

Protest, Resist, Upcycle: Producing Puffer Garments Using Zero-Waste Methodology

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ABSTRACT

This study explores an alternate possibility of zero-waste upcycling of pre-consumer and post-consumer textile waste to prevent fabrics from going to the landfill and limit use of virgin materials. There are many issues which prevent the industrial-scale adoption of upcycling. The most pronounced one is the small-sized textile waste generated during the production of textile products referred to as marking loss - unusable areas between pattern pieces. It is extremely difficult to achieve zero wastage during cutting due to irregular shapes of the pattern pieces that can't be nested with one hundred percent efficiency. Thus, the cutting process creates an unpredictable stream of high volumes of fabric offcuts that are extremely difficult to reuse.

The author utilizes practice-based research methods to investigate the circular zero-waste approach towards outerwear design and production practices, and to research the opportunity to produce upcycled puffer garments on an industrial scale. The primary objective of this study is to develop a methodology that ties together principles of upcycling and zero-waste design, which would be applicable for a larger production outcome and would ultimately contribute to a closed-loop strategy reproducible by the fashion industry.

As a result of the project, the zero-waste methodology for producing puffer garments was tested and proven successful. Two prototypes were developed to showcase the application in standardized garments and to explore unique design possibilities. Several techniques and approaches were tried out in this project, such as the digitization of design development processes, the use of shredded textile waste as an alternative for goose down and polyfill, the reuse of nonwoven material scraps through laser cutting techniques, and the elevation of post-consumer fabric design through surface design. Developed methodology offers a more standardized upcycling approach and a more predictable sourcing strategy to those companies striving to improve their practices.

Keywords: Mass upcycling, zero waste, circular fashion, closed-loop design approach, ethical design.

INTRODUCTION

This study focuses on the circular zero-waste approach in the form of upcycling in design and production practices, as well as primary causes of the growing issue of textile waste accumulation. Textile waste is defined as industrial waste generated as a side-product to manufacturing, pre-consumer waste which is stock that is damaged or unsuitable for sale, and post-consumer waste which covers textiles discarded by consumers (Leonas, 2017). Textile waste in landfills will result in greenhouse gasses emissions, pollution and soil erosion yet are only one facet of the total environmental impact of the industry that significantly contributes to climate change and a shortage of natural resources.

Given that the fashion industry is resource intensive, recycling would seem like a logical course of action to reduce the demand for raw materials. The main obstacle for successful implementation of this practice on the industrial level is the lack of adequate technology to recycle industrial waste on a commercial scale (Global Fashion Agenda, 2017). Existing commercial recycling technologies are extremely resource-intensive, require the complete deconstruction of materials and are usually applicable only to pure-fiber fabrics, which hinders the recycling of blended fiber garments into products of the same quality (Bridgens et al., 2018).

Research gap

One way to address the massive scale of waste and environmental and resource degradation is the pursuit of circular design and production practices that fit within the model of circular economy. According to this economic model, materials used during production should never go to waste or create a disbalance of natural resources (Ellen MacArthur Foundation, n.d.). Products are being brought back into the supply chain or directly to a consumer through practices such as upcycling, reuse, maintenance, refurbishment, and others (Ellen MacArthur Foundation, n.d.). The main objective of a circular economy is to detach economic activities from wastage of finite resources (Ellen MacArthur Foundation, n.d.).

There is, however, a dearth of practice-based research to support the implementation of circular design and production methods on an industrial scale. Therefore, a small number of brands and independent designers have thus far used fashion upcycling as a 'trial and error' method of design and production with produced garments that are made in small batches and not approaching the scale of waste needing to be addressed within the fashion industry (Petrouch, A., 2015). This study seeks to create outerwear prototypes to test the developed techniques and methods, investigating

the circular zero-waste approach in design and production practices. This study therefore aims to answer following research questions:

RQ1. Can pre-consumer/post-production textile waste be used to produce outerwear designs suitable for mass production and scale?

RQ2. Is it possible to fully eliminate textile and thread waste during design and production processes?

LITERATURE REVIEW

Pre-consumer waste

Upcycling and traditional design processes intersect and oftentimes use the same design techniques (Han et. al, 2016). The key difference between them is the way fabrics are sourced and how it impacts a design brief (Han et. al, 2016). According to the zero-waste expert Reet Aus (2021), the upcycling design aesthetic is dictated by the available material leftovers that can vary in size, shapes, and other characteristics. Aus emphasizes that this type of design process should always start with reviewing waste streams, identifying available materials and their properties (Aus, 2021). It requires system thinking skills and understanding of production practices from a designer, and a certain level of transparency within the supply chain (Aus, 2021).

There are some estimates which suggest that the highest environmental impact is in the production stage of a standard garment (Steinberger et. al, 2009). Yet, most upcycling design approaches tackle post-consumer waste and disregard pre-consumer waste as seen in fabric loss that occurs during production (Fischer & Pascucci, 2017; Singh & Ordoñez, 2016). In their research Aus (2021) identifies five types of pre-consumer waste: unsuitable fabric, excess fabric and overproduction, garment sampling, marking loss and leftovers occurring due to the technical particularities of the production process such as roll ends. Marking loss is affected not only by marker efficiency, or pattern layout efficiency, but also by shapes of the pattern pieces, fabric utilization standards, fabric quality and other characteristics that are difficult to regulate (Aus, 2021; Rissanen & McQuillan, 2015).

Post-consumer waste

Most designers prefer newly produced textiles over post-consumer waste such as second-hand garments. However, donated goods represent great sourcing opportunities and a wide range of diverse materials. In their research Bigolin et. al (2022) examine approximately 300 samples ranging from formal garments to bedding textiles sourced from medium-size second-hand stores. It is emphasized however, that materials were sourced from Swedish enterprises, meaning that the research is limited to western European countries, and the quality and quantity of clothes will depend on geographical location and the second-hand market related to it (Bigolin et.

al 2022). Still, all the materials from this extensive sample were notably new or barely used, which not only highlights the growing overconsumption and overproduction issues but also presents the opportunity for designers to reuse materials in a good condition (Bigolin et. al 2022).

Closed-loop design approach

Closed-loop design approach implies reconsidering conventional design practices and acknowledging that every product has a lifecycle that previously was disregarded by the majority of producers and consumers (Gwilt, 2020; Fry, 2009). Thus far the relationship between the product and its producer is considered over once the product is sold and in the hands of the consumer (Gwilt, 2020; Fletcher and Grose, 2012). Alternatively, life cycle thinking implies considering use and disposal phases as a stage of a product design. Greater understanding of the entire lifecycle journey at the beginning of design development allows the designer to build strategies that help to grow sustainable behaviors amongst wearers and prolong the fashion product's life (Gwilt, 2020).

The first step towards closed-loop design practices is to unlearn what we consider "good" materials for textile fashion and destigmatize use of second-hand clothes as a raw material (Ainamo, 2014). Even when looking at companies striving for a more sustainable approach, material sourcing still occurs at the last stages of the production process. If waste materials are being used, they are usually added to a traditional production flow, thus limiting upcycling opportunities (Bigolin et. al, 2022).

Upcycling methodologies

Upcycling has several definitions and is mainly connected to the textile and fashion field (Aus, 2021). In general, upcycling is associated with reusing discarded materials by enhancing its quality or aesthetic value (Bridgens et. al, 2018). Upcycling is usually influenced by its social context, whether reuse of waste materials is driven by necessity or by an art practice (Bridgens et. al, 2018). In case of fashion upcycling, pre-consumer or post-consumer textile leftovers are not sent to landfills or incinerators but are being used in such a way as to create products with higher retail value (Aus, 2011; Cassidy & Han, 2012; Han et al., 2015, 2017; Teli et al., 2015). Even though upcycling is often being compared to recycling, according to the concept of circular economy it is a preferable way of reusing discarded materials (Gwilt, 2020; Ellen McArthur Foundation, n.d.).

Historically, upcycling is considered the most efficient method of bringing valuable textiles back in the supply chain (Gwilt, 2020). Gwilt (2020) emphasizes that most upcycling practices are suitable for a single conceptual garment design but not for standardized garment or collection production. When producing a series of garments, reclaimed fabrics might be a difficult material to work with because of the unpredictable manner of sourcing and irregular supplies (Gwilt, 2020; Han et. al, 2016).

Additionally, in order to truly fit into the concept of circular design, any upcycling methodology has to consider multiple life cycles of a garment (Blum, 2021).

METHODOLOGY

Creative direction

Design development involved both primary and secondary visual research, as their combination proved to be the most in-depth approach to conducting creative investigation (Mbonu, 2022; Gaimster, 2011). Primary research methods included sketching, collaging, photography, and photo-manipulation techniques (Mbonu, 2022; Gaimster, 2011). Secondary research employed cultural references such as body adornment, architecture, musical artists, and subcultures, as well as historical references like dress, political events, political movements, artistic movements and associated visual codes (Mbonu, 2022; Gaimster, 2011). To establish the starting point for design development, as well as the design brief and overall aesthetic to pursue, a series of inspiration boards and mood boards were created.

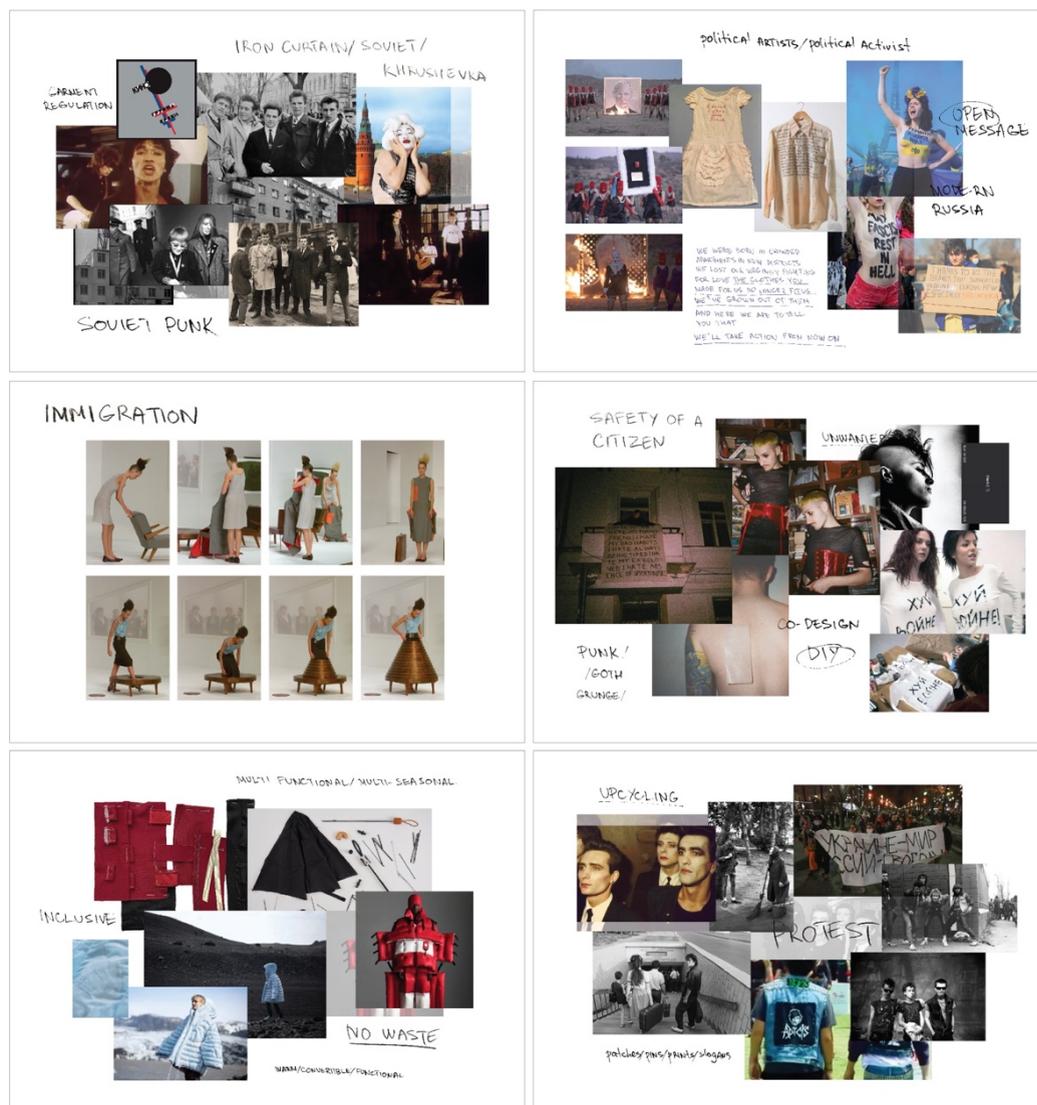


Fig. 1 Mood Boards and Inspiration Boards

The decision was made to focus on the development of a puffer jacket and vest, as they represented the primary area of interest for further design exploration. At this stage of the creative research, a decision was made to develop an alternative type of jacket filling made from upcycled materials and textile mix. This decision informed the rest of the design and material exploration and will be described in detail in later sections of the study. After analyzing the results of creative research using the primary research techniques described, sketches of the garment's front and back were drawn.



Fig. 2 Garment Sketch

Material research

It was decided to source post-consumer waste in a form of worn-out pre-owned garments from a second-hand chain that has multiple locations across the US to ensure the relevance of methodology for a wider geographical area. Before starting material investigation, a set of requirements for potential second-hand garments sourcing was established. These included maximizing the use of fabric obtained from the garment or fully reusing the garment. Additionally, materials were required to be durable and able to withstand manipulations associated with design development and consumer use.

Garments were expected to allow quick manual or equipment-aided disassembly within a design studio or factory setting. It was necessary for a constant supply of similar garments or apparel made from similar materials to be available in the store or other stores of the same second-hand chain. The use of trims was to be minimal, or trims should be easily removable and reusable. Desirable fabric for the project's purposes would also be made from materials that cannot be easily recycled using standard recycling technologies such as, but not limited to, synthetic fibers mixed with

natural fibers, a blend of several synthetic fibers, garments composed of multiple layers of different materials bonded together.

3D design and pattern development

The garment sketch was recreated in CLO3D software, providing an opportunity to transition the design process into the digital space. This allowed for experimentation with garment design by adjusting length and proportions without generating any waste, and reduced the number of physical preliminary fittings to just one. The size of the CLO3D avatar was set to match the author's body measurements. This was done to facilitate a comparison between the CLO3D avatar and a real body, determining the feasibility of digital preliminary fittings as part of the design and pattern development process. The approach proved successful as the fit of the physical garment closely resembled the digital version, requiring only one toile (prototype) fitting to proceed with further physical garment development.

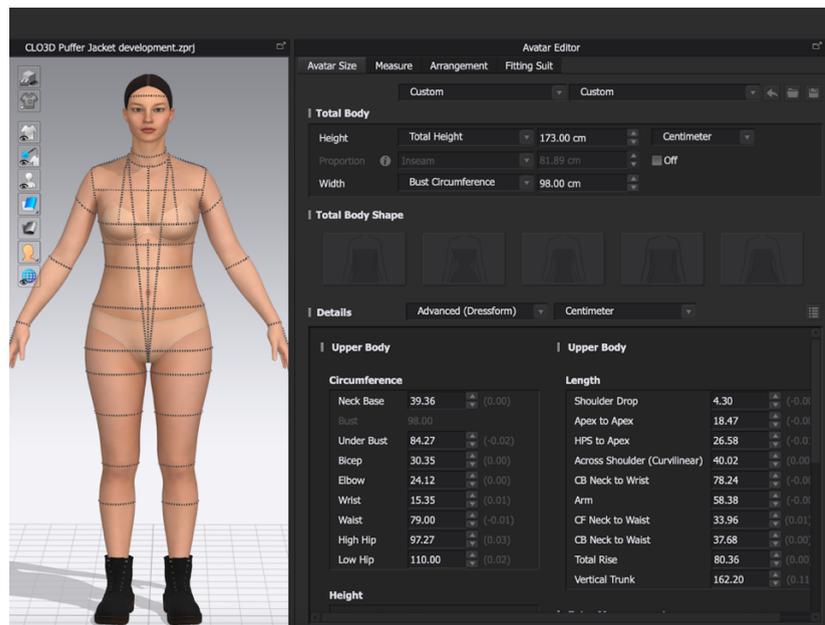


Fig. 3 CLO3D Avatar Body Measurements

During the 3D design development, a set of issues was identified, and garment design was adjusted and simplified to be reproducible reflecting numbers needed to work on an industrial scale. The most important design decisions that have been made were to separate the garment into two separate items (e.g., puffer jacket and puffer vest), eliminate trims that are difficult to source from second-hand garments by disassembly such as zippers, and reduce the amount of material types used for shell fabric to respond to fabric sourcing requirements set earlier.



Fig. 4 CLO3D Garment Mockups

Toile fitting

The toile garment was created to conduct a preliminary physical fitting and identify possible design or construction changes. In order to imitate the filling with shredded textile waste, three layers of discarded textured fabric (fiber content is unknown) with a brushed surface, high loops, and loose twist were used. Fabric layers were manually cut in the shape of garment details and placed on top of each other to achieve the desirable interlining thickness. This was done to ensure whether the general idea of using textiles for filling, instead of goose down or polyfill, is feasible. The preliminary fitting was successful and allowed for the determination of necessary changes in pattern design.



Fig. 5 Toile Fitting

Material Sourcing

Material research was documented through photography and categorized into groups of products similar to each other in terms of use, silhouette, color, and material. The following groups were identified to represent garment types or fabric types that can be sourced second-hand in bulk: classic denim apparel such as jeans and jean jackets, black pleather garments, basic jersey t-shirts in various colors and with various prints, knitted sweaters in neutral muted colors, nylon and polyester athleisure, and waterproof polyester and nylon outerwear in neutral colors. It was decided to source a black jacket with a shell fabric made out of 60% nylon and 40% polyester and lining made out of 100% acetate. This garment met all of the parameters established prior to material selection and fit into a material and garment group that is readily available second hand.



Fig. 6 Second-Hand Jacket Disassembly Process

Deadstock nylon fabric pieces were sourced from Socially Responsible Sweatshop (SRS) - the Ohio-based nonprofit charitable organization. The organization's primary activity involves repurposing deadstock textiles into various products, including home decor, yoga and meditation bolsters, and more (Socially Responsible Sweatshop, 2017a). Deadstock fabrics are donated to the SRS by for-profit businesses with fabric overstock to be reused for SRS products. However, the nylon fabrics mentioned above have not been used, nor are they planned to be used by SRS, as they do not fit into the range of products sold by the organization. Thus, the fabric had the potential to be truly repurposed and derived from the landfill since they had not been used by any previous owners and were donated to the author in the form of pre-cut fabric pieces instead of continuous yardage, which can be repurposed in a more traditional fashion.

Materials for jacket filling were repurposed fabric leftovers, which were utilized so that all fabric and thread offcuts created during the design development process, design experimentation, fittings and sewing were later used as a part of filling. Additionally, materials from the Kent State University School of Fashion fabric recycling system

were utilized, including but not limited to fabric offcuts from students' projects, damaged garments that were discarded into textile recycling bins instead of being donated, and yarn waste from the Kent State University School of Fashion digital knitting lab (KnitLAB).

RESULTS AND DISCUSSION

Interlining technology development

Fabric shredding was outsourced at the Socially Responsible Sweatshop (SRS). Through a collaborative research process involving organization's volunteers, it was confirmed that using larger pieces of textile waste instead of shoddy (shredded fabric utilized for insulation or stuffing) would be more feasible, as they can be easily secured in place using quilting techniques.

The initial technology involved securing textile waste pieces between two fabric layers, thus creating interlining details. This technology was chosen as a starting point to prevent unevenness on the garment surface and to facilitate the development of a feasible and efficient quilting pattern that would not be visible on the garment surface. Consequently, it avoids constraining technology development by the design brief and also does not limit design opportunities. The test prototype was developed using unused cotton fabric from the Socially Responsible Sweatshop sewing studio, along with a walking foot machine and an electric rotary cutter.

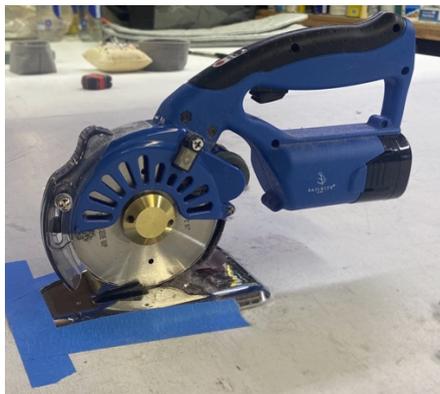


Fig. 7 Sailrite Li-ion 14.8 Volts Electric Rotary Cutter

After sourcing materials and cutting out garment details to obtain sufficient textile offcuts in the form of marking loss, the resulting textile waste, along with the toile garment, and a small amount of deadstock fabric pieces used during technology development, were shredded into small textile pieces approximately 2.7 inches in size. This size was chosen to ensure safe use of the electric rotary cutter, as it involves manual operation where a person moves the fabric under the rotating blade while keeping their hands close to the blade itself. The process involved simultaneous manual disassembly of the garment prototype and took approximately one hour to complete, which proved to be a reasonable amount of time and allowed for obtaining

enough fill material to fill at least one standard puffer jacket equivalent to, for example, Patagonia Men's Rubicon Down Jacket that uses 224 g or 7.9 oz of 650 fill power down (Patagonia, 2008).

Deadstock ripstop nylon fabric, the same material used for the shell fabric, was chosen for the main interlining details. A standard industrial sewing machine was utilized. Several techniques for creating interlining were tested:

1. Placing a thin layer of textile waste between ripstop fabric layers and creating quilting lines on the sewing machine;
2. Placing textile waste between ripstop fabric layers, adjusting the pressure of the presser foot by loosening it, and creating quilting lines on the sewing machine.
3. Placing textile waste between ripstop fabric layers, removing the machine's presser foot, and sewing with just a needle, manually moving the top layer of fabric to create chaotic quilting lines.
4. Sewing two layers of ripstop fabric together, creating sections reminiscent of pockets with an open edge, manually filling the sections, and closing the edges on the sewing machine.

The only technique that proved successful was the last one, and it was used to develop interlining pieces for the puffer jacket.

Following the chosen technique, two sets of puffer jacket front and back details, as well as sleeve details, were cut from nylon ripstop fabric and horizontally quilted with seams spaced approximately up to 3 inches apart. This spacing was chosen to effectively secure the shredded textile waste in place and potentially achieve the desired thickness for the garment. It is recommended to plan the placement of horizontal seams in accordance with the seam placement on the shell fabric. This ensured that the interlining can be connected to the shell fabric details, and that the machine presser foot can move freely between the filled sections. Additionally, due to the lack of constant access to a walking foot machine, a regular industrial sewing machine was used, and the pressure of the presser foot was adjusted by loosening it to the maximum. This ensured that the textile waste was evenly distributed and did not create puckering on the shell fabric.

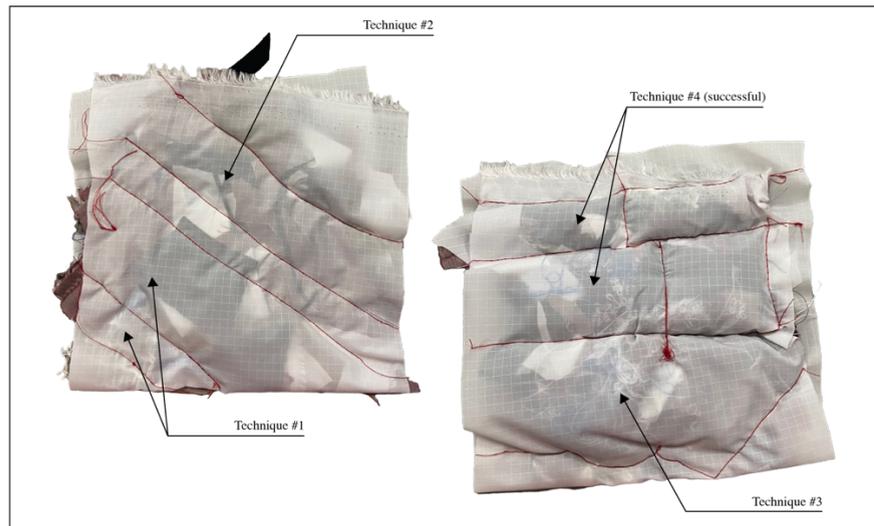


Fig. 8 Interlining Technique Prototypes



Fig. 9 Horizontal Seam Placement on Interlining

Where necessary, it was decided to additionally quilt interlining pieces with vertical seams placed in the areas of shoulder and waist darts on the back detail, as well as in the areas of elbow seams on the sleeve. This was done to secure textile waste in place and prevent it from migrating inside the interlining pieces. It also ensures that the garment remains flexible and body movement is not restricted by filling material that is sturdier than the regular materials used for puffer garment filling.



Fig. 10 Vertical Seam Placement on Interlining



Fig. 11 Puffer Jacket Interlining Details

Surface design development

The surface design development process included exploring the use of small pieces of non-woven fabrics that are not suitable for reuse in garment filling, such as pleather, leather, or rubber. Artwork designs were developed using Adobe Illustrator software and drew inspiration from familiar recycling, repurposing, and reusing symbols, as well as from the three R's of waste management (Gautam et al., 2021). Small sheets of laser-engravable rubber were cut on the Radian textile laser cutter.

Additionally, digital embroidery technology was used to decorate textiles obtained through second-hand garment deconstruction. This allowed for the elevation of fabric design in a safe and environmentally non-harmful manner, which can be reproduced in case of mass upcycling and batch manufacturing. Embroidery artworks were created in Adobe Illustrator software, then translated into 6D digital embroidery software, and produced on a Tajima industrial embroidery machine.



Fig. 12 Artworks for Laser Cutting and Embroidery Design Development

Jacket development

After being filled with shredded waste, the interlining details were covered with black and dark-gray upcycled shell fabric and quilted again to achieve the desired aesthetic without being restricted by the upcycling technology. It should be noted that covering the interlining with just one layer of shell fabric was insufficient to smooth the surface of the garment, resulting in lumpy contours of quilted sections becoming visible. Additionally, the size of the interlining decreased after being filled, creating empty spaces between the interlining and the shell fabric. To address this, a thin layer of textile waste was inserted into the middle part of the jacket's back and front, where laser-cut artworks are located, to smooth the surface. Furthermore, a small amount of textile waste was placed at the bottom of the jacket to pull its edge and create the more structured and voluminous garment shape initially planned in the sketch. Adding another layer of textile waste attained positive results and did not impact weight or size of the garment drastically.



Fig. 13 Jacket Bodice Before/After Inserting an Additional Layer of Textile Waste

During the post-assembling fitting, it was identified that the garment not only significantly reduced in length but also significantly shrank in size overall. It was determined that the proposed technology results in approximately a two-size reduction in garments. This factor should be taken into consideration in future size range planning, pattern development, and pattern grading.



Fig. 14 Puffer Jacket Final Prototype

Vest development

In contrast to the puffer jacket, which was created with the goal of showcasing the suitability of the proposed technique for producing standardized garments without restricting design options, the vest was designed to explore the unique design and aesthetic opportunities offered by this upcycling technique. During the development of the puffer jacket interlining, it was discovered that semi-sheer white ripstop fabric allowed for the creation of a chaotic print from textile waste, as mixed fabric pieces, threads, and yarn waste of different colors and textures became visible through the fabric surface. Thus, instead of being covered by another layer of fabric, vest details were left uncovered, allowing for the creation of a unique fabric pattern.

The only difference identified between jacket filling and vest filling methodology is that, since there is no cover fabric layer featured in the vest assembly process, the filling should be done more precisely, and waste has to be distributed more evenly. To avoid visible empty spots or uneven distribution of shredded fabrics in hard-to-reach areas such as seam corners or collar edges, it is recommended to start the manual stuffing process by filling seam corners and any other sharp edges with fluffier, softer, and more malleable materials or smaller pieces of textile waste. The best practice identified was to use pieces of sweater knit, lightweight jersey, deconstructed yarn waste, smaller offcuts of lightweight and thin linings, etc., securing them inside the corners and sharp edges manually or with the help of tools available at the factory or sewing studio.

After the front and back of the vest were filled in and assembled for fitting, it was identified that since the proposed technology drastically decreased the size of the garment, it was not responding to the desired design in terms of shape and proportions. Thus, different design solutions were tried out to improve the visual component of the garment. Finally, it was decided to change the overall proportions of the vest by cropping its length and adding a voluminous collar.



Fig. 15 Puffer Vest Design Experimentation

Two bottom sections of the garment were cut out; one section was emptied to leave some fabric for further hemming of the lining. The sections that were cut out were repurposed to create collars for a vest and a jacket.



Fig. 16 Puffer Vest Collar Design Experimentation



Fig. 17 Puffer Vest Final Prototype

CONCLUSION

As a result of the study, the methodology for producing puffer garments using shredded textiles was tested and proven successful. Two prototypes were developed to showcase the application in standardized garments and to explore unique design possibilities. In contrast to other upcycling technologies investigated during the literature review, which usually require precise manual deconstruction of seams to obtain larger fabric pieces and avoid offcuts, the developed technology allowed for quick disassembly of the garment.

It was identified that after the garment's life cycle has ended, it can be reintroduced into the supply chain and repurposed again. This was determined when the author successfully repurposed the toile garment, typically discarded after fitting, by

shredding it for interlining development and repurposing some garment details while altering the vest design.

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