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Sustainable Engineering of an Outdoor Jacket from Waste in 2030 †

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Abstract: Due to the almost linear textile chain, large amounts of non-renewable resources are consumed to produce cheap clothes that are only worn a few times. Particularly problematic are the fiber waste and the enormous water consumption of the textile industry. In this work, the development process of an outdoor jacket from the fiber to the finished product is sustainably presented. In the literature research, special attention is paid to fibers from waste and innovative processing methods. The practical part of the report describes the production of the convertible jacket design with the corresponding zero-waste pattern. The aim is to provide creative impulses and food for thought on the sustainability of a garment and to show that it is possible to produce a fashionable, durable, and water-repellent sustainable outdoor jacket.

Keywords: sustainability; textile waste; recycling; textile manufacturing; renewable sources; zero-waste; transformable design

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1. Introduction

The McKinsey study predicts large-scale fiber-to-fiber recycling by 2030, creating a sustainable circular economy in Europe [1]. The European Commission envisions durable, repairable, recyclable textile products made from recycled fibers, free from hazardous substances, and produced with respect for social rights by 2030 [2]. The garment manufacturing process produces a lot of waste, which includes not only fabric waste but also residual fibers and yarns, dyes, and chemicals used in the dyeing process of fibers and textile surfaces, which pollute the environment [3]. Waste, in particular, is a major problem in the textile industry. Each European consumes almost 30 kg of clothing per year, of which 11 kg is thrown away. Worldwide, less than 1% of clothing is recycled [4]. Meanwhile, waste from other industries can be turned into fibers and used as an environmentally friendly raw material for textile products [5]. At the garment manufacturing stage, an estimated 15% of fabrics are left unused and are, therefore, wasted [5]. It is not just the fabric that is wasted, but all the materials used to make it, the fibers and yarns, the chemicals and dyes produced and used in dyeing, the time, money, and labor invested in the production process. In addition, all these factors have an impact on the environment and a corresponding carbon footprint.

This work illustrates the sustainable development of an outdoor leisure jacket from fiber to finished product. The focus is on innovative, non-toxic materials derived from waste and recycled products from the textile and other industries that are available in sufficient quantities. In this work, the design and zero-waste pattern of the jacket has been realized to prove that the transformable design works. The aim of the work is to show

that it is possible to design a sustainable garment for everyday use in different weather conditions through the aspects of transformability of the design and sustainable materials.

2. Fibers from Waste

There are ample opportunities to recover fibers from agricultural, food, and cutting wastes in the textile production and recycling processes, but these methods often receive insufficient attention. For instance, in paper production, wood is commonly used to obtain cellulose, while the discarded tree bark is typically incinerated or discarded. Similarly, in pineapple or banana harvesting, the leaves and fruit contents contain valuable fibers that could be utilized as a sustainable alternative for pulp recovery, but they are often overlooked [6]. Despite their suitability for casein fibers, valuable by-products generated during milk production are often discarded and wasted. These by-products could be utilized to create sustainable casein fibers, thereby reducing waste and maximizing resource efficiency in the milk production process [7].

The casein protein utilized in creating the fabric is sourced from discarded milk that would otherwise go to waste, making it an eco-friendly option. Cellulosic fibers from sources like bast or stem fibers in the inner bark of dicotyledonous plants, leaf fibers in monocotyledonous plants, and fibers from seeds and fruits can be used for fiber production. Bio-based fibers like ramie, flax, hemp, jute, sisal, and coir are commonly used for technical purposes due to their rough texture and strong mechanical properties. These fibers can be obtained through isolation processes involving bacteria, fungi, as well as chemical and mechanical methods. Chitin, found in the cell wall of many fungi, can be extracted from fungal biomass through alkali treatment [8]. This presents a sustainable and eco-friendly resource for the production of textile fabrics with potential applications in sustainability-driven industries.

3. Sustainable Finishing

Chitin and chitosan, which can be obtained from tons of shell waste from the processing of crustaceans and fungi, are versatile materials used for the surface modification of textiles [9]. Their incorporation into textile finishing processes can improve properties such as dyeability and color strength [10]. In addition, chitosan applications in textile finishing can impart antimicrobial, anti-odor, anticoagulant, antistatic, and crease-resistant finishes, providing further functional benefits to textiles. These multifunctional properties make chitin and chitosan valuable resources for textile innovation and sustainability [11]. Other sustainable alternatives to petroleum-based wax systems for textile finishing include natural animal waxes such as beeswax and vegetable waxes (e.g., palm wax, soy wax, castor wax, sunflower wax). The bio-based waxes form a protective layer that repels water and prevents the sun's UV rays from drying out the plant [12].

4. Multifunctional Design

Design plays a significant role in the environmental impact a garment will have throughout its life cycle. The design stage sets the roadmap for the further production of a garment, so it is at this stage that sustainable practices need to be implemented to ensure a more sustainable garment production process. Today's fashion industry is based on rapid cycles of changing styles, creating a culture where psychological obsolescence becomes the norm. Consumers are under pressure to own the latest trends, so clothes go out of fashion at an increasingly rapid rate [13]. Nes and Cramer's theory suggests that by delaying product replacement, a consumer's period of use and lifetime is extended. By designing garments with multifunctional and adjustable features, the consumer's need for the new can be minimized. Designing for longevity means that the product can evolve with the owner, with the adaptability of transformable design increasing the chances of wearing the garment more and for longer [14]. Because the garment can be changed to suit different occasions and seasons, the wearer's needs and desires are met, which in turn leads to greater product satisfaction [15]. Ultimately, transformable design actively involves the

consumer in the design process, as they are the ones who decide which transformation stage they want to wear the garment in each time they wear it. This strengthens the emotional connection between the wearer and the garment, which directly leads to better care of the garment and, therefore, longer use.

5. Modular Transformable Design

The outdoor jacket was designed with the capability to transform itself into different pieces of clothing that showcase different styles and are wearable in different seasons, making this jacket not only wearable all through the year within different weather conditions, but also a fashionable piece that can be styled in a number of different ways. The design of this jacket aims to achieve multiple functional and/or aesthetic transformations achieved by different techniques, as shown in Figure 1.

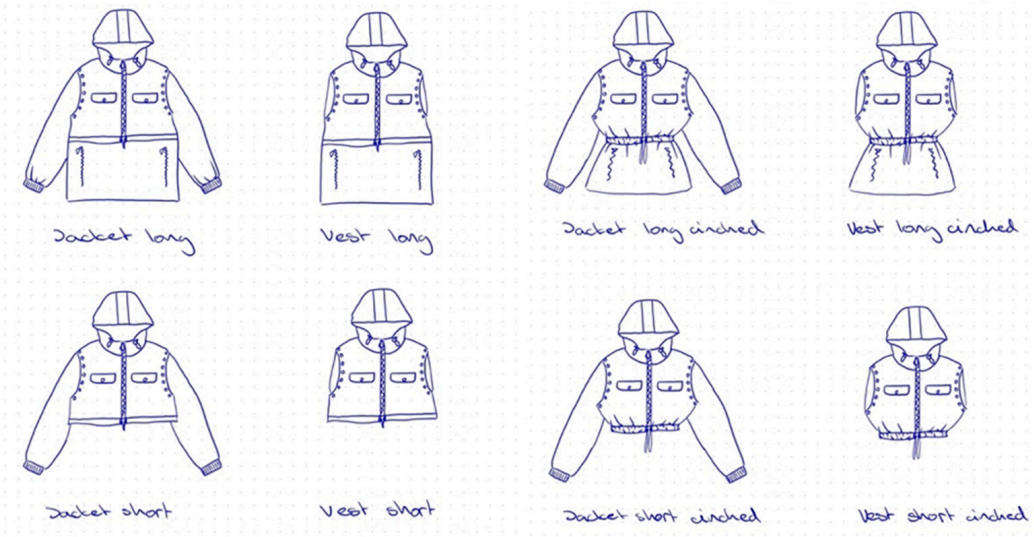

Figure 1. Sketches showing the eight variations in which the jacket can be worn. (Top row: jacket long, vest long, jacket long cinched, vest long cinched; upper row: jacker short, vest short, jacket short cinched, vest short cinched).

Overall, the jacket can be changed into eight different looks and has an incorporated bag that can be separated from the jacket. As shown in Figure 1, the sleeves can be removed through the strategic placement of press buttons, turning the jacket into a vest. The press buttons are fastened into the armhole part of the front and back of the jacket, with the respective buttons located at the top of the sleeve. While the sleeves are attached to the jacket, the buttons can be seen on the outside of the front and back of the jacket along the armhole. This visible placement is not only a functional one, but also a design choice. It would also be possible to hide the press buttons, but by riveting the buttons through the inner and outer layer of the fabrics they have a stronger clamp, which makes tearing the fabric far less likely. Utilizing the zippers, the jacket can be cropped at the waist, and with the additional use of the elastic band can be tightened into a more fitted design. The waist can be cinched whether the lower part is taken off or not. To achieve the bag transformation, the left side seam of the jacket is constructed with a double layer with a hidden compartment in between. The outer layer is held together by press buttons, and the front part of the jacket overlaps the back. The compartment is revealed once the buttons are opened. Hidden in the compartment are the straps of the bag.

6. Zero-Waste Pattern Making

Therefore, a zero-waste pattern-making approach is used to construct the jacket, ensuring a waste-free production. There are many techniques for making zero-waste patterns used by designers worldwide. For this jacket, the jigsaw approach is used. This

approach produces patterns that are the closest to traditional patterns in terms of other zero-waste techniques [16]. Traditional pattern-making techniques, such as the Müller and Sohn technique, construct patterns based on body measurements, where the pattern is fitted to individually measured and calculated sizes. The result is complex, two-dimensional pattern pieces that stand alone but come together to form a complete garment when sewn [17].

In zero-waste pattern making, the approach to the pattern-making process is different because the individual pieces of the pattern are not considered as individual working parts, but are constructed to fit together like a jigsaw puzzle. Therefore, the pieces need to be made in relation to each other, as the finished pattern needs to fit into a perfect rectangle. Zero-waste pattern making aims to use the entire area of the available fabric in its specific length and width. This is the only way to ensure that a true zero-waste pattern-making approach will be successful in its implementation [18].

Zero-waste pattern making is a completely different approach to conventional pattern making, although training in conventional techniques is helpful in learning zero-waste pattern making [19]. There are a number of challenges with zero-waste pattern making, as it is unpredictable and a remarkable design challenge. Zero-waste pattern making will never completely replace conventional pattern making, as some designs cannot be made without producing waste. However, it is possible to implement it in more designs being produced. The training of pattern makers would need to change and fit and silhouette expectations may need to be adjusted for certain designs. Another important factor is grading. Grading in zero-waste pattern making does not work in the same way as in conventional techniques. A reliable grading technique would have to be invented to make zero-waste pattern making a much more widespread technique in the garment industry. Zero-waste pattern making is an approach to fashion design that the industry needs to relearn. Since the industrial revolution, fabric has become a mass-produced product, making fabric a cheap abundance. Since fabric is no longer a finite and expensive resource, society has become wasteful. Zero-waste pattern making has been used throughout history because fabric was a scarce resource and wasting some of it was not an option. This can be seen in garments such as the traditional sari or kimono.

7. Conclusions and Future Outlook

The primary aim of this research was to explore the possibilities of reusing waste materials to produce a fashionable outdoor jacket. As illustrated in this work, it can be said that the production of such a jacket is now very close to being possible. More research needs to be done, but most of what has been illustrated here can already be implemented in the production of clothing. However, the use of waste materials needs to be considered carefully. In particular, the zero-waste pattern-making approach and the modular transformable design process are two things that can be implemented in the industry right now. For people working in the textile or clothing industry, it is common knowledge that the industry needs to change its practices to a more sustainable approach. This work shows that a wide range of sustainable solutions are available, more than are currently being used.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/ECP2023-14715/s1, Conference Poster: Sustainable Engineering of an Outdoor Jacket from Waste in 2030.

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