecasting also, in that past sales data, particularly customer feedback, can inform the use forecast. A range of lifecycle assessment tools now exist to assist designers to evaluate the potential environmental impacts of products in development (for example, Ecoinvent [49]). Therefore, as research into clothing use patterns deepens, it is feasible that in the future, quantitative measures may be developed to assist designers predict likely garment use. Brands will be able to develop proprietary use forecasting guides on the specific methods suitable for their range of products and target market, therefore streamlining the process.

Use forecasting should not be understood as a means of *predetermining* use, rather, by preempting likely use, desirable futures can be amplified, and undesirable ones designed out. Thus, the view of the future forecast is broad and considers intended and unintended consequences. For example, fabric choice can dictate cleaning methods for a garment, design details can render a garment obsolete beyond a particular point in time. This view stretches the forecast in keeping with the idea 'back-casting', a method of designing 'from the future to the present' [50]. From this perspective, trend forecasting can be seen to enable fast fashion, while use forecasting enables slow fashion.

The design of fashion garments for extended use necessitates an approach to design that pays greater attention to the practical side of how garments are worn and cared for, not merely what they look like on the body [51]. Under pressure to

[1]See, for example, Worth Global Style Network (WGSN) https://www.wgsn.com.

rapidly produce constant novelty, fashion designers are frequently more concerned with garment aesthetics than clothing functionality [13]. Garment designs in production may undergo a fit-test to trial the garment style on a live model who is representative of the target market. This test checks the fit and design features of the style on the body. Rarely does this test involve actual users; instead, professional fit models are employed. Garment use has limited consideration within the conventional fashion design and production process: materials and trims are carefully selected to ensure the washing/ironing advice provided on the care labels is suitable for all garment components. However, the durability of the garment is not so consistently addressed. The physical durability of the garment being designed varies with the target market profile and price point, which determines the acceptable fabric quality (pilling, holes, fading) and construction (seam and stitching strength, interlinings, and linings), to avoid faulty returns during the expected garment lifetime. High-quality garments may be designed with some provisions for alterations in fit and will include spare materials to assist with repairs. The popularity of fast fashion has resulted in consumer acceptance of poorer quality make and materials, given the short fashion life expectancy of garments. There is little or no perceived need for repair of such garments which will wear out as they go out of fashion. While recycling is an option for these worn-out garments, reuse is preferable [1].

3.3 Fashion Design for Reuse

Fashion designed for extended use will likely be worn by more than one owner sequentially or concurrently. To meet the various needs of different wearers over an extended garment lifetime, research into consumer clothing practices emphasizes the need for garments to be modifiable, to adapt to changes in the wearer's body, changes in their attitudes to themselves, and notions of fashion over time [52]. Ideally, the design of fashionable garments should open the garment to many possible future acts of reuse. Building on Klepp's research into patterns of clothing use [40, 53], Fig. 1 maps the disposal and reuse options for an unwanted garment. The options and pathways presented in the diagram have been determined through literature review and practice-based research, as outlined above. In preference to final disposal into the waste stream, garment use can be extended by various consumer actions of renewal to reinstate it to active use, or by recirculation for others to use. Currently, garments are largely repaired, recirculated, repurposed or refashioned in spite of their design and manufacture. For example, most garment types are typically mass manufactured with narrow, densely stitched seams that prohibit easy intervention to adjust the fit of a leg or sleeve, or to replace a broken zip or perished elastic from a waistline. Instead, if each of the outcomes in the diagram in Fig. 1 are anticipated at the design stage, decisions can be made on material choices and construction methods that facilitate extended use which itself can be conceived through a number of concepts addressed in this section.

Repair. A damaged garment might be repaired and then worn anew. Repair extends on typical garment care (washing and ironing) to describe acts of garment

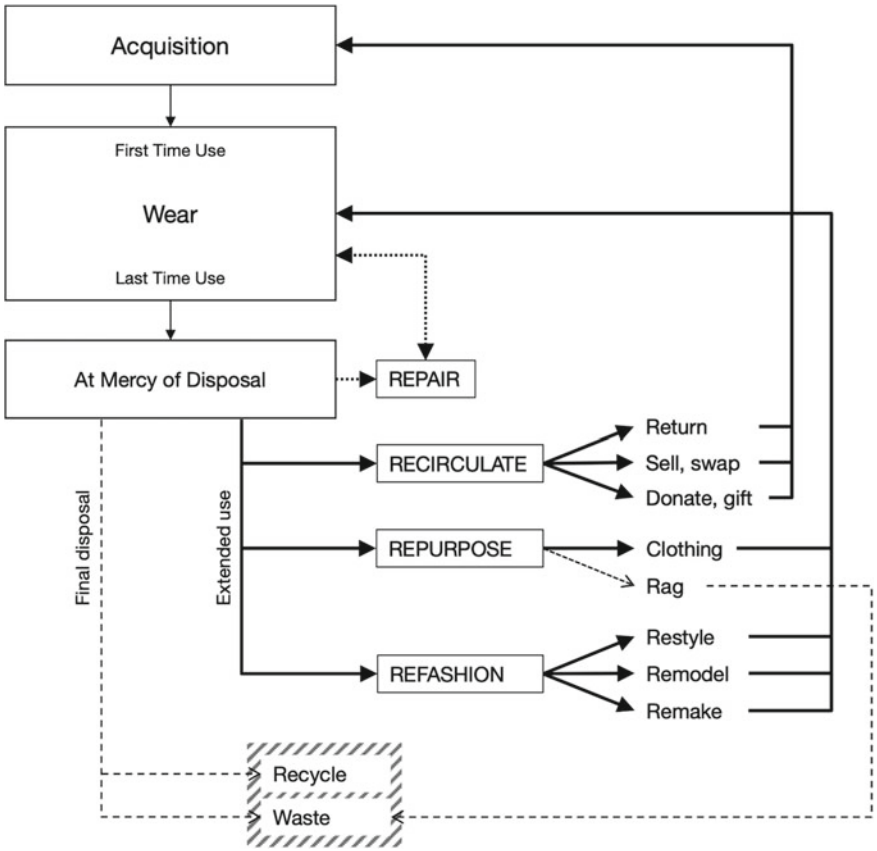

Fig. 1 Disposal and reuse options for discarded fashion garments. *Source* Prepared by the author

maintenance like reattaching a button, restitching a seam, patching, and darning holes to restore the garment to its original appearance and function. While invisible mending is a practiced craft, a search of the hashtag #visiblemending on the social media platform Instagram, returns thousands of colorful, decorative repairs that conceal garment flaws with eye-catching embellishment. The need for repair is anticipated for some garments which are sold with spare buttons and sometimes thread, beads or sequins. This provision for future repair can be extended with the inclusion of deep hem turnings for example, that make available excess fabric for patching. Other design considerations can assist repairs beyond the provision of spare materials: the construction methods used can assist or hinder actions of repair, so too fiber and fabric choice. Garments are assembled from cut pieces of fabric, trims and fastenings in a general order of assembly [54]. For example, one of the early steps in manufacturing a pair of trousers is to insert the zip, following which pockets, fly shields, the waistband, and top stitching details are added. This order of

construction inhibits the easy replacement of a broken zip as these other garment parts must be unpicked to access the zip for removal and replacement. Beyond construction methods, fabric choices impact how readily a garment might be repaired. Durability is important to long-term use in the first instance, but fabric construction and fiber content also impact how well a garment design responds to repair. In some fabrics, stitch lines visible once a seam has been undone may disappear when ironed, or an all-over print may negate the need for repair by concealing minor damage like a stain. Fabric testing can be undertaken as part of early design development to determine performance properties in relation to these qualities. Fabric producers could include such data with the fabric specifications they currently provide. A complementary design approach to facilitating repair is prevention of repair by predicting and reinforcing areas of likely wear. For example, the reintroduction of underarm shields into contemporary, conventional garment manufacture would not present any challenges to manufacturers and go a long way to extending the use of upper body garments susceptible to perspiration stains.

Recirculate. The simplest life extension option for an unwanted garment is to pass it on to someone who wants it. Clothing rental, subscription, and take-back services are growing in popularity, enabling consumers to return unwanted clothing to its provider for redistribution to subsequent wearers until its final disposal (ideally through appropriate recycling streams). Alternatively, unwanted clothing recirculates through the secondhand market, where discard channels comprise gifting to friends and family, donating to charity, swapping informally or at organized clothes swap events, and selling to resale boutiques or to peers via online platforms such as eBay, and depop. Recirculation recommences the cycle of acquisition/wear/disposal. The subsequent use period of a garment is estimated to be approximately half its initial use period [1]. Different recirculation methods are likely to require different capacities for longevity in garments. Clothing recirculated through clothing rental and subscription services can be expected to be used more intensively by more wearers than clothing that is gifted to family, donated to charity, or resold in the secondhand market. To withstand intensive use, garments need to be more physically durable: hard wearing fabrics, construction, colorfast prints and dyes. It can be anticipated that these garments will have an overall shorter lifespan in years, and therefore enduring visual appeal (a 'timeless' style) may be less relevant. However, for garments passed on through secondhand channels of gifting, donating, or selling, where the likely lifespan is longer, the capacity for the garment to be updated in keeping with new trends is more important. Also of importance in the secondhand market is the capacity for the garment to be altered to fit an individual figure. When first purchased, a garment is one of many of the same style, available different sizes. In the secondhand market, that garment is unique: it sits within the eclectic accumulation of the vintage boutique, charity shop on online resale platform. While it may appeal to a new wearer, it may not fit. Incorporating methods of variable sizing and flexible fit into the garment design can overcome some of the issues standardized sizing presents.

Repurpose. Within the hierarchy of reuse, repurposing is the lowest level, suitable for garments that are worn out, ideally having passed through several

cycles of reuse through other means. For example, a business shirt formerly worn to work is worn when gardening. The recategorization of the shirt within the wardrobe from "work" to "gardening" is the only action needed to extend its lifetime. While repurposing extends the use of the garment, it does not mitigate the purchase of a replacement garment, as there is now one shirt fewer to wear to work.

Refashion. Restyling, remodeling, and remaking present the greatest opportunity to refashion a garment and thus extend its use by maintaining its original value as a fashion garment. For the purposes of designing sustainable fashion, 'to refashion' is here defined as to reinstate a garment to a fashionable status (to make fashionable again). This definition extends the conventional connotation of refashion meaning "to remake, alter" [55], to describe the outcome of those actions. A garment may be refashioned through remodeling, by removing last season's ruffles. Through remaking, the fad fashions of five years past can be reworked to suit the prevailing tastes. The capacity for garments to be refashioned is critical to the longevity of fashion garments, as opposed to other types of clothing. Garments purchased to participate in current trends, to be fashionable, need to maintain pace with changing tastes if they are to be worn beyond the seasons for which they were created. Therefore, refashioning a garment is distinct to repurposing one, where the fashion garment is reused for its clothing, rather than fashion value.

Refashioning a garment draws together a number of design strategies with the potential to either return a discarded garment to its former fashionable status or to keep the garment in fashion throughout a prolonged period of use. These strategies speak to the emotional, rather than physical durability of the garment, and concern primarily the context within which the garment exists. The garment's capacity to connect the wearer to the prevailing taste of their surrounding culture changes with time and with the wearer's evolving needs and attitudes. Although the motivations for refashioning garments can seem intangible, the design strategies applicable can be particularly technical.

Restyle. To restyle a garment is to find a new way to wear it. Ethnographer Sophie Woodward discusses how fashionability is achieved through assemblage: the combination of new fashion garments with the existing wardrobe to create an outfit that is in keeping with the current fashions [21]. Restyling offers a way to renew the appeal of a garment by pairing it with different items in the wardrobe; perhaps newer garments and accessories, or those purchased for a different occasion. It does not require any modification of the garment. For example, layering a sleeveless dress over a long sleeve top. The 'shop your wardrobe' concept encourages consumers to reduce their consumption of new fashion garments by finding different ways of wearing garments they already own [56]. Garments with more versatility built into their design offer greater capacity to be restyled if, for example, waistlines can be cinched in or released. Innovations in modular garment design could build on the inherently adaptable material qualities of clothing by offering more ways to wear a garment.

Remodel. Remodeling describes alterations required to replace or conceal wear and damage, accommodate changes in fit, or to change part of the garment that dates it to a past moment in fashion. In contrast to repair which remedies damage to

the garment, remodeling modifies the existing garment form in a subtle or substantial way. For example, darts may be released to give comfort to an expanding waistline, a maxi skirt hemline shortened to a mini skirt as fashions cycle. As for repair, often the way a garment has been designed and manufactured makes such alterations difficult. In the early-mid twentieth century, garment remodeling was a common household practice. Dressmaker manuals from that time explain an extensive range of approaches to garment care, mending, making, and remaking clothing to ensure maximum lifespan [57]. They are methods that might be employed within existing industrial production processes and within contemporary domestic environments. For example, the inclusion of wide seam allowances typical of men's tailored trousers can be transposed to women's trousers to permit waistline alterations [58].

Remake. While remodeling does not fundamentally change the form or function of a garment, remaking describes a garment that is deconstructed and reassembled into a new form, often in combination with components from other garments or the addition of new fabric. In the language of contemporary sustainable garment design, remaking unworn garments into new forms is frequently termed 'up-cycling', to signal that the value of the original garment is maintained throughout the process. Remaking as a practice of sustainable fashion has been adopted by brands [59, 60], but also embraced by the online do-it-yourself (DIY) community [61, 62]. Within the huge online craft, sewing, and dressmaking community, users share both the methods and outcomes of remaking projects they have undertaken. For example, posts on the blog *Japan Couture Addicts* [63] describe projects completed from the book *Cool Couture Remake Dresses*, demonstrating possibilities to the wider community, inspiring and encouraging participation [64]. The popularity of up-cycling suggests considerable scope for brands to design garments in anticipation of their remaking.

Within these methods of refashioning, a hierarchy of difficulty is apparent. With little effort, a wearer can refashion a garment by finding a new way to wear it. Remodeling requires some degree of intervention by the wearer to adjust a garment to suit new circumstances. Refashioning a garment by remaking it into a new form requires the greatest effort on the part of the wearer to either carry out the remaking themselves or access a service to do so. Restyling, remodeling, and remaking are not mutually exclusive and can be approached within design as complementary and/or cumulative. Further, garment attributes that enable refashioning can support recirculation if a newly acquired secondhand garment can be adjusted to fit.

Recycling and Waste. All of the above garment life-extension strategies postpone final disposal of the garment into the waste stream. With few textile recycling systems yet available to consumers, dropping a garment into the rubbish bin is the most convenient action to take with an unwanted garment [42]. The main challenge to recycling clothing is the mix of materials typically used in one garment. Fabrics often contain blended natural and/or synthetic fibers, to which plastic and metal fastenings are attached. Internal structures like fusible interlinings, padding and boning contribute further material types. Currently, recycling systems for garments require material separation to effectively reclaim and recycle the different fibers into

good quality yarns for reuse. Therefore, to support this emerging technology, designers can reduce their material palette to as few different materials as possible and employ construction methods that more readily permit the separation of garment components at the end of the garment lifetime. The challenge here is ensuring durability of the garment is not compromised before that point.

Mapping the various reuse pathways for the extended use of a garment provides a suite of future use scenarios for which designers can plan. Within The Living Wardrobe study, as the prototypes were developed, each extended use scenario was considered in relation to the garment type being developed. For example, what are the likely reuse pathways for a dress compared to trousers? How do the design features, fabric, fastenings, construction impact those likely futures? While each garment type and design style warranted a response specific to its form and assembly of materials, a general suite of design principles for extended garment could be determined:

- Design for durability: reinforce areas of wear, use durable fabrics and trims, robust construction
- Design for adaptability: allow for changes in size and style
- Design for easy intervention: use simple production equipment and methods so later changes are easy to perform
- Design for easy replacement of parts: use a combination of fabrics within garments such that replacement with contrasting fabrics is suitable
- Design opportunities for renewal through remaking
- Design for a range of aptitudes: consider the skill level of the wearer in making repairs and modifications, offer simple as well as advanced options

By reevaluating design and construction methods for their capacity to enable future modifications in addition to economic viability (being quick to produce in a mass manufacture setting), garment use may be prolonged with little, if any cost to production. However, such changes can incur aesthetic costs: different design and construction methods can change the look of a garment, thus design for extended use potentially creates its own visual fashion language, as has mass manufacture. However, each style prototyped within The Living Wardrobe seeks to demonstrate that the design of living garments need not result in garments that look substantially different from the prevalent taste. Rather, sustainability through extended use can be incorporated into contemporary, conventional women's daywear design. Aesthetic similarity to conventional fashion is potentially a significant method of making sustainable fashion practices more accessible. Figure 2 shows a modular garment from The Living Wardrobe, comprising three interchangeable parts: the collar and sleeves are separate units worn over a singlet. The garment units can be swapped for others to restyle the look, and each unit has been constructed to enable easy repairs, remodeling, and remaking. In this case, the sustainable garment looks familiar, but enables practices of extended garment wear and care as a result of a

Fig. 2 Outfit from the living wardrobe: modular top and adjustable culottes. *Source* The author

design process connected to the use phase of the garment life cycle. This goes some way to making practices of sustainable fashion easy to adopt, if wearers are not expected to substantially change their look to suit their ethics.

3.4 Enabling Extended Use

A garment designed with affordances of extended use outlined above, including provisions for repair and refashioning, might contribute to new habits of garment care in use by making sustainable clothing care practices available to wearers. While the Living Wardrobe garment prototypes investigated how design can make sustainable clothing practices available to wearers within the garment artefact, they also revealed that those practices, including the invitation to interact, also need to be designed. That is, even if a garment is designed and manufactured for extended use, its enduring capacities may be entirely overlooked if they are not clearly signaled to

the wearer. While some of the enduring capacities of The Living Wardrobe garment prototypes are self-evident (wide seam allowances), others require explanation and instruction, or risk being overlooked (that components are designed to be replaced). Further, that once the invitation to keep the garment in use is accepted, the wearer may need assistance to do so. Therefore, the aims of the garment prototypes became to produce garments that contained within them both their 'futuring' capacities [50] and the means to communicate and facilitate access to those capacities. This resulted in prototyping of both garments and resources to support those garments: Quick Response (QR) code labels that link the garment to a website of resources that explain what the garment does and further guides the wearer in taking those actions. The embroidered QR code garment label embeds within each garment of The Living Wardrobe, a durable hyperlink to a website that might be accessed at any stage in the garment's lifetime. A website of resources for enabling wearer interaction with the garment offers a potential solution to the challenge that wearers may have limited garment literacy to read the futuring capacities or the know-how to act on those capacities. There is potential for this information to evolve as the garment ages, initially supporting sale and first wear, then refashioning for subsequent wear and finally recycling. This presents new possibilities for counteracting the fashion cycle if garment styles produced years prior can remain contemporary through the ongoing discourse that surrounds them online.

4 Conclusions: Reconceptualizing the Garment Lifetime

At the heart of this chapter is a challenge to the cliché of giving your clothes a second life (Fig. 3). Describing an extended life as a subsequent life mis-represents the actual garment lifecycle that is, in fact, a *single* lifetime *inclusive* of the garment being modified or changing hands, before final disposal. The idea that a garment lifetime is synonymous with ownership undermines the value of the garment artefact: the garment does not "die" when it is discarded and is not "resurrected" by subsequent ownership. Reconceiving ownership of clothing as garment 'custody' would help support the extended use of fashion, if possession of a garment is understood as merely one phase in the lifetime of the garment. Custody implies a duty to take care of the garment so that others may use it in the future. Therefore, it warrants fashion design strategies for sustainability that look beyond the initial use phase, to design for the possibility of subsequent use phases.

Currently, clothing is not designed for recirculation within secondhand markets. As the secondhand market grows, fashion brands will need to change how they produce and promote their clothing to foster longevity in the market. Brand value in the secondhand market will become increasingly important. Already, reselling platforms routinely promote top sellers to customers [65]. Fashion reseller ThredUp publishes their highest performing brands in their annual report [66]. Research into what qualities of garments and brands persist in the secondhand market would assist

Fig. 3 Clothing donation bin at a suburban supermarket in Melbourne. *Source* The author

in determining what percentage of secondhand success is due to garment qualities, to brand reputation, or to other factors.

If fast fashion describes the constant acquisition and discard of fashion garments, then slow fashion might be defined as garments produced for extended use. Future impacts of current fashion industry practices are well understood: the pollution generated across the production supply chain and the post-consumer waste problem caused by excessive consumption. These issues are becoming increasingly hard for designers and producers of fashion to ignore, raising the issue of responsibility: who should take it and how. To mitigate the impacts of textile waste on the environment, enabling the various actions of reuse and recirculation described above, must be the priority for sustainable fashion design. Use forecasting is an essential tool for designers to contribute to a circular fashion system.

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