Upcycling as a **design strategy** to **innovate fashion processes** and **create a local value chain with** the support of **digital technologies**. The Offbeat District case.

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ABSTRACT

Within the field of sustainability, the fashion system is under scrutiny for its impactful and unethical practices spread across the different steps of the value chain. The circular economy framework is one of the most promising among the various solutions being studied since it provides a way to address this wicked problem from a holistic perspective and ultimately aims at minimizing fashion's environmental impact by decoupling profit from the production and consumption of virgin raw materials. Simultaneously, digital transformation profoundly affects fashion's value chain by implementing digital technologies across all processes, from sourcing and design to manufacturing, retail, and the use phase. Therefore, the benefits of pursuing digital transformation within the circular economy framework are widely studied and reported in the literature, claiming that the first enable and triggers the second.

Upcycling is a widely acclaimed circular practice with an excellent sustainability performance, on which many designers are basing their creative process, and many brands of all kinds and sizes are building their business models. Because of the rising number of practitioners taking up upcycling, the media and academia have started to focus on this topic as an emergent field of research. Although upcycling is widespread, the available knowledge is limited due to the need for practical investigations on how designers carry out this activity. Moreover, more available literature must be available on how upcycling brands and designers can benefit from digital technologies. Therefore, this research aims to understand upcycling as a design strategy to innovate fashion processes and create a local value chain with the support of digital technologies.

The research was realized using different qualitative data collection and analysis methods. First, the literature review mapped the available academic knowledge about fashion's digital transformation, the circular economy, and upcycling. Second, three case studies were analyzed to understand how upcycling could give birth to different types of businesses. Third, visual research was necessary to study upcycling methods. The fifth chapter involved a single case study with visual research and design practice.

This research proved that upcycling-based slow-fashion brands could benefit from digital transformation by transforming the value chain into an entirely local one that leverages the local community as a core project stakeholder. Moreover, three phygital-based upcycling workflows were outlined, providing a standardized methodology for repurposing local textile waste.

Because of the disconnection between production and consumption that characterizes our society, reconnecting people and material culture is crucial to implementing sustainable and circular value chains effectively. This research will help other designers understand how to leverage their local network and community and create a local value chain for upcycling textile waste with the help of digital technologies, spreading awareness about the material and immaterial value of manual labor.

INTRODUCTION

An overview of the current state of the fashion system highlighted that the transition towards a sustainable fashion system is a wicked problem because it needs to involve multiple stakeholders cooperating to solve it. Each stakeholder needs to change its practice for the better: improving the welfare of employees, reducing carbon and water footprint, avoiding the use of chemicals, building successful closed-loop recycling systems, and designing materials and garments for biodegradability, recyclability, and longevity. In addition, logistics and retail need to be sustainable, and second-hand resell routes must be safe for developing local industries in developing countries. Researchers of the consulted literature agree that digital technology and its innovation potential could trigger a switch in practices achieving circularity and sustainable development, from raw material extraction to manufacturing, retail, use-phase, and end-of-life, achieving systematic product and service innovation.

The industry needs to create alternative models to fast fashion by applying critical approaches such as limiting production and consumption growth, reducing waste, and promoting a circular economy. The fashion system can aim at avoiding waste by designing it out of production thanks to the pivotal role of the designer (Niinimäki et al., 2020). A radical approach – such as zero-waste design – avoids all textile waste in the pattern-cutting phase, whereas 3D fashion design can significantly reduce pre-consumer textile waste during product development, digitizing garment sampling, and fitting. Zero-waste fashion design can be powered by 3D technologies, altering the design process. There is no need to have a physical sample to adjust the fit - and, consequently, the 2D pattern. The iterative product development process is entirely transferred to the digital software, and a physical sample is done only after the fit and the 2D pattern reach their final shape (McQuillan, 2020).

The transition to a circular economy is a complex process requiring a comprehensive perspective of the industrial system. The designer needs to have a broader awareness of the processes involved and design with improved efficiency by adopting innovative technologies, closing the loop of resources, being aware

of products' life cycle, and aiming to extend the latter to improve garments' and accessories' durability and longevity – both functional and emotional. A design-driven approach is critical in achieving an innovation of meaning, from fashion as cheap entertainment to fashion as an actor for systemic change (Niinimäki et al., 2020).

Lastly, psychological aspects underlying production and consumption patterns are equally relevant as drivers for achieving product longevity, as the consumers are ultimately the ones who will decide when and how to dispose of what they own. Design for emotional durability requires the designer to understand how value is created and how it can be transformed through usage instead of reduced to zero.

Many innovative business models are being tested within the scope of circularity, such as renting, repurposing, and reselling. Repurposing textile waste is a core concept that builds upon upcycling, recycling, and downcycling. The difference among these three processes lies in their ability to retain a certain amount of value – higher, similar, or lower – which is transferred from the wasted textile into the new product.

The upcycling practice was embedded in our culture until the 19th century, when people would sew their garments and take care of them by mending, repairing, and upgrading them. After the Industrial Revolution, throw-away culture replaced the sufficiency-based lifestyle that characterized that time. Because of this, most of the upcycling know-how that people had previously passed on to the new generations was forgotten. The economic boom of the 1950s ended prosumerism but simultaneously fostered a countertrend among young people who wanted to criticize the mainstream capitalist culture. For instance, this is the case of the DIY movement that took place from the Sixties with the hippies to the Eighties and Nineties with the punks.

Upcycling is an example of the practice of deconstruction, which originated in the homonymous philosophical concept founded by Jacques Derrida. The concept is about breaking fixed binary oppositions - the structures of society. Designers like Martin Margiela have contributed to the rejection of consolidated perceptions of the body and dress, generating new possibilities of construction and signification and demystifying the secret language of fashion.

There is no fixed methodology for upcycling, but a few general methods that the designer freely combines according to the possibility that each specific case provides. These methods include subtraction, deconstruction, addition, function, and using deadstock fabric. Established and emerging businesses are orienting towards upcycling, configured differently in each case. It may be more standardized and scalable, such as in the accessories manufacturer Freitag, it can be in the shape of a slow-fashion artisanal design studio, or it can be a service-based model for people and designers to co-create. Choosing a method and creating a methodology triggers a specific business model for an upcycling brand.

The leading case study of this research is Offbeat District, a slow-fashion upcycling brand based in Pordenone, Italy. The brand is creating an upcycling methodology based on local deadstock, second-hand raw materials, and local design and manufacturing. The study aims to understand how digital transformation affects the upcycling design process by analyzing how the brand has leveraged 3D modeling, AR technologies, digital databases, and an online platform to establish a local value chain.

METHODOLOGY

This study was conducted through a combination of qualitative research methods.

Data collection. In Chapters 1 and 2, a literature review of sustainable fashion's current state and design's role in the fashion green transition was carried out. Chapter 3 is a literature review on upcycling focusing on the design process. In this chapter, research based on design practice was necessary to understand how digitalization affected the upcycling process due to a lack of relevant literature. Chapter 4 is a study of the upcycling practice through an initial literature review, further supported by case studies of the upcycling practice carried out through desk research and visual research. Finally, chapter 5 is a qualitative single case study (Baxter and Jack, 2008) of my own upcycling experience carried out through practice. Moreover, books and catalogs were consulted with primary sources such as fabrics, laces, and garments to understand the connection between the collected raw material and the region's textile heritage.

Data analysis. The literature review in chapters 1, 2, 3, and 4 was analyzed with thematic analysis, reporting agreement or disagreement between the authors on different topics. Further research suggestions mentioned in the literature were taken into consideration. In chapter 3, the research on digital technologies and the design process was analyzed through inductive reasoning to be applied to the upcycling process. The case studies of chapter 4 were analyzed by understanding their business model canvas and drawing conclusions on how upcycling can give birth to different types of methodologies and businesses. The visual research of examples of the upcycling practice was analyzed through categories provided by the literature. The Offbeat District single case study (chapter 5) was analyzed by describing the brand's value proposition and understanding the project's ecosystem with a stakeholder map. The supply and value chains were analyzed by localizing each step on a map. Raw materials' data were analyzed after sorting and cataloging, dividing them into categories. The emerging product categories influenced the design process and the conceptualization of a methodology. An initial guess of the possibilities is explained, to be later tested with design and prototyping practice. The raw materials provided a fertile field of study. They were analyzed qualitatively with a table to understand the distribution of each material type among donors of different socio-cultural backgrounds. Analyzing the design and prototyping process that was carried out, three upcycling design workflows were described. Lastly, a methodology for upcycling was defined by listing design priorities hierarchically and generating design dogmas.

CHAPTER ONE: STATE OF SUSTAINABLE FASHION

INTRODUCTION

The past century's flourishing economic and industrial development - rewarded by the globalization process that affected all industry sectors during the past 30 years - has profoundly transformed how we produce and consume goods. A wider availability of resources and mass production has broadened and democratized the consumption of specific product categories. Fashion products are representative of this paradigm shift – becoming one of the industries with the highest environmental impact globally (Niinimäki et al., 2020).

A make-use-dispose model across all industry sectors characterizes products and businesses today. This model is tangible in fashion, where globalized value chains can deliver new designs at a pace that has widely surpassed the traditional seasonal drops. Even though this process acceleration and disposability of goods are traditionally associated with the fast-fashion (or ultra-fast fashion) phenomenon, ready-to-wear and luxury brands also played a part in developing and sustaining these patterns (Martínez, 2021). In addition, fashion brands respond to and encourage consumerism across the industry (Palomo-Lovinski and Hahn, 2015).

No matter the data available to prove the environmental consequences of the current model, the number of textiles consumed by the public is predicted to grow due to higher production efficiency has led to lower retail prices (Niinimäki et al., 2020). Therefore, the fashion industry needs a proper "re-design" now more than ever because of its intensive resource use, pollution, and dramatic social cost connected to the mass production and consumption of garments and accessories. To achieve this goal, institutions are designing guidelines to promote and reach sustainable development.

Global value chains

Fashion product manufacturing requires a combination of different industrial processes that are disseminated across the globe. These processes – agriculture, petrochemicals, manufacturing, logistics, and retail – are responsible for water, carbon, and chemical footprints. Therefore, not just our planet will bear the consequences of this production model, but also people. First, the ones who are employed and exploited in agricultural and manufacturing sites. Second, those affected by the rising contamination of air, water, and accumulation of waste (Directorate-General for Environment, 2022; Niinimäki et al., 2020).

Washing garments causes the dispersion of 500.000 tons of plastic microfibers per year – since 60% of all fabrics produced are made of polyester) – and this equals 50 billion water bottles (Martínez, 2021). Indeed, this is something worth considering when calculating a garment's environmental impact.

Over 15000 chemicals are used across different industrial processes, such as pesticides and herbicides for cultivation, lubricants, solvents for spinning and weaving, and bleaches, softeners, and dyes during wet processing (Niinimäki et al., 2020).

Water, carbon, and chemical footprint of textile production

While product design typically happens in the USA or the EU, manufacturing processes are delegated to the global south. During the production process, raw materials and garments travel multiple times across the World, resulting in unavoidable production errors, pre-consumption waste, and air pollution due to logistics.

Fiber, yarn, and textile manufacturing are responsible for massive water consumption. It has been calculated that the industry consumed 79 billion cubic meters of water in 2015. Researchers estimate a proportion of 200 tons of water usage for each ton of textile.

Textile production is responsible for about 10% of global greenhouse gas (GHG) emissions, and the fashion industry alone emits approximately 8.1% of global CO2 equivalent emissions. These estimates do not include the use phase of apparel and footwear, which requires other logistics and is responsible for laundry-related environmental impact (Niinimäki et al., 2020).

Impact on people

Every production stage is harmful not just to the planet but to people as well. Air and water pollution, waste generation, and labor exploitation affect global health. (Niinimäki et al., 2020; Palomo-Lovinski and Hahn, 2015). Among the significant garments exporting countries, it is worth mentioning China, India, Vietnam, and Bangladesh – primarily Asian-Pacific countries with few regulations and poverty (Martínez, 2021). The fashion and textile industries employ approximately 86,6 million people – 80% of which are women (Koch, 2019) – across the globe, most working with no official contract, established working hours, and no protection and workers' benefits by law. The workers' health is constantly threatened due to destructive industrial processes and the handling of hazardous chemicals. The salaries perceived by textile and garment workers violate international labor standards and average 200 USD monthly for 50 hours of work. Inside these factories, there is an evident gender opportunity and salary gap and countless reports of sexual harassment. Child labor is widely diffused in Asia, employing kids in the agriculture sector, for instance, in cotton fields (Martínez, 2021).

Life cycle mindset

The globalization of industry processes, the stress on resources, water, and carbon footprint, and the extensive use of chemicals highlight how there is no product life-cycle mindset during the design phase and, overall, in fashion business models. As a result, the current trends in design and production lead to the unavoidable accumulation of waste, which will worsen with the increasing intensity of production and consumption predicted for years to come (Niinimäki et al., 2020).

The amount of waste generated is not easily managed. The current value chain does not include recovering, recycling, or regenerating textiles – best practices that facilitate the birth of a circular model. Instead, linear value chains cause textiles to be incinerated, landfilled, or resold to developing countries. Traditionally, European and American developed countries have sold second-hand textiles to Uganda and India (Hawley, 2011) – among others – but the rising amount of waste generated is causing the recipients to ban its import and foster the development of a local textile industry (Niinimäki et al., 2020). Moreover, second-hand clothing export is causing a financial imbalance in importing countries because of reduced product quality and increasing volumes (Han et al., 2017).

Transition towards a circular fashion industry

Research has recognized the circular economy (CE) as a critical approach to making industries – among which fashion – more sustainable. By designing waste out of products, innovating throughout the value chain, and implementing solutions at the end of products' life-cycle, the framework for sustainability based on circularity aims to "maximize resource efficiency and minimize waste" ("Deselnicu: Towards a circular economy–a zero waste... - Google Scholar"). The goal is to create a new paradigm in which production processes fit into a closed-loop system that separates economic growth from resource consumption and raw material extraction (Brydges, 2021).

Institutions promoting and regulating the transition towards circularity

The design of a circular paradigm is being researched extensively in academia and regulated by institutions. For instance, the European Commission is proposing guidelines for sustainable product design and regulating production through legislation. They are helping integrate circular processes both in downstream and upstream processes. Circularity in downstream processes alters the customer value proposition through models such as reselling, renting, returning and extending a product's life span without varying the internal activities of the brand, while adopting circularity in upstream processes affects the design, development, and production phases (Huynh, 2021). The European Commission proposes solutions to adapt the textile industry to a circular model. The "Circular Economy Action plan" suggests we must ensure products are fit for circularity. This goal can be achieved by enabling the users to easily access reuse and repair services, promoting product-as-a-service models, circular materials, and production processes, and increasing transparency. The possibility of sorting, reusing, and recycling textiles needs to be improved. After addressing the issue of waste in terms of prevention, we need to consider textile waste to achieve circularity. Secondary raw materials could be standardized waste streams for further industrial applications (European Commission, 2020).

Further suggestions for the future development of products in a circular economy framework are explained in the "EU Strategy for Sustainable and Circular Textiles," where mandatory Eco-design requirements are introduced. The design phase is crucial to achieving product longevity and increasing the durability of textiles and garments. Further recommendations from this report include: stopping the destruction of unsold or returned goods, tackling microplastic pollution, introducing a Digital Product Passport, defining criteria for brands to make green claims on product labels, extending the manufacturer's responsibility, and boosting the reuse and recycling of textile waste (Directorate-General for Environment, 2022).

At a global level, the United Nations Organization's Sustainable Development Goals (SDGs) provide a more general framework for companies and institutions to work towards expected environmental, social, and economic benefits. The fashion industry is among the core players, asked to achieve the following SDGs: "goal 9: build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation; goal 12: ensure sustainable production and consumption patterns; and goal 13: take urgent action to combat climate change and its impacts" (Akram et al., 2022).

CHAPTER TWO: THE ROLE OF DESIGN IN THE FASHION GREEN TRANSITION

Sustainable practices in the textile and fashion industry

The production process of textiles and fashion, the use phase, and the end-of-life burden the environment and people. As this industry is such a complex and globalized system, each step's impact must be carefully measured and addressed as a single process and related to the whole value chain. Product and process innovations are emerging for fashion to embrace a green transition (Islam et al., 2020). Today there are different possible paths for brands and designers to achieve this.
The concept of sustainable development by itself has lost momentum among academics and practitioners because it needs to be more specific to be addressed (Kirchherr et al., 2017). Other frameworks, such as the circular economy, are preferred. The literature shows that the main fields in which this industry's sustainable practices focus are eco-design, green sourcing, eco-friendly processing, clean energy, transportation, green operations, waste minimization and recycling, and resource efficiency. These practices fit the triple-bottom-line sustainability principles, meaning that companies should equally tackle environmental, social, and economic aspects (Islam et al., 2020).

The circular economy framework

The CE (circular economy) framework is gaining academic and practical importance, allowing it to systematically address different aspects of sustainable development. There is no univocal definition for CE; instead, it is being defined over time by applying "R's principles" such as reducing, reusing, and recycling, as most frequently mentioned in the literature. Most definitions prioritize recycling over other principles. Reducing (production and consumption) is the pillar of circularity. However, practitioners do not frequently promote it because it requires shifting to a new business model – such as product-as-a-service – to ensure economic growth. Instead, CE must be approached holistically, considering "environmental quality, economic prosperity, and social equity" (Kirchherr et al., 2017). Ignoring one of the three founding pillars of sustainable development will result in an unsustainable implementation of CE.

Circularity is not a universally effective solution but rather a case-specific transformative process that aims at achieving goals with different degrees of priority. These goals have been conceptualized – emerging from R's concepts – into 9 strategies gradually placed from a linear to a circular economy.

9Rs' principles framework for CE

R's principles are traditionally three: reduce, reuse, and recycle. However, with the growing number of available research and design practices involving the R's principles, this framework has been examined to define better the priorities for brands and consumers to work towards circularity.

Today, the three Rs have evolved into well-structured strategies and diagnostic tools to measure the effectiveness of the CE transition process. The literature suggests the "useful application of materials" through recovering (R9) and recycling (R8) as the least impactful approach. Within textiles, these principles include the incineration of materials with energy recovery and recycling resources into new materials of the same or lower quality.

Between linearity and circularity lies the "extend the lifespan of products and its parts" approach through repurposing (R7), remanufacturing (R6), refurbishing (R5), repairing (R4), and reusing (R3). These strategies are achieved through activities such as using discarded products in new products with different or the same function, restoring products, repairing defective products to be used in their original shape, and reuse of a discarded product that is still in good condition by a different user.

A significant transition towards circularity is achieved through the "smarter product use and manufacture" approach, which includes reducing (R2), rethinking (R1), and refusing (R0). Best strategies are about increasing the efficiency in manufacturing or use – allowing for more intensive use of products through sharing or multi-functionality – and making products redundant through a radical innovation in the product function (Potting et al., 2017).

Multiple processes must be "diagnosed" within the fashion system to improve the transition towards a CE: raw material manufacturing, textile wet and dry processes, pre-consumer waste, trims and packaging, use-phase, and disposal. The transition is led by the analysis and redefinition of the design process, which has a significant responsibility in defining the industry, as mentioned earlier processes.

Material selection addressing the impact of raw materials

Fiber processing, yarn, and fabric manufacturing play a significant role in the overall environmental impact of the fashion system. Crucial design practices to address sustainability in these phases include using eco-friendly fibers, whose performance is measured through a Life Cycle Assessment (Islam et al., 2020). These studies allow us to measure CO2 emissions, water, and energy consumption of manufacturing processes and logistics.

Textile dyeing, finishing, and washing

Water consumption and air and water pollution are vital issues in fashion and textile manufacturing processes and the maintenance of finished products. More specifically, this refers to textile dyeing, finishing, and washing. Emerging practices addressing this issue include waterless dyeing technology, reducing harmful chemicals and waste, improving resource efficiency, digital textile printing, and innovative materials and processes for garment washing.

Pre-consumer waste: fabric cutting, sampling, apparel assembly, and deadstock

About 10-30% of the fabric is wasted before the products reach consumers. This waste is a consequence of a lack of precision and automation. However, pattern cutting for fashion implies having leftover fabric unless the designer or modelist adopts a zero-waste pattern-cutting technique. The literature suggests approximately 26.5% of waste when the fabric is checked for flaws and cut patterns. To address this issue and improve precision and automation, companies have used CAD/CAM software. Garment manufacturing accounts for another 10-30% of pre-consumer waste (Islam et al., 2020; Niinimäki et al., 2020). Lastly, there is a significant amount of pre-consumer waste in unsold products, known as deadstock, which makes up to 1/3 of all garments manufactured within the European Union (Islam et al., 2020). At the core of product development, there is the sampling process. Sampling implies a trial-and-error mechanism and carries many opportunities for implementing process innovations and avoiding waste. Paying more attention to sampling, powered by automation and new technologies can significantly reduce the amount of waste and optimize resources. Digital transformation – whose necessity was increased by the pandemic – can affect sampling and mass customization processes. Industry 4.0 is a new paradigm that deeply affects design and manufacturing processes enabling an intelligent factory with digital transformation at its core (Islam et al., 2020).

Trims, accessories, and packaging

According to academia, the sustainability of trims' manufacturing processes needs to be addressed as an area of research. Nonetheless, the environmental and social impact of trims, accessories, and packaging cannot be overlooked. Fashion products require a wide range of trims and accessories, such as zippers, buttons, and buckles. These items expand the number of materials involved in fashion manufacturing processes considerably. For instance, plastics and metals' environmental impact needs to be measured with a life cycle assessment. Current solutions include additive manufacturing, which helps avoid outsourcing production and relying on harmful manufacturing processes, rather than suggesting 3D printing for functional or decorative items. Packaging and logistics are responsible for a considerable amount of carbon emissions, and they need to be addressed as much as the other aspects. Major multinational brands claim these processes sum up to 51% of the overall carbon footprint of the whole business (Islam et al., 2020).

Strategies for sustainable and circular product design

According to the literature, the design phase is responsible for about 70-80% of the environmental impact of a product and may have great opportunities to articulate sustainability (European Commission, n.d.; Palomo-Lovinski and Hahn, 2015). Therefore, a critical approach is gathering efforts to implement circularity and achieve sustainable development in the design phase. Sustainable product design requires designers to focus on techniques, strategies, materials, and innovative processes to lower the environmental impact of a product (Islam et al., 2020). In addition, design activity is responsible for aesthetic qualities and material selection, directly influencing cost, quality, and durability.

There is no univocal formula for a sustainable approach to fashion design, although institutions, researchers, and practitioners agree on a series of guidelines.

Important actors in the sustainable design research panorama include the Ellen McArthur Foundation, whose researchers have outlined a set of strategies for circular design (Ellen McArthur Foundation, s.d.). Further literature in academia proposes that products be designed either to be completely compostable or wholly disassembled and recycled to obtain usable raw material (Palomo-Lovinski and Hahn, 2015). The literature suggests that sorting and recycling technologies efficiency could be influenced at the design stage through structural decisions about products' material selection – although this would be challenging due to disconnected industry processes (Karell and Niinimäki, 2019). Moreover, others suggest that designers should minimize energy and resource consumption and design long-lasting products. Given that the activities and choices of the designer affect the whole value chain, they must consider the entire life cycle of the product they create, including disposal in the design brief (Palomo-Lovinski and Hahn, 2015).

First, **design for emotional and/or physical durability** is a core strategy that allows products to be in use for a longer period. While physical durability can be achieved with technological innovations - such as better materials and processes - clear strategies to achieve emotional durability have not been outlined yet.

Consumers still discard products that work perfectly, no matter how durable the raw materials or how functional the product is. Why does this happen? Jonathan Chapman describes the current design culture as responsible for generating "wasteful cycles of desire and frustration within consumers by delivering only short-lived glimpses of progress" (Chapman, 2005). These glimpses are short-term utopias of consumption, where people feel empowered by purchasing a new product that will inevitably be discarded shortly after introducing some technological improvement. According to the author, sustainable design has adopted a symptom-focused approach, lacking philosophical depth. Focusing on the symptoms of the climate crisis – rather than its causes – design became technocentric, adopting new technologies into products without understanding the drivers of human consumption that systematically fuel throw-away culture (Chapman, 2005).

Because of this, sustainable design must not simply tackle functional obsolescence – improving products' physical endurance – as well as psychological obsolescence. Products that are emotionally durable are the ones capable of building a long-lasting empathic relationship with the user. To achieve this, the designer must understand this connection's intangible and ephemeral nature: what causes attachment and detachment and what is the product narrative. Psychological obsolescence causes the cycle of desire and disappointment to repeat itself, pushing consumers to substitute fully functioning products with new ones to achieve an improved status and establish a new emotional connection. In conclusion, emotional and functional durability go together when designing sustainable products, proving that sustainability cannot be addressed with a merely technocratic approach. Instead, it must consider psychological drivers – such as empathy – (Chapman, 2009).

There is currently no agreement on a strategy to achieve psychological durability. This aspect is critical in the fashion industry – whose products are, by nature, trend-led and cyclically substituted to achieve constant newness. For emotional bonds to be durable, products must provide different kinds of value in the long term (Haug, 2019).

Moreover, there can be a focus on **designing for low-waste** with strategies such as zero-waste design and upcycling. The first one is a way of creating products that doesn't produce any leftovers in any of its processes. For instance, in fashion it can involve zero-waste pattern cutting in which every piece of the cut fabric is employed in the final design. Second, upcycling is a technique of repurposing textile waste that doesn't degrade the value and mechanical properties of the raw materials such as in fiber-to-fiber recycling, instead it elevates it with a deconstruction process.

Products can be **designed for recyclability** by using the mono-material approach. This process can happen only when a garment is made of just one fiber type, because the equipment involved can successfully recreate new textiles and control its mechanical properties for industrial production. Fabric blends cannot be recycled because the current available technologies do not allow for their separation and the creation of a raw material of the same quality - while it can be downcycled into a lower-quality material, useless for applications in the fashion industry.

Other approaches include **design for easy disassembly** and choosing **compostable materials**. Disassembly is key for end-of-life management of garments. If they cannot be easily disassembled, recycling and upcycling become unlikely. Compostable materials manage to avoid accumulating tons of textile waste in landfills, since they can be easily and safely discarded. This approach needs to consider trims and packaging as well as the main fabric a garment is made of.

Another strategy is **design for low-impact processes**, based on the adoption of safe, recycled, or renewable materials, avoiding hazardous substances.

This set of strategies is ultimately achieved by achieving transparency and traceability throughout the value chain. These two key concepts assure that we are able to "trace products, components, and materials, as well as the social and environmental conditions in which they were made" and "make such information available to all actors of the supply chain, inclusing users to allow common understanding, accessibility, comparability, and clarity" (Ellen McArthur Foundation, Vision of a circular economy for fashion, s.d.)

The role of digital technologies in the fashion green transition

Available research highlights the connection between developing environmental agendas and fostering innovation through digital technologies (Akram et al., 2022; Bertola and Teunissen, 2018; Casciani et al., 2022; Huynh, 2021). Digital transformation is affecting the application of sustainability within the fashion system both in the front- and in the back-end of the value chain. The COVID-19 pandemic has helped overcome issues hindering a broader industry shift towards a virtual landscape. All aspects of sustainability are affected: environmental, social, economic, and cultural. From a business perspective, there is a shift towards a service-oriented, network-based, and user-driven approach, thanks to a radical change in the value creation process. Since fashion is a culture-intensive industry, digital transformation can provide benefits for preserving the tangible and the intangible heritage, such as traditional techniques, processes, and values. (Casciani et al., 2022)

Back-end/supply chain digital transformation

The benefits that lie in the digitalization of the supply chain are numerous. First, product design and product development become highly intertwined because of the possibility to design in 3D, integrating design with patternmaking and fitting – sharing the same virtual space. This approach shortens the cyclical iterations of adjustments necessary to achieve the final design. Collaboration and communication are enhanced between the style, product, and prototyping departments – generating a space for stylists, designers, and patternmakers to participate in hybrid teams (Casciani et al., 2022).

Digital fashion allows for unreal outputs, such as garments made of materials that could not exist in the real world. For virtual-only products, this is a space for greater creativity and expression. Alternatively, 3D technology can be used to create digital twins (DT), which will closely resemble a physical product, accurately showing details via photo-realistic rendering. Lastly, this approach can help the zero-waste fashion design approach, which is notoriously complex due to the necessity to achieve specific volumes with unconventional pattern-cutting methods (Casciani et al., 2022; McQuillan, 2020).

Production is also optimized thanks to the possibility to adopt a made-to-measure and on-demand production, which can happen in local micro-factories. This production model is convenient for reducing waste created by deadstock products and materials created by overproduction and returns by a customer for wrong garment sizing. Furthermore, this allows small businesses to thrive, because they can focus on unique, customized digital or phygital products (Bertola and Teunissen, 2018; Casciani et al., 2022) and rely on locally sourced raw materials and manufacturing.

The visualization of collections and garments is radically improved thanks to digital transformation, affecting B2B presentations and trade shows, exhibitions, digital showrooms, portfolios, and any kind of interactive visualization, allowing for an enhanced sensory experience. Augmented and interactive tools allow for a more widely available, detailed, and true-to-reality visualization. In addition, the digitized product can show the know-how of the brand and construction details in 360°, embedding their heritage and cultural capital (Casciani et al., 2022).

The creation of digital images affects marketing and communication, providing dynamic and interactive visual content. Consequently, brands are exploiting this innovation to create online and offline retail experiences. In addition, there is a bridge between physical and digital retail, where body scanners can create avatars with people's accurate measurements and digitally fit a pattern or a 3D garment. These innovative tools, combined with AR try-on technology, can provide immersive experiences for retail as well as exhibitions, museums, and brands' archives (Casciani et al., 2022; Choi, 2022; Martin and Vacca, 2018).

Front-end digital transformation: the customer's perspective

Business models' digital transformation

Digital technologies generate various innovations for business models, radically changing how brands capture the value and propose it to their target customers. Established firms and digitally born startups can benefit from this shift in the value-creation process: innovation in product development is enhanced by the open-source approach, facilitated by the support of a network and community of 3D designers. The management of relationships with stakeholders is improved through co-creation opportunities. Delivering products and collections to stakeholders and customers now can happen through an enhanced virtual experience, for instance, the customers' value proposition is radically affected by providing them with multiple options in terms of variants visualization in real-time and customization (Casciani et al., 2022; Huynh, 2021).

Circularity is triggered and enabled by digital technologies

Digital technologies help innovate business models improving their circularity and shifting from product-centric to service-centric value propositions. Improvements such as tracking materials and products across the supply and value chains are crucial and could happen thanks to data collection systems. In addition, databases collecting products' data enable smart management of resources at the end of life. However, academic research highlights the need for more empirical evidence about how companies apply digital technologies to implement circularity, and the gap between research and practice must be addressed (Ranta et al., 2021).

Blockchain technology and IoT enable the traceability of garments' materials and manufacturing processes. These two technologies could enable sorting for upcycling or recycling, two best practices for circularity. Institutions are introducing mandatory requirements for product transparency, for instance, a digital tracking or tagging system that allows universal access to value chain data (Karell and Niinimäki, 2019). As the European Commission suggests, to achieve sustainable and circular products and sustainable consumption patterns, customers need to be empowered by access to relevant information (European Commission, 2020). This technology enables consumers to know metrics such as composition, carbon and water footprint, and industrial processes associated with manufacturing what they are buying. This innovation increases the possibility of reusing, repairing, and recycling at the end of life.

Another digitally-enabled innovation is an online platform – a technology that allows customers to rent, repair, and resell what they own. Finally, a radically innovative approach that involves digital technologies is shifting from mass production based on the traditional seasonal forecasting method to real-time demand-driven production. This model involving designers and consumers is possible thanks to the digitization of designs and prototypes in the product development phase. For instance, consumers can have customized garments using avatar-based 3D technology, reducing overproduction (Huynh, 2021).

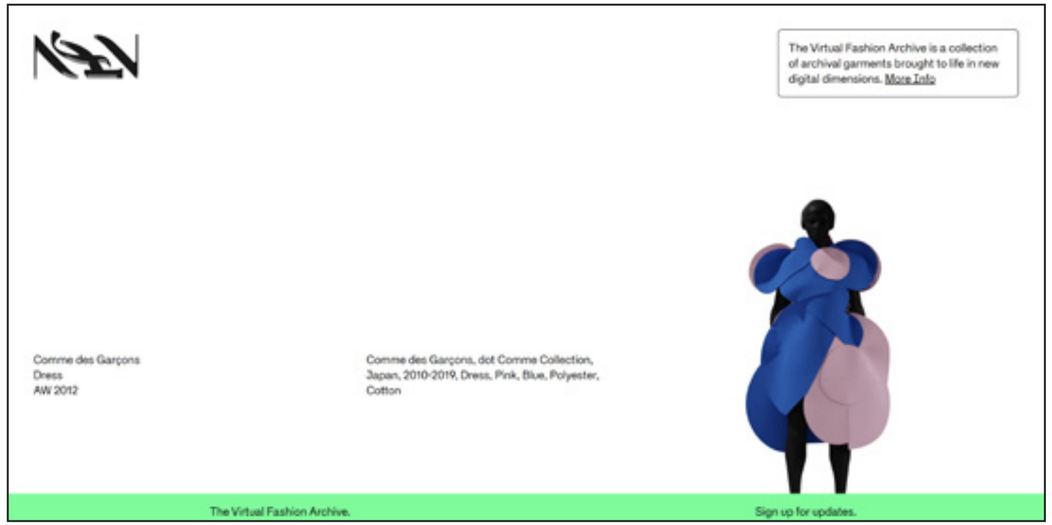


Image 2.1 - *The Virtual Fashion Archive. An example of digital archive of iconic fashion products.*

The digital transformation of cultural heritage

Thanks to the adoption of digital technologies, the specific cultural heritage of communities can be preserved (see **Image 2.1** - *The Virtual Fashion Archive*). Brands can create digitized archives available to the public, improving the brand and cultural heritage awareness through tools, methods, and values (know-how). Moreover, museums and exhibitions can be supported by digitalized experiences, extending the users' experience (Martin and Vacca, 2018; Rossi et al., 2022). Brands can embed cultural capital through co-creation, fueling the creative process and having the opportunity to change the cultural norms of fashion consumption. Since sustainability is ultimately achieved by adopting a sustainable consumption pattern by the users, this aspect can be crucial in overcoming emotional and psychological obsolescence. (Casciani et al., 2022)

CHAPTER THREE: UPCYCLING

Repurposing waste: a key approach to circularity

Recycling is a widely known process that involves recovering fibers from products at the end of life and remanufacturing them into new raw materials with the same mechanical properties. However, the state of the art of recycling technology may not be the most eco-friendly choice for repurposing textiles, except from some small-scale but successful case studies (Islam et al., 2020; Sanchis-Sebastiá et al., 2021). In addition, recycling fibers requires consuming further energy and chemicals – with subsequent CO2 emissions (Parung et al., 2022). Moreover, recycled fibers tend to have worse mechanical properties than virgin ones, with which they need to be blended to produce textiles that are durable enough to be used for production (Karell and Niinimäki, 2019; Potting et al., 2017).

Remanufacturing fibers is likely a downcycling process because the outcome does not withhold the same value as the prior. In addition, the lower mechanical properties of the fibers and, therefore, of the textiles do not allow for to manufacture of the same products, which require a higher standard of quality (Potting et al., 2017; Sanchis-Sebastiá et al., 2021).

On the other hand, upcycling is a repurposing technique for textile waste based on deconstruction rather than dismembering the textiles into fibers. This approach is less energy-intensive than recycling and is the best way to repurpose old textiles (Parung et al., 2022).

Image 3.1 - *A piece of second-hand denim with the original zipper and a button (following page).*

Definition of upcycling

The designer's involvement in aiding the recycling process is limited – as researchers agree it is too early to provide guidelines to "design for recycling" because of missing accurate information about the exact material composition and chemicals used along the supply chain (Karell and Niinimäki, 2019).

"Up"-cycling – on the other hand – implies that the value embedded in the material is enhanced through remanufacturing (Bigolin et al., 2022; Han et al., 2017; Koch, 2019), which is a design-driven process enabled by a designer's work that creatively reimagines disassembled and deadstock garments and textiles into new products. Upcycling elevates wasted textiles, replacing their old meaning "waste, uselessness" – with a new meaning and value – "sustainable, high quality, timeless fashion" (Chiais, 2022). Typically, upcycling is a "slow fashion" process.

Slow-fashion movement

Slow fashion focuses on long-lasting, locally manufactured clothing from sustainably sourced materials. This phenomenon comes in the shape of a movement rather than a business and questions the industry's pursuit of economic growth at the expense of people's welfare and the environment's deterioration. Slow fashion fosters reconnection to a community by emphasizing traditional values and employing premium materials and manufacturing quality. Moreover, it has an educational approach aiming at sharing knowledge and, ultimately, its benefits (Štefko and Steffek, 2018).

Academia regards slow fashion as a movement unable to withstand competition on a traditional business level because of lacking financial resources and power (Koch, 2019). However, on the bright side, key competitive factors that distinguish slow fashion from fast fashion are the quality and timelessness of design and materials and unique personalized services (Štefko and Steffek, 2018). This phenomenon is worth mentioning; notably, production-consumption degrowth is essential for future-proofing fashion in sustainable development (Niinimäki et al., 2020).

Slow-fashion and clothing upcycling

Slow fashion and clothing upcycling are traditionally intertwined - they both reached the status of "global movement," stemming from designers who are researching new practices and techniques to respond to global fashion issues, increasing the value of local and sustainable raw materials – textile waste, for instance (Koch, 2019).

This design-driven approach responds to the need of the fashion industry to slow down and close the loop of resources by streamlining and lightening the overall impact of production and consumption by creating long-lasting, ethically made garments using waste as a raw material. Upcycling builds on traditional crafts such as home-sewing, patchwork, and restyling garments. These practices have always questioned human needs and materials' value and meaning (Koch, 2019)

Beyond the technical definition of upcycling as a method for enhancing the value of a product through a remanufacturing process, its role as a social movement is highlighted across the literature. This practice may have a specific political message and connect with movements such as slow fashion and DIY. Making own clothes is a response to the research of alternative ways of belonging: fashion reproduces dominant cultural norms, but in its manifestations, it provides the tools for criticizing and problematizing its structure. In conclusion, slow fashion and upcycling connect local and global identities and issues. The specificities of each place affect how each designer practices upcycling, although the push to do it comes from global issues such as textile waste and the need to create social change (Koch, 2019).

Standard versus upcycling design process

Upcycling and traditional fashion design methods start with a design problem statement (brief). In addition, they are iterative, meaning that designers must go back and forth in the process multiple times. (Han et al., 2017).

The main difference between upcycled and standard design processes is that the first intentionally opposes traditional production and consumption dynamics, placing the idea of reducing, together with reusing and recycling, at the core of the design activity by transforming both the design process and the meaning of the product outcome (Chiais, 2022). Another core differentiation lies in the fabric sourcing phase, which is placed at the beginning (upcycling process) or after the development of samples for buyers (traditional fashion design process) (Han et al., 2017)

The standard fashion design process is responsible for the ineffective management of textile waste, limiting upcycling potential and options for extending a garment's end-of-life or life cycle. In this case, waste is added to standard design and production flaws (Bigolin et al., 2022).

Upcycling is about changing the fate of pre- or post-consumer waste through reducing, reusing, and repurposing (Chiais, 2022). Moreover, upcycling is set apart from traditional processes because it produces extraordinary results. In other words, it drives product innovation because it generates a unique combination of resources, people, skills, creativity, and needs, ultimately giving birth to one-of-a-kind items (Parung et al., 2022).

A comparison between these two processes is summarized through the following stages: design brief, sourcing, research, design, promotion, production, retail, and use-phase (see **Diagram 3.1**).

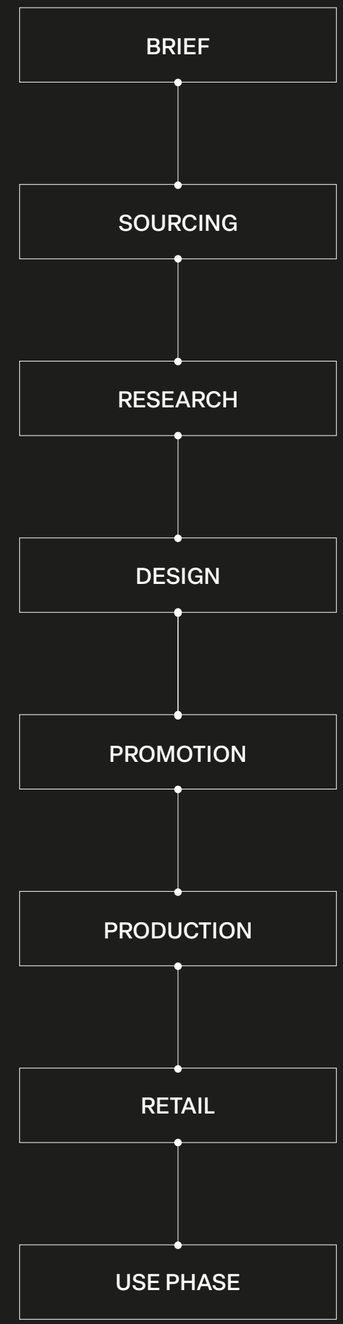


Diagram 3.1 - *Steps of the design process analyzed in this chapter.*

Standard design process

The standard fashion design process brief is defined through the research and analysis of consumer data, mass-market insights, and trend research and forecasting. The sourcing phase happens after wholesale orders are taken – before production – having no direct influence on inspiration and design.

There is a substantial shift in the designer's role within a standard or upcycled fashion brand. Most of the time, the designer is merely involved in designing garments and overseeing sampling – and the latter may not be accurate for more prominent companies, where designers are even less involved with manual sampling. Most likely, they research market trends and translate them to new styles. Some brands report a more negligible designer involvement, limiting it to research and concept definition. On this premise, considerations about sustainability within the material selection and product design are withdrawn from the designers' field of business (see **Diagram 3.2**).

The production looks considerably different in the two processes; namely, standard fashion production relies on a traditional division of labor where workers are assigned a single machine and the completion of a single part of the assembly.

Distribution and retail happen on a large scale, enabling data collection about user preferences and the overall success of the research and design for next year's merchandising plan.

The engagement with the public could be much higher during sales and customer services. (Han et al., 2017).

Upcycling design process

The upcycling design process includes different sustainable design strategies that embrace circularity. Firstly, the brief is focused on "design for waste minimization" as a guideline and ethos for design. Sourcing occurs at the beginning stage, posing the design problem of textile waste in brief. Availability of raw materials is not taken for granted but is a driver for design solutions that vary according to the number of textiles the brands can collect (see **Diagram 3.2**).

Upcycling practitioners need to gather research about customers, design inspiration, and materials available for supply. Then, the designer needs to be promptly informed about the availability to plan the production.

Design for upcycling implies that the designer directly performs a broader range of duties such as sourcing, design, manufacturing, promotion, and retail – up to all in artisanal and micro-sized businesses. In addition, the designer is also a curator and facilitator, increasing the level of involvement and sustainability within the brand.

Upcycling designers will only produce at a large scale if a wholesaler places an order. This model prevents overproduction and overconsumption completely (a design for a slower consumption strategy). Moreover, upcycling can implement design for user participation through social media and offline events. A design for an end-of-life strategy can be implemented by offering customers the opportunity to return or swap clothes.

Upcycled garment production is a complex process with a high potential for social well-being. It requires designing new and non-traditional flat patterns to obtain a product from one that already comes in small components. The literature suggests that upcycling practitioners can develop a modular system where designers and manufacturers perform multiple processes and employ different machines. This system allows workers to acquire new skills beyond their specific responsibility of a standard production method, improves flexibility and autonomy, and increases job satisfaction.

Retail of upcycled products is like standard ones, except for the possibility of reaching a higher level of consumer engagement and personalized services. Online retail is vital for these brands to create consumer demand – although engagement can also be offline. Examples include workshops and clothes swap events to communicate the principles behind sustainable consumption and decouple the brand's user experience from a necessary purchase (Han et al., 2017).

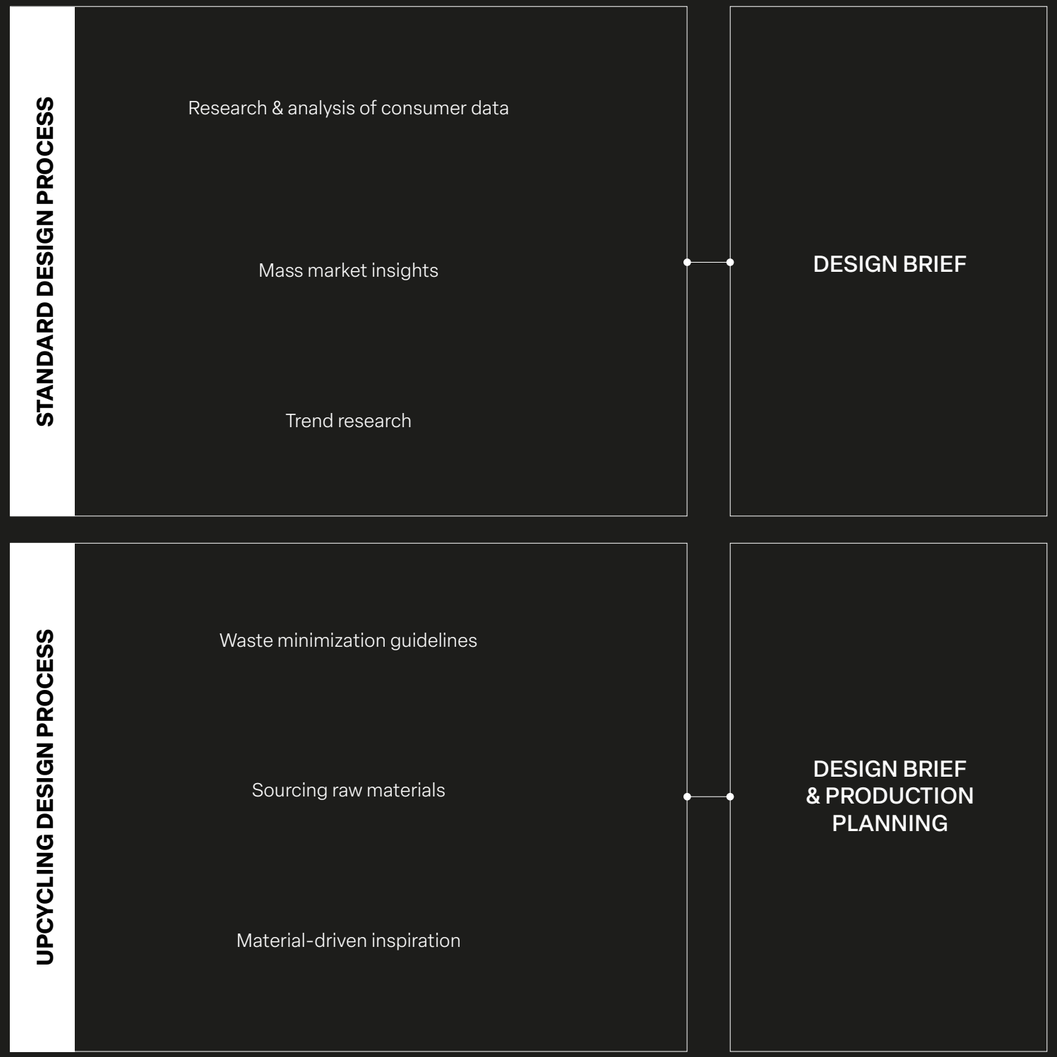


Diagram 3.2 - *Comparing the standard and the upcycling design processes: what defines the design brief in each case.*

Scaling up the upcycling process

Overall, the upcycling phenomenon allows us to address some of the core sustainability issues in the fashion system and provides a mindset together with a methodology to profoundly transform how we create, produce, promote, consume, and dispose of fashion products.

The increasing attention to upcycling practices by academia and the increasing number of case studies available allow for a degree of conceptualization and standardization of this process. Consequently, some research focuses on scaling this practice to a mass-market level.

Image 3.2 - *Textile waste sorted by material and color.*

Large-scale upcycling through the improvement of sorting and recycling technologies

Even though raw material for upcycling is available at a high volume (Janigo et al., 2017), this practice is traditionally done in the shape of small and artisan-led businesses. Having the most significant sustainability performance, Han et al. believe upcycling scalability is critical to having more comprehensive environmental, economic, and social benefits. Research shows that large-scale upcycling is possible through collecting, identifying, and sorting second-hand textiles (Han et al., 2017). However, state-of-the-art sorting and recycling technologies do not allow this to be automated yet (Karell and Niinimäki, 2019). Therefore, the implementation of large-scale upcycling requires skilled workers to identify and sort textiles, such as second-hand clothing (see **Image 3.2**).

Upcycling scale-up controversy

Scaling up upcycling – from a small business scale to the mass market – could be controversial because of its cultural bond with the slow-fashion movement – namely, degrowth of production and consumption – a fundamental approach for the future of fashion and the successful implementation of circularity. Moreover, in its nature, the process creates a psychological bond between the designer or user and the product because of one-of-a-kind and custom-made items, creating emotional durability.

Upcycling today struggles between the need for a broader adoption to survive financially and the consequent risk of impoverishing its symbolic value. As Han et al. suggest, mainstreaming a niche context will inevitably preserve its aesthetic value (namely, the uniqueness of each piece, as seen in **Image 3.3**), emptying it of the content that ensures its success (Chiais, 2022). Upcycling is an act of decoding and subsequent interpretation carried out by a designer and leads to exceptional results. On the one hand, integrating upcycling practices in the fashion industry at a scale would reduce resource and energy consumption and reduce the number of textiles in landfills (Janigo et al., 2017). On the other hand, upcycling cannot be defined as a mere sourcing, design, and production strategy. However, a cultural phenomenon tied to specific social, economic, and environmental conditions from which it was born and through which it constantly evolves. Namely, it is a methodology driven by a maker's need to connect with textile waste emotionally, transforming its meaning and dissociating it from standard ways of production. Each product's actual and symbolic uniqueness and immaterial value are the genuine plus factor that sets this strategy apart from standard fashion (Chiais, 2022). Scaling up this practice would result in standardization and depletion of each product's value – such as uniqueness and high craftsmanship. (Binotto and Payne, 2017; Chiais, 2022).

Image 3.3 - *Large-scale upcycling production of bags and backpacks by the brand Freitag*

Discussion: upcycling and digital transformation

Of all the innovations generated by digital transformation in the fashion industry, some are of specific interest for upcycling – affecting the design process, the business model, the relationship with the stakeholder, and the broader ecosystem. As in the value chain of a standard fashion design process, digital transformation can happen in the back and front ends. It can affect suppliers, designers, manufacturers, retailers, communities, and the brand's cultural heritage. Moreover, digitalization can help design and manage product life cycles. The literature provides extensive knowledge about digital transformation within the fashion system and its implications for sustainability, although only one study was found to connect upcycling and digital fashion (Chen et al., 2021). Therefore, the following considerations are built upon practice and prior literature review on digital transformation and sustainability.

3D technologies for a dynamic upcycling design process

In the upcycling design process, more than in any other, the iterative steps of product development and prototyping pose a significant issue for the designer. Any material used for prototyping comes from wasted textiles or deadstock, which makes it almost impossible to replicate a process or a product identically. Shapes, sizes, colors, prints, and trims always come in a unique way, as well as the signs of wear, stains, rips, and cuts which may be present in the raw material. Therefore, the designer needs to prototype with the available materials to understand the possible outcome in terms of each garment's fit, volume, and aesthetic qualities. Prototyping a physical garment will cause several problems, turning the product development and prototyping phases into a hustle for the designer. One main reason is that the process is very time-consuming – and this is an issue because most upcycling practitioners work in small teams or individually. Moreover, the uniqueness of every piece of raw materials does not allow for creating multiple prototypes building on the same basic shapes – unless using an identical garment or piece of fabric, which is hardly available.

Despite the difficulty a designer may encounter in replicating the pattern pieces or the available fabric scraps digitally with the exact measurements, 3D fashion design can provide a sufficiently accurate preview of the possible volumes obtained through deconstruction. Furthermore, software like Clo3D provides tools to understand the exact fit after choosing the avatar size, allowing the designer to understand whether the garment can fit a specific body (Choi, 2022). This technique implies the possibility of creating made-to-measure upcycled garments if the customer provides their measurements. The software can also automate pattern grading, allowing small studios of upcycling practitioners to quickly provide garments in different sizes, saving considerable time (All About Grading, 2020).

As described in the previous paragraph, the upcycling process can start with available shapes combined to achieve a deconstructed volume. Alternatively, a traditional pattern is employed, patchworking fabric scraps to achieve the traditional shape of the pattern piece. As well as before, the upcycling designer can benefit from 3D fashion design by plotting these patterns and physically creating the required shapes. In both ways, the workflow is highly fluent, replicable, and streamlined compared to a physical-only upcycling process.

Previewing fit, volumes, color combinations, and trims are crucial for the upcycling designer because it allows them to avoid wasting precious resources. In addition, once textiles are cut or sewn, they will likely show the signs of manufacturing – such as fraying and stitching holes caused by the sewing needle– hindering the possibility of disassembling and reusing them to make another prototype.

Real-time dynamic systems transforming upcycling fashion throughout the value chain

In traditional fashion design, implementing 3D garments as dynamic fashion with changeable colors, styles, or textiles is proof of the innovation potential in terms of expression, aesthetics, and sustainability. These benefits include maximizing self-expression and experimentation options, leveraging the power of social media as an indispensable creative platform for collaboration, creating a solid link between electronic entertainment and fashion, merging identity, representation, and commerce, and streamlining the fashion design process (Choi, 2022). Today, available technologies allow not just to render of static images or videos of digital garments but also real-time enabling tools such as AR and VR for the users (see **Images 3.4** and **3.5**), with increased opportunities for interaction, customization, and new ways of communication through social media platforms (Udiono and Maryani, 2021). AR is integrated into the most widely used social media platforms; for instance, Instagram and Facebook allow one to visualize a 3D object with texture variations within the same filter. Other platforms – such as Snap Chat and TikTok – have body tracking tools, allowing one to place a digital garment or outfit on the user's body ("Body Avatar Drive," 2022).

Upcycling can benefit from real-time dynamic systems to preview a product's variations and color combinations, as in the standard fashion design process. While in the standard process, variations are limited to a series of colors or prints provided by the brand (Choi, 2022) – which will be industrially manufactured in large amounts – for upcycling designers, variations are not just an extra feature but an irrevocable aspect of the practice. The uniqueness of an upcycled product can be successfully communicated to the customer in real-time and easily updated when the designer needs to replicate a product with a different fabric.

Image 3.4 & 3.5 - *Two screenshots of the Zero10 app, created for virtually trying on digital fashion products.*

Merging real and virtual worlds: digital labelling for upcycled products

Upcycling is considered a best practice of circularity for using deadstock or second-hand raw material and turning it into a product with a higher value. Nonetheless, true circularity is achieved with the total traceability of materials, creating a product that can be managed at the end-of-life phase by recycling, disassembling, upcycling, or enabling renting or reselling pathways. In any case, the stakeholders responsible for this part of the value chain need to be empowered with the proper knowledge to allow another product life cycle to start. An operational life cycle management can be achieved for standard and upcycled products – by creating digital labels and a way to access them, whichever the product conditions.

Whether in the distribution, retail, use, or disposal phase, specific data about products need to be accessible to all stakeholders. This data may be composition, care instructions, place of raw material supply, place of manufacturing, date of manufacturing, amount of labor necessary for manufacturing, CO_2 emissions, water, energy consumption, and end-of-life options, to mention a few. In addition, in an open-source context, an organization may disclose tools to repair the product, for instance, the CAD patterns, for the user to recreate missing or worn pieces. All this data can be made available on digital labels – digital product IDs – easily embedded into garments through waterproof NFC tags (Liu and Ma, 2018).

Table 3.1 - *Compared benefits of digital transformation between standard and upcycled fashion.*

DIGITAL TECHNOLOGY TYPE	BENEFITS FOR STANDARD FASHION	ADDED BENEFITS FOR UPCYCLING FASHION
3D tools for design and prototyping	Cost-saving: less labor is required for product design and development, and smaller financial investments. Timesaving: technical drawing and toile development are substituted by 2D/3D CAD and modelling of the digital garment. Environmentally friendly: less raw material consumption and sampling. Higher creative freedom.	Micro brands or individual designers need fewer financial investments to design and develop products (democratization) 3D toile development allows for smaller teams or individuals to prototype faster. Unique scraps of fabrics can be previewed digitally before cutting or sewing, providing more creative freedom and preserving unique pieces until the final design is reached.
Real-time systems fro dynamic products	B2B presentation of collections or samples (showrooms, trade shows, etc) are improved and augmented. B2C communication is augmented, enhancing (mass) customization opportunities. Design of AR and VR user experiences.	Possibility of co-creation of an upcycled garment with a customer showing different creative outputs. Product variation visualization through AR filters on social media to communicate with a global audience (useful for small businesses).
Digital labelling via NFC	Opportunity of powering the digital label with blockchain technology for total transparency. Consumers are empowered with knowledge about products' end-of-life options. Easier product life cycle management. Integration of reselling/renting/swapping platforms Care instructions and material composition don't get lost because the label is also available digitally.	Providing a digital label allows showing data about the manufacturing process, which is crucial for upcycled products. End-of-life management: repairing instructions, disassembling instructions for further upcycling.

Conclusions

If digital technologies are triggering and enabling circular business models, their benefits for upcycling are noteworthy. In addition to the most widely recognized advantages, such as cost-saving, time-saving, and resource-saving opportunities, 3D design and product development tools can democratize fashion businesses and encourage small teams of designers or individual practitioners to start their businesses with no need for high financial investments in prototyping and sampling. Moreover, previewing the upcycling process is crucial when using one-of-a-kind scraps of fabric which cannot be replicated once cut and sewn. Real-time visualization of product variation is helpful for customers to perceive how each product is unique and enables them to co-create, suggesting design changes. AR product visualization allows small businesses to communicate to a broader audience, sharing detailed digital twins of their design worldwide. It has been found that AR visualization increases brand engagement and consumer trust in the brand (Udiono and Maryani, 2021). End-of-life management for products is an issue for traditional and upcycled fashion alike. Upcycled fashion could benefit from NFC-powered digital labels to ensure that the high value embedded in the product is bequeathed to a potential future owner. Moreover, it could empower users to correctly disassemble the product – whether to dispose of it or to remanufacture it. Lastly, it could provide manufacturing data critical in upcycled products for signature-added value compared to standard fashion.

CHAPTER FOUR: MAPPING UPCYCLING PRACTICES

Origins of the upcycling practice

Upcycling as repairing and repurposing resources was embedded in western societies until the 19th century. Back then, people were prosumers – who would produce the same products they consumed. Prosumerism helped create relationships between people and products through repairing, maintenance, and upgrading. However, the past century's Industrial Revolution has replaced a sufficiency-based lifestyle in favor of throw-away culture, where it is more convenient to replace a product than repair it. Consequently, people have lost their skills of maintenance that date back centuries.

However, this paradigm shift did not happen overnight. Western societies were mainly characterized by production at the beginning of the industrial revolution (Singh, 2022). Upcycling was still prevalent in contexts of dearth where people would "make do" with little resources (Koch, 2019). For instance, during the 1940s, British citizens were encouraged to mend their clothes to make supplies last longer during times of struggle ("The evolution and history of Upcycling," n.d.).

It was only in the 1950s when the increasing amount of consumer products and the adoption of marketing, advertising, and branding turned consumption into a core phenomenon of western societies. This balance between production and consumption separated producers and consumers as independent entities (Singh, 2022). During this period, the term planned obsolescence was coined since the deliberate shortening of products' lifespan became a concept of great fascination for producers (Chapman, 2005).

Upcycling as criticism of mainstream culture

A significant cultural phenomenon that involves upcycling happened during the second half of the past century, when upcycling became a way of criticizing mainstream culture. The DIY movement – which promotes upcycling to repurpose local resources and increase value – represents a way to become prosumers again, promoting collaborative production and sharing skills and raw materials. Moreover, the rise of this trend creates social and economic benefits. First, they increase products' lifespans, preventing the purchase of new products. Second, they catalyze the revival of repair culture in western societies through skills, tools, and resource exchange (Singh, 2022). In this case, its adoption by youth cultures is caused by the need to connect human culture and ecology. Anti-capitalist movements during the Sixties and the Seventies – such as the hippies and the punks – used upcycling and DIY as an act of emancipation from the growing consumerism of the masses (Chiais, 2022). These youth movements were born in a context of the precarity of the youth, especially in the punks' DIY practice, which was a form of resistance and opposition to the dominant capitalist cultural production (Bennett, 2018). Later, upcycling – a word introduced in 1994 by Reiner Pilz – gave birth to the customization movement during the 1980s and 1990s in the UK ("The evolution and history of Upcycling," n.d.).

Upcycling as re-meaning through design and deconstruction

What makes upcycling relevant from a cultural point of view is the practitioners' ability to re-design the meaning of every piece of clothing or deadstock material through the fashion design practice (for instance, in the corset of the previous page, **Image 4.1**). Other than extending the life span of a garment, at a symbolic level, it consists of an intervention and process of re-meaning. The original piece is disassembled and broken down into smaller pieces, later reconstructed into a new piece with a new meaning. Through upcycling, the old is not forgotten but keeps living in the new thanks to a garment bridging these two contexts – the past and the present. Using a garment or textile from a different time or place will cause the superimposition of its meaning and value with those of the newly reconstructed item, with an emphasis on the concrete uniqueness of each piece (Chiais, 2022).

A bond is inevitably created, connecting the maker, the user – although sometimes these two figures coincide – and the material culture of consumable objects. Emotional connection is a dominant upcycling feature when the consumer is also the producer – such as in DIY practices – for projecting one's vision and needs into an object. The emotional bond consequently abates when the user gets less involved in the upcycling practice.

Image 4.1 - *A handmade upcycled corset by Offbeat District, made in 2021.*

Fashion deconstruction in the 1980s and 1990s

The upcycling practice in fashion has its roots in the philosophical concept of deconstruction and its adoption by deconstruction designers that have questioned the meaning of fashion, dress, the body, and their relationship since the early 1980s.

The father of deconstruction is the philosopher Jacques Derrida, according to whom deconstruction is not a methodology but an activity that intends to destabilize the layers of metaphysics that have dominated philosophy for centuries. It disrupts traditional interpretations by displacing the structures of society, whether they are material, cultural, economic, pedagogical, or political – questioning the foundations on which our society is structured, unleashing new possibilities of signification and representation.

Deconstruction aims at breaking fixed binary oppositions, such as language/thought, practice/theory, literature/criticism, and signifier/signified – namely, the signified is never found in the signifier in its whole being. Instead, it is characterized both by being within and being absent.

Deconstruction has become a fertile field of activity for many creative disciplines, not a unitary concept but a plural one, with a necessary heterogeneous multiplicity of actions. It cannot be synthesized in a system or a method because it considers each context's peculiarity – being subject to every contingency.

In fashion, deconstruction was adopted in the early 1980s by Japanese designers Rei Kawakubo, Yohji Yamamoto, and Issey Miyake, and later by the Belgian designer Martin Margiela. They contributed to rejecting the already consolidated perceptions of glamour and the body silhouette, generating new possibilities of construction and signification. In addition, they challenged traditional opposition that had so far determined what is high or low in fashion—for instance, refusing to finish, using subtractions, displacement, and rethinking the meaning of the garment itself. Moreover, it reflects on the interaction and relationship between the body and the garment and on the body itself.

Margiela's work is about disrupting dress structures, causing the disenchantment of the traditional mechanism of fascination in fashion (Loscialpo, 2020), and encouraging a non-systematic, non-logical, and non-fashion mindset (Purgaj, n.d.). This approach was compared to sub-cultural manifestations of anti-fashion, such as cutting, ripping, and patchworking typical of the punk and post-punk movements. However, deconstruction fashion is a dialectical device that exposes fashion's operations and its relation to the body and the structures of fashion (Loscialpo, 2020). The strategy behind Margiela's process is to bridge the past with the present, symbolically reusing and reworking raw materials (Chiais, 2022), thoroughly considering fashion history and its current condition (Loscialpo, 2020).

The power of deconstruction can only be realized through the conditions of its existence. First, it must be confronted with parameters that determine fashion today – reflecting traditional tailoring with the body at the center. Suppose the latter represents the territory where our identity's visible and sensory aspects occur. In that case, deconstruction can show how it is affected by absence, dislocation, or reproduction, destroying its idealization. The textures and layers of materials in a deconstructed garment are objects of interest rather than tools to draw attention or shape the body. This design philosophy is not a form of insufficiency or a limit but just one of the many possibilities of reflection upon preconceived borders and oppositions.

The ethical mantra of deconstruction is that fashion does not need to reinvent itself continuously. This concept is highlighted by refusing any constriction or direction dictated by temporary trends. Instead, it happens by replicating clothes or using fabrics from the past, which highlights how there is no univocal standpoint for reinterpreting but rather a constant dialogue with our past to allow new landscapes to emerge. Acknowledging that what is now always refers to the past, deconstruction helps us understand how creation never comes to light from a blank slate.

Image 4.2 - *Wig Vest by Maison Martin Margiela, SS 2009. Made of synthetic hair, inspired by AW 2005.*

Image 4.3 - *A garment made of a disco ball designed by Maison Martin Margiela for the SS 2008 Collection.*

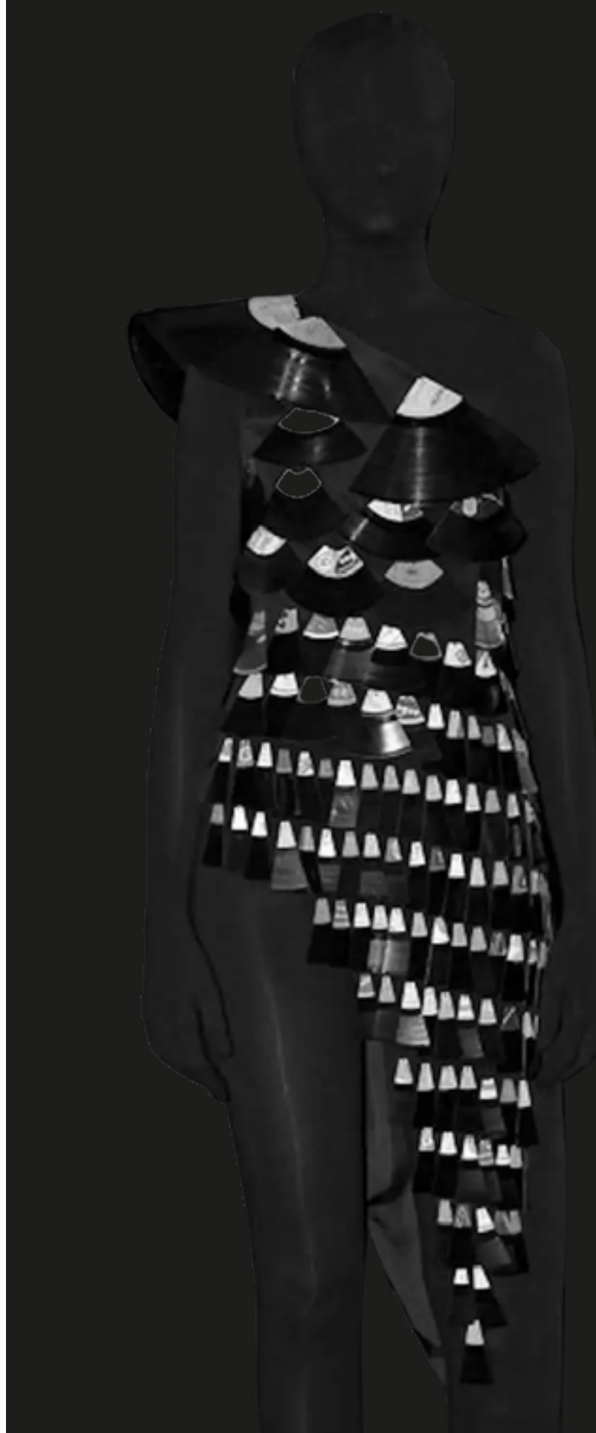
Image 4.4- *A garment made of vinyls designed by Maison Martin Margiela for the Artisanal Collection in 2008 (next page).*

This activity addresses the separation between production and consumption, which is typical of consumer culture. For example, in his Artisanal collection (all data and images about the Maison are sourced from the book Maison Martin Margiela (Maison Martin Margiela, n.d.)), Martin Margiela creates couture by using humble raw materials – such as paper or plastic – causing luxury to shift semantically. Traditionally, luxury is associated with prestigious and expensive raw materials; now, it is measured by the number of working hours necessary for garment fabrication – which is exposed on the product label. This act highlights human labor as the real source of value.

Margiela's fashion deconstruction is not a critique of consumerism in the shape of a parody or a caricature of existing methods but rather shows awareness that fashion critiques are nonetheless tied to a specific moment of capitalist production and specific technologies. The outcome is characterized by individuality and contingency. Therefore, when its replication is attempted, it would bear significant dissimilarities.

Highlighting the labor-intensive nature of fashion production, Margiela overcomes the alienation that traditionally defines the relationship between product and consumer. The production process and the consumer are again reconciled, while mechanisms that cause fascination are re-discussed. No deconstructed creation is independent of traditions and history, and fashion cannot escape its past. Deconstruction problematizes opposing pairs and idealized parameters, such as subject-object, absence-presence, and inside-outside. Therefore, deconstruction designers can listen to fashion history and its paradigms, dialoguing with the present and exposing other options (Loscialpo, 2020).

A parallel can be drawn between Margiela's Artisanal line and Dadaism – first, as a deviation from established artistic or industrial practice with the denial of existing systems, values, ideals, and norms. The method for selecting materials for their designs is like that of Dada's ready-made – a random process of choosing objects and changing their form or function into something new.



Margiela's process allows any object to function as a piece of clothing, as in the artisanal Record Dress of 2008, made of vinyl records cut in different sizes to create a dress, the Wig Vest, and in the Discoball top (**Images 4.2, 4.3,** and **4.4** in the previous page).

In some cases, his work has demystified the secret language of fashion. For example, the public – unfamiliar with the tailoring process – was introduced to bodies wearing tailoring busts and paper patterns during the Spring/Summer and Fall/Winter 1997 catwalks (see **Images 4.5** and **4.6**) . By doing this, Margiela has changed the meaning of the body and its interaction with garments, embodying the abstract language of tailoring (Purgaj, n.d.)

Image 4.5 & 4.6 - *Outfits from the FW 1997 catwalk by Maison Martin Margiela.*

Upcycling methods

The actual upcycling process through which garments and textiles are transformed into a different product has been conceptualized in the literature (Han et al., 2017). In reality, each product comes to life through a different combination of techniques that is never precisely replicable. The design process, as well as the final output, are unique for each garment or accessory. Therefore, there can be a certain degree of generalization in this methodology. However, it is essential to remember that it involves a combination of people, knowledge, skills, specific cultural aspects and traditions, and creative thought that directly influences the process and its outcome. In the upcycling practice, there is a necessary component of improvisation dictated by the ever-changing shapes and types of material available. Some practitioners have adopted similar methods across different cultural and social contexts, but each one has a high specificity and uniqueness (Parung et al., 2022).

There are four main upcycling methods, according to the literature. These methods do not exclude each other – they can be freely combined to get unique results: subtraction, deconstruction, addition, and function.

The use of deadstock fabric (number 5) is also considered an upcycling method, although it was not included in the list by Parung et al. The main feature of this method is that the fabric does not require a deconstruction process but comes in an uncut roll, allowing the designer to freely cut “virgin” shapes as in the standard fashion design process. However, unlike regular fabrics, deadstock may have undesirable details such as stains, burns, and holes, be misprinted, or have weaving errors that make it useless for traditional fashion manufacturing. For upcycling designers, on the other hand, a flawed textile may be a starting point for a creative interpretation of the fabric through textile manipulation, for instance (as in **Image 4.7**).

Image 4.7 - *An upcycled textile surface decorated with different types of fabrics and laces embroidered with cotton yarn.*

Subtraction

Subtraction involves reducing part of a garment through cutting, laser cutting, or slashing. For example, before starting the Artisanal Collection, in 1991, Margiela had created a belt by transforming a pair of painted jeans with the subtraction method (**Image 4.8**). The belt is fastened with the trousers' button in the center front, and the hems have a frayed finish ("Maison Martin Margiela 'artisanal' painted denim trousers cut into a belt — fall 1991," n.d.). Next, the designer Aenrmous created the Feliage Hole Top (**Images 4.9** and **4.10**) in brown and black colors by slashing the fabric and creating holes around the garment. Moreover, the holes define the lines of the garment by having cut-out pieces by the shoulders and an irregular hem at the bottom. Finally, the garment is refined with a visible serger stitch.

Image 4.8 - *Maison Martin Margiela, painted denim trousers cut into a belt, designed in 1991 before the creation of Line 0 "Artisanal".*

Image 4.9 & 4.10 - *Aenrmous' Feliage Hole Top in black and beige color variations (following page).*

Deconstruction

While deconstruction – within the broader scope of fashion – is a term that refers to the activity of creating a semantic shift for objects and using garments to function as clothes through subtraction, addition, and function, within the scope of upcycling practices, deconstruction can be defined as a technique of upcycling garments that specifically unconventionally interprets pattern pieces. For instance, deconstruction could involve shifting the orientation of a pattern piece or combining them to become another pattern piece, offsetting or removing pockets, and moving button latches and zippers to create unexpected silhouettes, among other things. For example, the Denim Wrap by Polyhedron **(Image 4.11)** is a skirt made of different pattern pieces, such as trousers and the front of a jacket – from which the buttons and buttonholes are deconstructed into the actual latch of the skirt. A side piece was left open on the top side on purpose to create a pocket. In the center front, there used to be a denim pocket, which was removed to show a contrast in color derived from the finishing treatment of denim garments, which affects the fabric only superficially.

Image 4.11 - *Denim Wrap by the brand Polyhedron (following page).*

The Deconstructed Jacket by Ruby Mariama (**Image 4.12**) is made of two tailored suits of different colors merged at the center front and back. The garment has a customized volume – a pleat was created on the left side, while part of the correct front pattern seems to be cut off and reduced in volume, then sewn back together. The right pocket was cut in half and displaced with different orientations. The garment has visible signs of burn on the left river and shoulder, while the opposite side has a shoulder opening. The front slanting latch was created by maintaining the ones from the original garments, which – probably of different sizes and styles – inevitably do not match completely. Therefore, they create a unique fit, volume, and overall garment finish.

Image 4.12 - *Ruby Mariama, Deconstructed Jacket*

Common Parts designed a long cape with oversized shoulders (Image **4.13**) by un-stitching a pair of jeans and placing them open to create the front and back of the garment. The waistline of the trousers turns into shoulders, while the sides of the legs are joined in the center front with a zipper. Belt loops are displaced from the trousers' waist to the cape's waist, where the old belt is used as the latch. The rest of the cape is completed by more denim fabric to cover shoulders and arms and an ivory fabric to the sides and bottom.

Image 4.13 - *Common Parts, long cape with oversized shoulders.*

Addition

Addition involves different techniques of attaching or adding details to a garment, such as embellishments (patchwork, mending, embroidery, fringes), surface design (painting, printing), and textile manipulation (pleating, smocking).

The Pocket Dress by Marine Serre designed in 2019 (**Image 4.14**), is an example of the addition method, where a garment is studded with cargo pants' pockets of different sizes and slight color variations. In addition, Lou De Bètoly turned a tailored jacket into a unique garment by adding plissé fabric scraps of different colors, materials, and sizes asymmetrically.

Image 4.14 - *Marine Serre, Pocket Dress, 2019.*

Refunction

Refunctioning is a method to transform one or multiple products into a product of a different type or category. It is a case of decontextualization where the same object features apply differently for how the item has been changed – usually combining multiple items of the same type. Archetypes of this method are Margiela's Record Dress, designed in 2008 **(Image 4.5**, the Wig Vest of 2009 **(Image 4.6)**, and garments made with bandages in 2005-2006.

An example is Hepzibah Lyon's Blue HVML Mini Shopper Bag **(Image 4.15)**, made of textile waste. In this case, strips of fabric have been combined to create crochet yarn with which the designer has created unique products. There are endless possibilities of colors, gradients, and color combinations just by matching fabric scraps. Refunctioning allows using scraps of fabric which – for being too small to be sewn together – serve a new function and become a yarn.

Alectra Rothshield proposes the combination of multiple fishnets and stockings into a top, joining them with cross-stitches **(Image 4.16)**, while Olivia Rubens combines crochet doilies to create a skirt **(Image 4.17)**. Lastly, Marland Backus refunctioned rings into a necklace **(Image 4.18)**.

From left to right:

Image 4.15 - *Hepzibah Lyon's Blue HVML Mini Shopper made of textile waste.*

Image 4.16 - *Alectra Rothshield, Fishnet top.*

Image 4.17 - *Olivia Rubens, Off White Crochet Wrap Skirt.*

Image 4.18 - *Marland Backus, Rings Necklace.*

Deadstock

Deadstock fabric is any leftover coming from industrial textile manufacturing (**Image 4.19**). This raw material is generated when brands may order excessive fabric or because the manufacturing process is incorrect. As a result, misprints or other damage may make the textile useless for its original purpose. While the use of deadstock seems to be a sustainable practice, there are growing concerns that manufacturers produce deadstock on purpose, for it will eventually be sold to the many growing brands claiming sustainable production for using this type of raw material ("What Is Deadstock Fabric and Is It Sustainable?," 2022).

In this research, rather than deadstock fabrics, the focus will be on secondhand textiles – which may include deadstock if supplied under specific conditions. For instance, upcycling deadstock fabric sourced from a factory that purposely overproduces raw materials is highly unsustainable. On the other hand, sourcing leftover or secondhand fabrics from the local community, including artisans, trusted local factories, and fabric stores, can provide sustainable deadstock to a local upcycling brand.

Image 4.19 - *A pile of deadstock fabrics.*

Combining methods

The methods listed above are not to be considered sealed-off compartments. On the contrary, upcycling designers often combine different methods to transform raw materials into garments and accessories.

Lou De Bètoly's cashmere tank top (**Image 4.20**) is made by subtracting pieces of knit and adding threads and pearls as embellishments, combining the subtraction and addition methods.

Image 4.20 - *Lou De Bètoly, cashmere tank top.*

Image 4.21 - *Arezou, Detachable Waxed Cotton Jacket.*

The brand Arezou created a modular jacket transforming deadstock materials from the fishing industry. The Detachable Waxed Cotton Jacket (**Image 4.21**) can be worn as a complete garment, vest, and crop garment by adding or removing the blocks joined by the rope. This product is designed with a combination of using deadstock and the refunction method.

Case studies of upcycling brands

The upcycling practice is one of the main trends in the current fashion landscape (Singh, 2022), and together with the fact that it is considered one of the most impactful solutions for accelerating sustainable development (Han et al., 2017), upcycling is laying the foundations for new business models. Furthermore, the increasing number of upcycling practitioners and the rise of consumers' awareness about sustainable production and consumption is helping to generate many new design-driven businesses and marketplaces that exclusively host upcycled products (Bugamelli, 2021).

Image 4.22 - *A backpack by the brand Freitag.*

Freitag: large-scale upcycling

Freitag is one of the most successful and popular upcycling stories. The brand was born in 19993 in Zurich and managed to scale up the upcycling process to reach the mass market. The products are designed to last, from discarded truck tarps, B-stock airbags, recycled PET, and biodegradable fabrics ("FREITAG | Pezzi unici ricavati da teloni di camion riciclati," n.d.). Freitag is a brand that has focused on circularity since its birth and delivered high-quality and unique products considered a design icon today. Moreover, Freitag's bags are one-of-a-kind because of the randomness of the print, emphasizing the individuality that only upcycled products can deliver (**Image 4.22**). Their products have a higher price point than expected because the founders want to highlight the value of slow and meaningful consumption. Because of this, the products are never discounted. Their effort in producing quality bags and other kinds of accessories is openly explained through their channels. The brand is very transparent about its commitment to reaching a circular economy. They communicate the high value of their product, justifying the higher price (Sung et al., 2022).

Freitag's product-service system is highly innovative and exciting. The product is very functional and free from the influence of seasonal trends. Moreover, it has a certain degree of adjustability through the straps, and the customers can customize it according to their taste. The end-of-life stage of products is considered through a take-back system and a "SWAP" service, through which customers can exchange a bag for another without paying more. The storytelling process educates the customer and the DIY micro-factory where the people can build their bags (Sung et al., 2022), acquiring new skills and connecting with the brand at a deeper level. A participatory approach to design through personalization activities could improve the emotional connection between the product and the user (Haug, 2019), which is one of the critical aspects of design for products' emotional longevity (Chapman, 2009).

Studio Mend: upcycling through visible mending

Studio Mend is a one-person studio based in Oslo, Norway. The studio is specialized in visible mending as an upcycling technique (**Image 4.23**). The founder is Sunniva Rademacher Flesland, a Norwegian designer who thrifts secondhand garments online and offline and mends them with different hand-embroidery techniques. By visible mending, garments are turned into unique pieces. The stains or holes in the garment make them unique, highlighted in different colors (“About - StudioMend,” n.d.).

Visible mending is a technique of intervention to increase the lifespan of clothes, repairing and updating them through methods such as hand-stitching and embroidery. The repair is “dynamic” because it is experimental and transformational. The mending practice creates a deep connection between the practitioner and the textile, and it frequently happens when the designer or maker is particularly attached to a garment. For this method to create long-lasting products, they must consider the garment’s wearability so that the repair is not affected by wear immediately after the new use phase starts (Jones and Girouard, 2021).

Image 4.23 - *A trench coat by Studio Mend, decorated with the visible mending technique.*

MutaWear: a participated customization service

MutaWear is a slow-fashion upcycling brand located in Singapore. Its revenue model embraces the concept of reduced consumption through products-as-a-service and total customization through co-creation with the customer. Apart from a few ready-made products – such as shoppers made with textile waste – MutaWear offers the possibility to co-design a product. Customers can bring their textile waste or garments they wish to transform, deconstruct, or turn into yarn and give it a new life. There are different upcycled options from which to choose: necklace, bag (M), bag (L), top or bottom, full-body one-piece, or tailored garment. For the end-of-life, the brand provides repair and return-for-recycling services.

Another product-as-a-service that MutaWear is selling on their website is upcycling workshops, teaching specific upcycling techniques to make bags, crochet, and sewing basics (mending, repairing, and reconstruction) (“Crafting/Upcycling Workshops,” n.d.).

Image 4.24 - *An upcycled garment and neck accessory by MutaWear.*

ANALYSIS	FREITAG	STUDIO MEND	MUTAWEAR
Value proposition	One-of-a-kind durable pieces made from recycled tarps	One-of-a-kind thrifted luxury garments transformed through visible mending	Co-designing products with the customer by transforming their own garments
Upcycling method	Deconstruction + deadstock	Visible mending	Deconstruction + refunction
Further considerations about sustainability in the design process	End-of-life options such as swapping products through their own website	Zero-waste process	Zero-waste process
Raw material	Truck tarps, F-ABRIC, R-Pet, B-Stock airbags, natural fibers	Thrifted designer garments	Second-hand garments
Sourcing raw materials	F-ABRIC is a bast fiber developed by the brand and produced in Europe; tarps are spotted around Europe. (European supply)	Thrift shops (local supply)	Provided by the customers (local supply)
Number of products	Large-scale production	Small-scale production (5-10 products per collection)	Upon request (made-to-order)
Customization options	Yes	No	No
End-of-life options	S.W.A.P.	No	Repair service available, the website mentions recycling but there is no further info about how and where they will recycle their products.
Assortment	Accessories (bags, backpacks, pouches, notebooks)	Basic clothes (t-shirts, pants)	Garments, necklaces, and bags, according to the customer request

ANALYSIS	FREITAG	STUDIO MEND	MUTAWEAR
Value chain transparency	Yes	Yes, the designer thrifts garments and transforms them in her studio in Oslo. There is no info about where the thrifted garments come from.	The brand works mostly at a local level, collecting raw material and organizing offline workshops. No transparency issue
Value chain traceability with a digital label	Tarps are catalogued by the brand for internal tracking of raw material. Not publicly available.	No	No
Is the brand/ designer educating about upcycling and sustainability?	Yes, through an open factory where customers can create their own bag.	Yes, through workshops about visible mending techniques.	Yes, through workshops about upcycling and sewing techniques, and through co-design.
Target customer	Conscious consumers who value function and design over trends	Minimalist luxury conscious consumers	Conscious consumers seeking a tailor-made experience and DIY enthusiasts
Emphasis on all 3 Rs of circularity	Reduce: a higher price point is helping valuing products and reducing consumption, according to Freitag. Reuse: the brand reuses plastic and textile waste to make the bags. The S.W.A.P platform allows customers to re-use someone else's bag and swap it with their own. Recycle: depending on the material, not fully circular yet.	Reduce: few products are made; overproduction and overconsumption are not an issue. Reuse: thrifted garments are the raw material. Recycle: it's not mentioned whether there is an end-of-life option	Reduce (consumption and production) through made-to-order model. Reuse: upcycling textile waste, giving a second life to garments. Recycle: transforming textile waste, recycling at the end-of-life.
Digital technologies involved in the user experience?	There is an online customization service where customers can create their own bag placing the pattern pieces on the tarp.	No	No

Discussion

The main change brought by upcycling in fashion brands is adopting a design-driven perspective across different company sectors. A design-driven approach is not simply influencing the style or material of a product but its meaning. Product meanings influence consumers' choices: acquiring a product is not just about solving a functional need but also a psychological one – and meaning is how it happens. A new meaning is radical product innovation – while functional improvements are incremental innovations (Verganti, 2009).

Upcycling can give birth to different types of design-driven businesses (see **Table 3.2**). On the one hand, there need to be scalable solutions to produce and consume sustainably for consumers to help achieve the environmental goals outlined by the institutions. On the other hand, the concept of reducing must be considered, as well as recycling and reusing – and scaling up a sustainable solution might have unsustainable side effects, which are pretty hard to foresee. Freitag's solution is thoughtful in this sense for considering different options for the end-of-life phase of their products. Even by producing higher volumes, the brand could embed a higher value – good quality, timeless design, functionality – in their products and emphasize the life-cycle concept providing a way for customers to return or swap products. A core aspect that makes this approach work across life cycles is the favoring of a functional and design-led product rather than a trend-led one, ensuring that the users will not discard the products for losing their "aesthetic functionality" when the trend cycle that determined the aspect of the product (colors, materials) is over. Freitag's upcycling method is affirmed at this point – refunctioning old truck tarps. Improvisation in the design phase is reduced to the minimum since the only variable is the print on the tarp. This method allowed to creation of a semi-automated manufacturing process based on upcycling.

Differently, some practitioners maintain a small-scale production. Many of them – such as Studio Mend – are skilled artisans that make one-of-a-kind products and adopt a unique combination of techniques. These products are usually quite artsy, and their production cannot be scaled up in numbers because

Table 3.2 - *Compared features of three upcycling brands (previous page).*

manufacturing requires a slow-fashion approach. Moreover, the raw material flow is generally more random and unpredictable than Freitag's. Supplies for this type of brand typically come from thrifting, while the previous brand has managed to create a stable and predictable supply chain of the same type of raw material. When this is impossible, designers must constantly adapt designs to the available raw material and adjust their process accordingly. This type of brand generally focuses on one product life cycle because individual designers and studios usually cannot manage their products' end-of-life phase. Since products are always slightly different in material composition and design, disassembly or recycling does not seem easy. This issue is even more significant when the design includes fabric manipulation and patchworking, combining different materials so that it is hard to sort recycling materials – if it is possible to know the composition in the first place when using thrifted textiles. In this case, the designer uses an additional method for upcycling whose variable is the location and size of the blemish that needs to be disguised. The process can be streamlined but always requires a certain degree of improvisation.

Adopting the product-as-a-service approach as their core value proposition, the third brand provides a more tailored user experience with a direct relationship between customer and designer through co-design. Here, upcycling is disclosed to the public with an educational approach. The users directly supply raw materials for the brand to create new garments. The designers become "design consultants," helping users understand what their old clothes could become through the upcycling design process. This case is interesting because it bridges the public with design, materials, and textile culture. Unlike the above cases, customers are empowered to actively participate in the design process and enable upcycling, contributing by donating their clothes. Such a supply method is changing the journey textile waste undertakes. They are, firstly, avoiding flooding the second-hand market with garments of questionable quality. Secondly, creating the opportunity for customers to be familiar with upcycled products as they see their garments being transformed into something

else – maintaining some familiar elements that involve them emotionally, especially when upcycling something to which they were particularly attached. This method creates a unique story for each product that is entirely special for the customer because they are the “beholders” of that product’s life cycle history. Lastly, this approach allows a brand to supply materials in their local community, avoiding relying on a dubious second-hand market without access to any information about the garments’ journey and origins. Suppose the garment owner donates it to an upcycling facility. In that case, it is more likely they can provide helpful information about the fabric composition, place and date of purchase, and the brand that designed it – all of which are frequently unavailable when using thrifted products.

Moreover, suppose the garment is tailored-made, or the textile has a particular design. In that case, the users may be able to explain its inception – such as in traditional lace or embroidery, helping the designers understand whether it is connected to a specific cultural heritage. This last case study is not based on a chosen upcycling method but rather on an upcycling philosophy/methodology, a set of techniques employed to solve design problems and co-create with the customer. This last approach is the most time-consuming because it requires ad hoc solutions for each product and highly skilled craftsmanship with multiple specializations.

Conclusion

The choice of a method or methodology for upcycling is the triggering factor of different types of business models – and this fully embodies the concept of design-driven business. The more methods and workflows the brand employs to carry out the upcycling process, the more variables and outcomes arise. For example, if a brand aims at upscaling its upcycling business, it must automate material supply and manufacturing as much as possible to ensure higher inventories and continuous production. In this case, the workflow and methodology are fixed. On the other hand, small businesses and artisans may use a combination of methods where the workflow can be changed according to the available raw material supply.

Consequently, smaller brands, studios, or artisans may have less standardization and less process automation. The output products embed a higher value because of involving more skilled labor, ad hoc problem-solving, and results that are harder to reproduce. Freitag's bags are, indeed, one-of-a-kind, but the manufacturing process is standardized and automated where possible. The uniqueness lies in the print and color variation of the tarp. On the contrary, small-scale upcycling brands that supply raw materials more randomly do not just create unique products but also unique, irreplicable processes.

Co-creation and customization are not exclusive features of large- or small-scale upcycling but can develop with different degrees of user involvement in both cases. For example, the large-scale upcycling brand Freitag allows users to customize a bag by choosing where the bag's pattern piece is cut on the tarp. Even though this allows for an engaging mass-customization tool, having the customer choose the placement on the tarp may result in questionable raw material use. As seen in **Image 4.25**, there is a high amount of leftover material because of the poor consideration of the pattern placement. Small brands and artisanal studios that provide customization options can rely on more co-creation with the user in many process phases. Users can supply raw materials creating a high emotional and psychological involvement, discuss desires and goals in terms of design, and help manufacture the final product. In this case, the brand and designer become creative facilitators, generating a more tailored experience and final made-to-measure product with DIY elements.

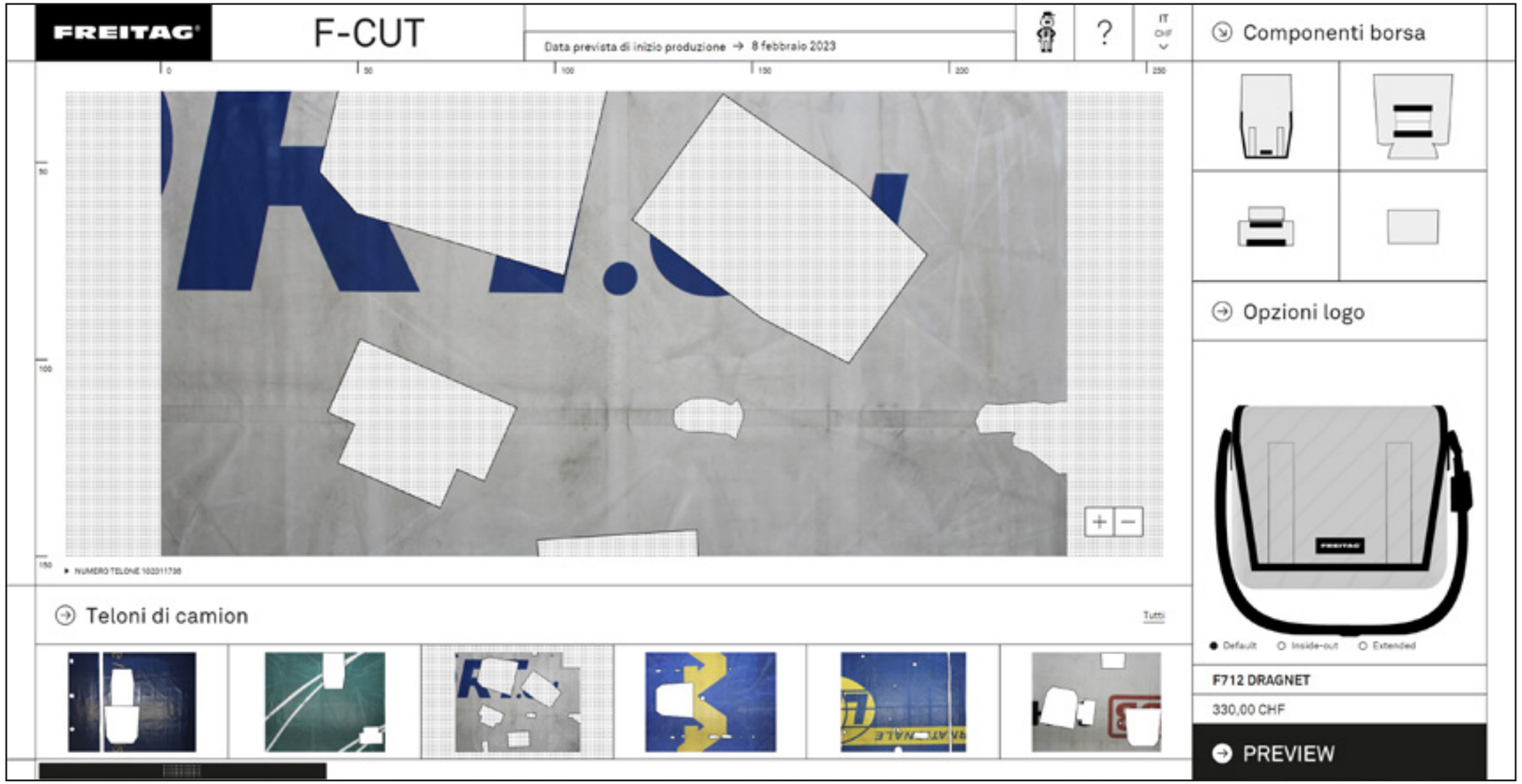


Image 4.25 - *A screenshot of the F-Cut customization tool by Freitag.*

This overview highlights that digital technologies in the front-end of the project are starting to be adopted by major upcycling brands such as Freitag. On the ohter hand, small businesses and artisanal activities don't employ any digitized service to connect with the users - except from social media platforms and websites. There is no evidence on whether they use back-end digital technologies.

CHAPTER FIVE: UPCYCLING IN THE NORTH-EAST OF ITALY - THE OFFBEAT DISTRICT CASE STUDY

INTRODUCTION

Offbeat District is a slow-fashion project founded in 2021 that focuses on supplying textile waste for upcycling garments and accessories in the northeast area of Italy. The location was an exciting domain where this activity could be established because of the wide availability of raw materials (**Image 5.1**) and strong community support. The Offbeat District project is now a case study of design-driven innovation of the fashion system in the context of digital transformation. This case study analyzed how the brand has leveraged digital innovations in the value chain's back, and front ends.

Image 5.1 - *Second-hand pillowcases.*

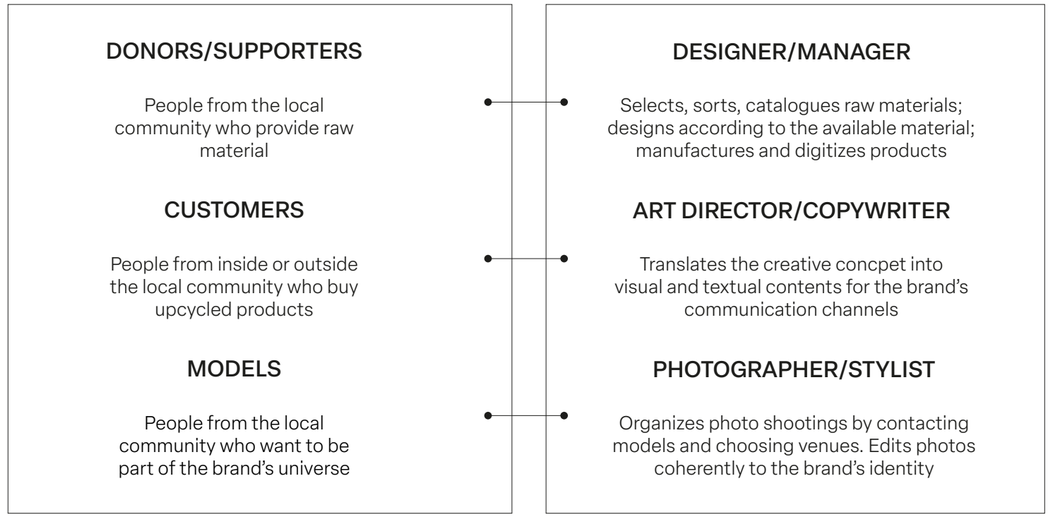
Value proposition

The brand's value proposition is repurposing local textile waste and streaming it back into the fashion market in the shape of upcycled, one-of-a-kind products by designing functional and durable products with a particular aesthetic interpretation (**Image 5.2**), which is the focus of the design process. The added value of Offbeat District's products is that the design and creative processes are highly influenced by digitalization, are fully documented, and all the available knowledge is shared with customers through digital product IDs, digital patterns, and tutorials. These documents allow for tracing back materials and processes, helping to achieve a longer product life cycle and eventually recycling at the end of life. Therefore, the brand develops a few models made-to-order and customizable sizes for clients, using a unique combination of textiles and surface design, resulting in unique and unique products. The brand experience is supported by "digital twins" to give a product preview and create an upcycling archive for both users and designers to consult once the product has been sold. Offbeat District's design identity is unique, maximalist, and eccentric.

Image 5.2 - *Model wearing Offbeat District upcycled top and skirt.*

Project's stakeholder map

Map 5.1 - *Offbeat District's stakeholder map.*



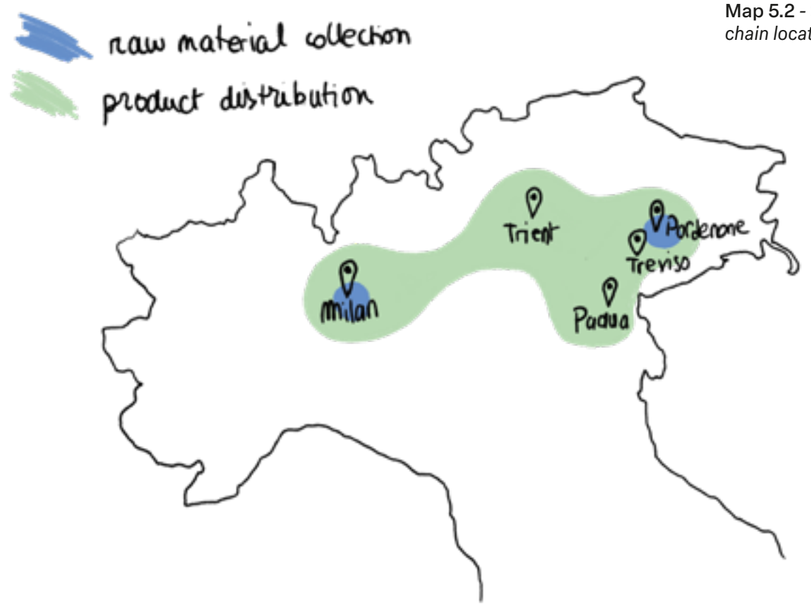
Offbeat District's focus is the local community, both as a way to supply raw material but also for manufacturing and distribution. As shown in the diagram (**Map 5.1**), the community is the main enabler for the design process to start. People are called to donate and support the project by giving their own unused clothes or fabrics. The raw material is carefully selected by the designer who attempts at recognizing the fiber type and the fabric weave type. Once this is done, the design process can start. During this time, the art director is responsible for creating the brand's communication strategy with visuals and text to be published in various channels (social media, website, flyers, etc.). Once a few products are available, the photographer-stylist figure is involved and their task is to organize photo shoots, choosing venues and finding models. The models are picked from the local community and – most of the times – spontaneously reach out to the brand to participate in photoshoots. Models and donors-supporters are stakeholders who sometimes overlap. It's very likely that a person who gets to know the project by participating in a photoshoot is then more willing to donate textiles. Vice versa, donors who get in touch with the brand are likely to be comfortable in taking part in a photoshoot. So far, the "customer" category doesn't overlap with models or donors – instead, they mostly come from outside the local community.

Project's value chain location

Most of the brand's activities are in the province of Pordenone, located in northeast Italy. Generally, people from the region can donate textiles instead of throwing them in recycling bins. This sourcing method allows the brand to work only with local textile waste without thrifting. The raw material is then collected, sorted, and stored in Pordenone, where products are designed and manufactured.

The sourcing and manufacturing phases of the value chain are entirely localized in one city. Distribution, on the other hand, is not. So far, all customers who purchased a product from the e-commerce website are in northern Italy, including Pordenone, Milan, Padua, Treviso, and Trient (**Map 5.2**).

Map 5.2 - *Offbeat District's value chain location.*



Raw materials

When sourcing second-hand textiles, product types must be carefully evaluated and categorized to build an information database on the available fabrics. The fabric or garment type, condition, quality, and aesthetic properties are key drivers of the design process. So far, the collected raw material can be categorized as follows:

Deadstock fabric was donated by a local seamstress who retired. She has been collecting good quality and designer fabric for her practice – the earliest samples date back to the 1980s and are sourced across Lombardy textile districts.

Second-hand garments of all types – fast-fashion, ready-to-wear, and tailored garments. Most people donated jeans, cotton shirts, coats, jackets, and tailored suits. Only a few donated undergarments, such as bras. A few donated leggings and swimsuits, while nobody donated sportswear garments.

Second-hand accessories (handbags, scarves, ties, and handkerchiefs), among which the most popular items are printed scarves, most of which are made of silk.

Underwear trimmings included nude-colored elastic straps and hooks collected as deadstock from a store.

Home textiles, including tablecloths, napkins, curtains, bedsheets, towels, and doilies. These items were given away because they had holes, sunburns, and stains caused by the usage or inappropriate conservation.

All kinds of lace were donated, including embroidered surfaces, trimmings, and crochet embellishments. These trimmings are of various kinds, ages, and conditions – artisanal handmade, and industrial (**Image 5.3 & 5.4**).

Some of the collected textiles allowed for recovering additional materials, such as zippers, buttons, trimmings, collars, and lace.

Image 5.3 - *Some of the donated raw materials for the project.*

From this categorization emerges the availability of a primary raw material – garments, accessories – and a secondary raw material – trimmings – derived from the first.

Even if these categories built up spontaneously thanks to the community's donations, the following donors were suggested to give similar items to achieve some standardization in the design process after creating a few prototypes and starting to understand how to build a workflow with these textile categories. New ideas are always considered, but improving the workflow and having a constant availability of the same material type is crucial to allow the process to be repeated and speeded up. Establishing different workflows from different raw material streams could turn artisanal upcycling into a more automated and standardized process – albeit not renouncing the one-of-a-kind identity that characterizes upcycled products.

Image 5.4 - *A large embroidered doily (donation)*

Raw materials database

The collected materials were divided by type, size, and composition and cataloged digitally on a spreadsheet. Each material was given an identification code and documented with a picture. The materials catalog contains the following information:

ID code (given by the date of recovery and material composition)

Name of the donor

Date of donation

Place of donation

Quantity (how many pieces of the same textile are available)

Material composition (when available from a label, otherwise guessing through observation and burn-test)

Type of textile (weave/knit type/embroidery style/ lace type/garment type)

Color(s)

Height

Width

Area

Weight

Weight by square meter

A short description (any surface details, shape of the piece of fabric)

Other materials included in the piece of fabric (such as buttons, zippers, trims, etc.)

Flaws (presence of stains, holes, etc.)

Suggested use

Drafting this spreadsheet is a way of tracking inventory using a sourcing strategy such as donation-based. Even if specific product categories were suggested when talking to the donors, there was still some spontaneity in their choices, suggesting new categories and requiring further categorization of the collected materials.

Framing a material-driven design brief

Different quality and textile properties allow for different kinds of manufacturing, similar to the standard design process. Although, the designer's choice is not merely based on picking from a list of freshly weaved or knitted textiles because other aspects must also be considered. These variables include the size of the piece of fabric, the quality of the material, the wear, and the presence of rips, holes, stains, and other flaws in the fabric or knit.

Deadstock full-sized fabrics

These textiles can be used similarly to virgin textiles, cutting traditional pattern pieces and creating the base for clothing and bags. A more sustainable approach could be including zero-waste pattern-cutting techniques to avoid creating waste in the first place. The wide availability of a specific type of textile allows for better product development. These textiles are suitable for creating the bases for applying unique embellishments and functional decoration. This way, there can be a standardized, replicable fit, but the product is still unique. Pattern cutting and sewing inevitably create waste, such as scraps and threads, which create a new raw material category with a different purpose.

Deadstock is not just easier to use for pattern cutting and fitting but also for understanding the fiber composition, the weave, or knit type – many fabrics come with information about the fabric composition and finishing treatments written on the selvage – easing the categorization process and consequently the labeling of the final product and recycling at the end of life.

Second-hand garments

Second-hand garments (**Image 5.5**) must go through a partial or total deconstruction process to be repurposed. There are far too many variables to make a unique statement on how to repurpose garments. However, it can be affirmed that they often present signs of wear. Once they are disassembled, their durability and aesthetic qualities are undermined – because of the stress caused by using the product and the signs left behind by the seams.

Another complexity that arises from using garments for upcycling is understanding the fiber composition. When Disassembling many garments, labels did not turn out to be a reliable source of information regarding materials because trims, seam threads', and interlinings' compositions are not disclosed on the label. Often labels on shirts and jeans claim a 100% cotton composition and contain synthetic interlinings, non-woven fabrics, and plastic films inside collars, cuffs, and pants' belts. Confirming what was found in the literature, data about trims such as zippers and buttons are completely neglected as a field of research; in fact, garment labels do not mention what they are made of – preventing sorting or recycling. Upcycling allows for repurposing some of it – although it is impossible to manage their end-of-life because we do not know how to dispose of them.

The disassembled garment pieces can be repurposed with all the techniques found in the literature (subtraction, deconstruction, addition, and refunction). For instance, removing curve cuts in disassembled pattern pieces and somehow reducing them to rectangles simplifies the shapes, allowing patchworking them together and rebuilding a new pattern piece. This methodology is based on deconstruction, subtraction, and addition.

The peculiarity of textile and garment upcycling is that one methodology enables another through its by-products or cut-outs. For instance, if a garment has been cropped (subtraction), the remaining scraps can be used on another product as embellishments or, in some cases, even be suitable as a functional pattern piece (addition). For this reason, the upcycling process and its outcomes are in a constant state of becoming. Therefore, the designer needs to be capable of improvising and systematically finding creative solutions, even when the inventory allows for a certain degree of standardization. Pants can quickly provide four large rectangles corresponding to the front/back left/right sides – slightly adjusting if there are any curves. The hem can easily be opened and ironed to obtain a few more centimeters of fabric. The top part of pants is perhaps the hardest to repurpose due to its rounder volume near the hips and crotch and due to the presence of pockets, the button flap, and the belt. Specific solutions need to be found for these parts. Alternatively, they can be used as they come in a different product category – such as handbags – following the refunctioning technique. Tops need to be analyzed separately according to the type. Generally, sleeves can be deconstructed and sewn together on the sloped straight line that follows the arm with pieces upside-down so that once

they are stitched, they create a bigger scrap of fabric. Although, the pieces obtained from deconstruction can be combined differently according to the necessary pattern piece. Applied pockets can be removed from garments and re-applied in a different location or product, as they are – avoiding cutting. Zippers, buttons, and trimmings can be removed and repurposed from any garment. Skirts can provide considerable fabric, especially if they are pleated or ruffled – and easily patched together to create a larger piece. Depending on the skirt type, different outcomes are possible. For instance, straight skirts are quickly turned into rectangular pieces, although radial skirts cannot undergo the same process. In this case, the upcycling designer needs to exploit the curve intelligently to avoid wasting fabric – which frequently happens when trying to repurpose curved cuts.

The approach must be radically different when dealing with knits and stretch fabrics; deconstructing stretchy garments results in entirely different pattern pieces. They typically have a smaller size and take more time and care to disassemble because the pattern pieces are sewn together with a serger. They tend to rip when disassembled, and the knit is very lightweight. The garments I had the opportunity to work with were made of a low-quality knit, making wear too evident for repurposing and disassembly very time-consuming. In addition, the fabric would be too damaged to use as a structural pattern piece. This issue is not limited to knits but applies to all low-quality textiles – although canvas fabrics seem to have better durability than knits, even from fast-fashion manufacturing. A possible way of repurposing lightweight knits is as filling, albeit a form of downcycling instead of upcycling.

Image 5.5 - *Second-hand linen pants (donation)*

Second-hand accessories

Accessories include many kinds of product types. Generally, accessories have a smaller size and must be patchworked to create a pattern piece. However, some categories, such as scarves and handkerchiefs, are easy to repurpose because they are rectangular and can be easily patched together.

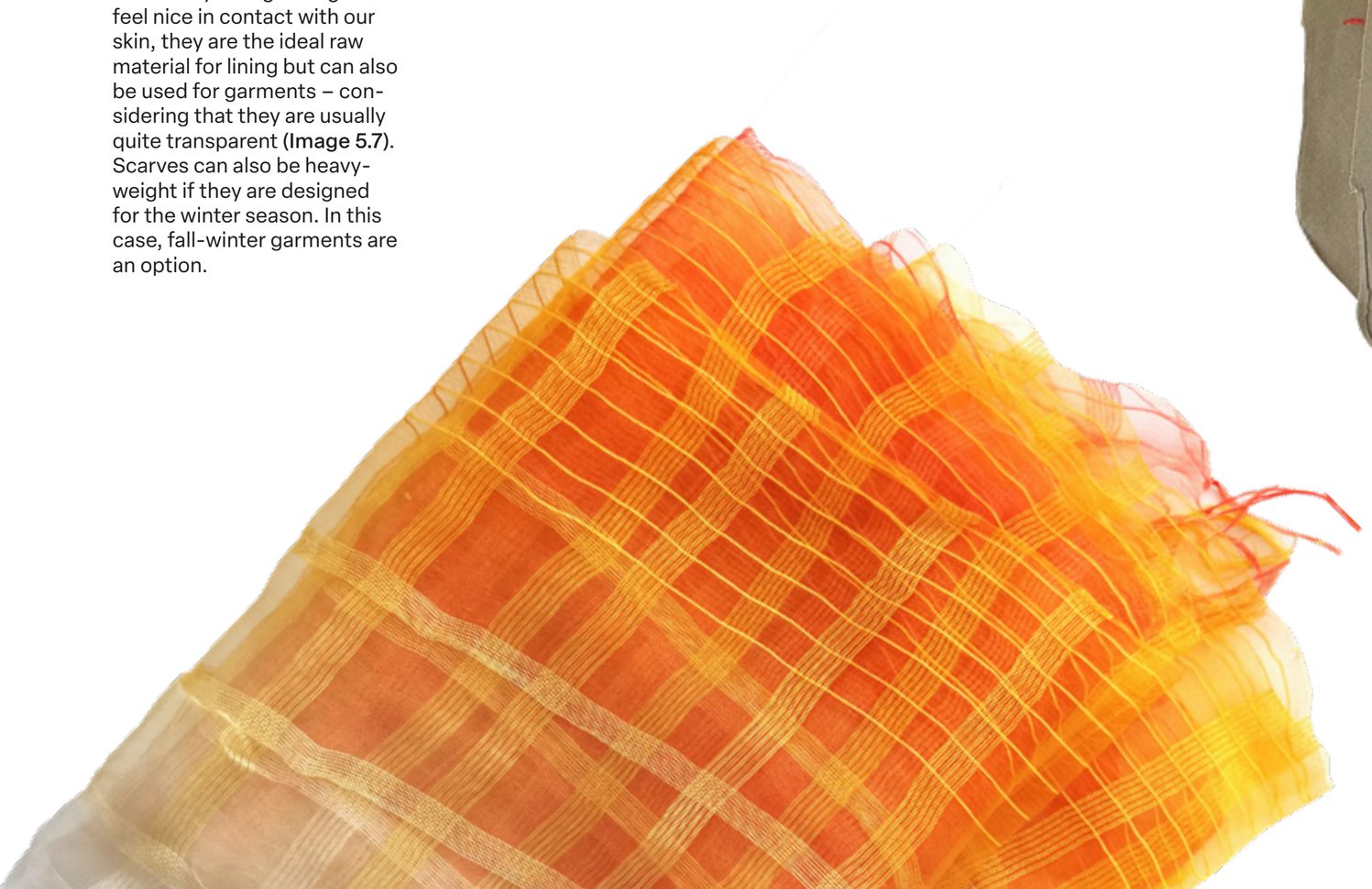
Handbags. Typically, bags can provide heavyweight fabrics, such as leather, synthetic leather, heavy canvas, linings, buttons, zippers, and snap hooks. Upcycling the outer fabric from handbags is a challenge since most of them are made with low-quality synthetic leather that peels off when the pieces are disassembled – and, most importantly, it is not desirable to upcycle something that will splinter a few months after that, having no durability (**Image 5.6**). This downside is an issue with jackets made of synthetic leather as well. Hooks usually maintain a good quality – although many fast-fashion products may have metal-pleated hooks that could strip their outer layer looking undesirable.

Image 5.6 - *A second-hand handbag (donation).*

Scarves. They are rectangles or squares of fabric – silk, linen, wool, polyester, and viscose, for the most part. They typically have special weaves, prints, finishings, and hems, making them a fascinating texture for upcycling. Since they are lightweight and feel nice in contact with our skin, they are the ideal raw material for lining but can also be used for garments – considering that they are usually quite transparent (**Image 5.7**). Scarves can also be heavyweight if they are designed for the winter season. In this case, fall-winter garments are an option.

Image 5.7 - *Second-hand scarf (donation)*

Image 5.8 - *Second-hand ties (donation, next page)*



Ties. They come in different shapes and lengths according to the style, and the manufacturing quality highly impacts the repurposing options. Some ties are made of a maximum of two pieces sewn together and have a special finish (**Image 5.8**). Cheaper ties are made of many pieces of biased fabric, often assembled without any finishing. Inside ties, there is a layer of strengthening canvas, mostly bias cut in the exact shape of the tie. All ties had a label indicating the manufacturer and the fabric composition of the main piece, although the label did not mention the fabric composition of the strengthening canvas.

Handkerchiefs. Made of pure cotton or linen canvas, they are ultra-lightweight like scarves. The collected ones are made of simple canvas printed with lines of standard colors, such as shades of blue, dark green, and grey **(Image 5.9)**. Some are made of a solid color or printed with a brand's logo. They seem to work well as lining but also for spring-summer lightweight garments.

Image 5.9 - *Second-hand handkerchiefs (donation)*

Home textiles

Home textiles are easily repurposed as a non-stretchy fabric for different applications.

Image 5.10 - *Second-hand tablecloth (donation)*

Tablecloths function similarly to scarves, consisting of squares or rectangles of good-quality fabric – typically cotton or linen. The fabric weight varies a lot. The colors are mainly white and ivory, with few exceptions. Most tablecloths come with unique trimmings near the hem and handmade embroideries. Their shape suggests smartly placing patterns to repurpose these embellishments **(Image 5.10)**. They tend to be quite transparent, which may be an issue for specific garments.

Image 5.11 - *Second-hand napkins (donation)*

Napkins are usually made of linen or cotton canvas (or a blend). Some match a tablecloth. Their size is about twice that of a handkerchief, and the shape is a square or rectangle (**Image 5.11**).

Curtains are also made of canvas, but differently from the previous categories, they often include synthetic fibers. The fabric weight can vary, but very thick fabrics are found more quickly in this case. Because of the purpose of this category, no matter the thickness of the yarns, they are very transparent (**Image 5.12**). If the canvas is very thick, it may be suitable to create shopper bags or similar products that carry much weight – while they may feel quite uncomfortable if worn directly near the skin.

Image 5.12 - *Second-hand curtain (donation)*

The collected **bedsheets** are made of cotton (**Image 5.13**), linen canvas, or a blend of the two – rarely of silk. They function as large pieces of fabric and can be easily used to cut patterns. This category can also include duvet covers, two slightly thicker bedsheets sewn together in a sack. These items were used to make large amounts of aprons and shopper bags, and they seem very suitable. Some bedsheets might have flaws that compromise the durability and functionality of the upcycled products. For instance, wear on bedsheets usually concentrates in the middle part, thinning the fabric and making it unsuitable to be repurposed for a structural pattern piece – while the sides of the fabric usually maintain an excellent structure even after many years of use.

Image 5.13 - *Second-hand bedsheet (donation)*

Towels. Mostly made of heavyweight linen or cotton, they include precious embroideries.

Doilies are handmade in cotton or linen with crochet or bobbin lace techniques (**Image 5.14**).

Image 5.14 - *Second-hand embroideries and laces (donation)*

Image 5.15, 5.16, 5.17, 5.18 - *Second-hand trimmings for underwear.*

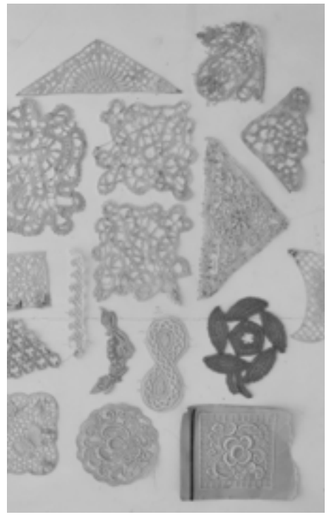
Image 5.19, 5.20, 5.21, 5.22 - *Second-hand laces, crochets, and trimmings.*

Underwear trimmings

Elastic straps, hooks, and all underwear trimmings were collected as deadstock from a store. They are instrumental in designing upcycled tops, allowing the creation of corsets (**Image 5.15-5.18**). However, because of their composition, the elastics' condition must be carefully analyzed because they are subject to oxidation. Old elastics cannot be upcycled because their functionality and durability are compromised – once they are degraded, restoration is impossible.

Laces, embellishments, crochets, and trimmings

These pieces of textile are generally more fragile than fabric. Even if they can be used as pattern pieces for some very lightweight summer garments (crop tops, cardigans, shawls, dresses), they work best as embellishments on other garments and accessories (**Image 5.19-5.22**). Depending on the fiber quality and its degree of preservation, old lace is too fragile even as an embellishment because it rips apart when slightly pulled.



The cultural heritage of Friuli Venezia Giulia's textiles

The Friuli Venezia Giulia region has a long history of textile manufacturing (**Image 5.23**) and embroidery that has characterized local arts, crafts, and industrial production (Morandini and Zanella, 1988). Collecting second-hand textiles has caused peculiar features about their nature to surface. It proved that what is collected in one area is different from another, especially when dealing with fabrics from the past century, which had been stored in people's storage rooms for a very long time. The collection of this sort of fabrics and trims sparked the idea that the region's cultural heritage may be transferred through them with the upcycling practice. Primary and secondary sources were consulted to understand and recognize traditional manufacturing techniques and styles.

Image 5.23 - *Traditional outfit from the Friuli Venezia Giulia Region, 1700s.*

Weaving and dyeing tradition

Linen. The textile industry in the Friuli Venezia Giulia region was established during the 1700s when Jacopo Linussio (1691 – 1747) reached excellent technical manufacturing quality of linen fabrics and commercial success (Ganer, 1991). His heritage was passed on thanks to the introduction of the *libri dei tacamenti* (books to explain the weaving techniques), manuscripts, and sketches for weaving designs. Even after the factory shut down, many artisans continued weaving with the same know-how, preserving Linussio's technical heritage until the 1900s.

Countless techniques and decorations are available for consulting today, documented with sketches, notes, and specific symbolic language, highlighting the fundamental creative and design skills of the weavers of that time. After the notes left by Linussio, the second most ancient source of technical weaving knowledge of that time is the *Libro di tacamenti* by Antonio Candotto di Ampezzo, written in 1791, followed by many others. Apart from reporting technical schemes of weaving patterns, these notebooks contained recipes for the natural dyeing of yarns and calculus to mount the fabric warp on the loom (Morandini and Romeo, 1991).

Cotton. In 1857 Luigi Spezzotti founded a linen and cotton factory in Udine with around a thousand looms. In 1876 the looms were completely automated, and the factory introduced dyeing technologies. The Spezzotti weaving mill produced fabrics for the masses in Italy and abroad. Since then, it has grown constantly, with a peak around the 1950s and 1960s. After that, the factory reduced production until 1982, when it shut down. The heritage left by the Spezzotti family includes ten pattern books containing 19.957 samples and thirteen *cartolari* (production sheets) containing 1959 schemes, among other documents.

The Spezzotti factory used to produce cotton canvas for the most part (flannel and popeline) and hemp fabrics. The pattern decorations included squares and stripes, damask, and small decorations ascribable to Carnia's and Friuli's textile tradition. During the 1930s, fabrics and clothes were to be in an Italian style as a mandatory patriotic gesture. In this period, synthetic fibers such as rayon and terital are introduced. The factory provided

countless coloring options changing year by year. Moreover, they produced large amounts of canvas for workwear – blue for steelworkers and brown for woodworkers. They also produced indigo blue jeans and – more recently – precious corduroy cotton velvet for pants and canvas for sails (Romeo, 2021).

Silk. After a long period of neglecting the value of fashion and applied arts' cultural value, at the beginning of the 1900s, Giovanni Cossàr – director of the Musei Provinciali di Gorizia – took charge of the collection of artifacts, industrial, and artisanal manufacturing equipment that 90 years later gave birth to the Museo della Moda e dell Arti Applicate (**Image 5.25**). The exhibition starts with the textile production section on silk spinning and weaving. The Gorizia and Gradisca County Territories – located in the southeast area of the region – used to be southern provinces of the Hapsburg Empire from 1500 to 1918, where silk production was a core aspect of industrial development. Originally, peasants were responsible for cultivating mulberry trees and breeding silkworms. In the counties, people would also manufacture woven silk, *piccoli operati*, damasks, ribbons, trims, stockings, and handkerchiefs. Between 1726 and 1791, silk production was highly industrialized thanks to the introduction of a silk factory. However, because of the 1800s French and Asian competition, the Gorizia and Gradisca counties' silk production declined, favoring the cultivation and breeding of raw material to be weaved elsewhere (Vienna and Bohemia).

Nevertheless, these areas were essential for producing lightweight silk weaves – imposed by the Hapsburg's laws to not compete with the silk production in Vienna. Furthermore, these fabrics included fewer complex weaves, such as satin and taffetas, brocatelle, damasks, and *mezza seta*. Among these, the manufacturing of damasks is what made Gorizia's textile culture renowned around the Empire. In addition, these fabrics were employed in producing clothes, furniture, and sacred religious vestments (Martina and Sgubin, 2005).

Textile printing. There is no documentation about a specific textile printing culture in Gorizia – although it is proven that since

Image 5.24 - *Artisanal textile printing tools from the Friuli Venezia Giulia region, 1800s.*

Image 5.25 - *Traditional garment made of regional silk, preserved in Gorizia's Musei Provinciali.*

1780 four dyeing factories have been active and used to apply finishing treatments to silk fabrics. A technologically underdeveloped domestic printing activity was likely done using small wooden mold pleated with metallic, thoroughly designed symbols (**Image 5.24**) (Martina and Sgubin, 2005).

The region's weaving tradition was abandoned and recovered during the 1950s by promoting textile education that in 1964 gave birth to Tessitura Carnica, called Carnica Arte Tessile today. The factory is widely known for producing high-quality textiles for home decor. The factory was destroyed by fire in 2020, and only an old loom and some green yarns were recovered. The factory was rebuilt and is currently active ("Storia - Carnica arte tessile," n.d.). The production's raw materials are long-fibered linen from Europe, Egyptian makò cotton, and Merino wool.

Trims, lace, and embroidery tradition

The history of embroidery in the region is mainly tied to the activities of the Sant'Orsola nuns, a community established in Gorizia in 1672. The Sant'Orsola company had a significant focus on education; a catholic school was founded immediately after that. Even if the school had been profoundly transformed according to the new laws and change of domination after the Wars, the institution survived until 2013 when the nuns moved away from Gorizia (Pillon and Sgubin, 2021; Shoenholzer Nichols and Sgubin, 2011).

The design and production of laces and embroidery is a way for the Ursuline nuns to make a living. The most frequent techniques include bobbin lace and needle embroidery (**Image 5.26 & 5.27**). The savoir-faire of embroidering with this type of tool was imported from northern Europe in a particular time frame (1725 – 1775). Initially, one type of bobbin lace technique (*merletti a fuselli a fili continui*) was practiced by nuns in the Flanders and Wallonia areas. This technique was adopted in Gorizia but immediately put aside for its complexity and the lack of new designs. The other type of bobbin lace that has existed since the 1600s and was later adopted by the nuns in Gorizia was the *merletti a fuselli a nastrini continui*, which allowed a quicker production. This technique is still practiced today (Pillon and Sgubin, 2021).

The use of bobbin lace in liturgical clothing is widely documented. Some were handmade; some were mechanically manufactured – it is impossible to tell the difference. What is certain is that these laces were sewn to liturgical vestments to add a spark of light to the changing color of the robe. The nuns were responsible for designing and producing these robes, enriched with bright colors and unique precious embroideries. Their know-how is renowned for the high technical and aesthetic ability that led to the creation of breathtaking decorations. It has been said they paint with the needle. They used to design unique embroideries inspired by fashionable fabrics produced between the end of the 1600s and the beginning of the 1700s. The subjects of the decorations were imaginary flowers, leaves, and fruit. Sometimes, tridimensional effects were created with golden or silk thread to obtain a more plastic effect. The Ursuline nuns mastered the

Image 5.26 & 5.27 - *Bobbin lace made by Ursuline nuns in Gorizia. Samples.*

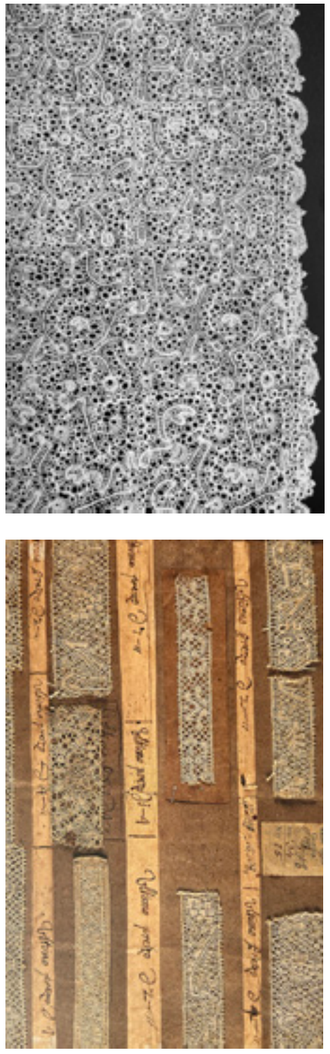


Image 5.28 & 5.29 - *Detail of a fabric embellished with the* fleck *technique.*

fleck embroidery technique (**Image 5.28 & 5.29**). It creates new patterns by combining different fabrics and colors, and textures. The fabrics used for the fleck technique are small pieces bought intentionally or repurposed from leftovers. The pieces of fabric were cut into hundreds of shapes, assembled, attached to the fabric, and embroidered with the needle as a finishing technique (Pillon and Sgubin, 2021).

Ribbons, trims, ropes. Together with silk fabric manufacturing, the area of Gorizia provided ribbons, trims, and ropes. During the 1700s, the dominant dress style demanded multiple ornaments on clothing. For instance, they used to be placed on corsets or on the pagoda sleeves by the elbow to highlight the widening of the shape up to the wrists. These ribbons were made with a taffeta or gros de Tours weaving technique. Decorated and embroidered trims were primarily used in menswear and military uniforms (Martina and Sgubin, 2005).

Regional cultural heritage in the collection of second-hand textiles

It is impossible to determine the exact origin of every piece of textile collected during the project's raw material sourcing process. The nature of what was collected depended on the socio-cultural background of the donor. However, they can be analyzed in the following way:

ID	NAME	AGE	M/F	PLACE OF DONATION	SOCIO-CULTURAL BACKGROUND	WHAT WAS DONATED
A	Ny.	29	F	Milan	International university student from Brazil who lives in Milan.	Clothes of various kind, mostly from fast-fashion brands and one Brazilian t-shirt.
B	Mk.	25	F	Pordenone	Grown up in Pordenone, now studying at Florence University.	Handbags, pillowcases, embroidered doilies.
C	G.	24	F	Pordenone	Grown up in Pordenone, now studying at university in the UK. The family is originally from Puglia.	Jeans, sweatshirts, leggings, bra, leather jacket, fabric cutouts.
D	A.	30	M	Pordenone	Originally from Trento, grown up in Pordenone.	Ties, handkerchiefs, printed scarves, pairs of jeans, shirts, tapestry swatch book.
E	N.	85	F	Pordenone	A retired seamstress who started her career in Lombardy and has continued to work in Pordenone after the 1980s.	Full-sized high-quality fabrics up to 6 meters in length. The donor was able to tell the site of manufacturing of some of them.
F	Mi.	80	F	Pordenone	Fabrics and laces collector.	Bed sheets, blankets, garments, bobbin lace, other kinds of lace, embroidered surfaces.
G	Ma.	80	F	Pordenone	A Belgian woman who currently lives in Pordenone.	Laces and textiles of high craftsmanship, mostly of French or Belgian manufacturing.
H	P.	55	F	Pordenone	A teacher donating clothes that belonged to her grandma.	Old clothes, laces, and trims which aren't well-preserved. Considering the style, they may be designed in the 1950s.
I	D.	50	M	Pordenone	A man working in a waste management facility.	Unsold deadstock garments with the original label still attached and second-hand clothes.

Table 5.1 - *List of fabric and second-hand clothing donors of the project.*

Discussion. Gender, location, and age are critical in determining the kind and number of textiles donated. So far, the raw material has been collected from nine donors. More proposals had been made, but the collection process had to be paused due to the high number of textiles that needed to be cataloged. Of nine donors, seven are women; two are men, four are under 30, three are beyond 80, and two are in their fifties.

In each case, the nature of what was given and the motivation people had to have stored these textiles up until then were different. Donors A, C, and I donated garments without connection to a regional cultural heritage of medium and low-quality raw materials and manufacturing. Donors B, D, F, G, and H donated similar materials despite being of different ages and socio-cultural backgrounds, including laces, embroidered surfaces, traditional clothing, and textiles for the house. Lastly, donor E gave actual fabrics and no garments or accessories.

Conclusion. The variety of people who contributed to the collection process for the project is insufficient to generalize. Although, it is a starting point for a reflection on how different socio-cultural backgrounds and our heritage can influence if and how we keep a collection of textiles in our homes. Thanks to the co-existence of multiple generations, people with a strong connection with their own heritage are more likely to have collected textiles from the past, honoring their ancestors. These textiles are precious witnesses of the habits and know-how of their relatives and close friends who would sew, embroider, or paint all sorts of fabrics to decorate their homes. From this point of view, each textile collection is unique. However, some patterns can be identified, such as the large amounts of bobbin lace recovered and the occasional presence of striped cotton canvas. The bobbin lace and the striped printed cotton are part of the region's textile cultural heritage. Interestingly, donors are of all ages, from young adults to the elderly.

Nevertheless, there is a different reason for donating according to age. People under 30 spontaneously reached out after the brand had published an open call on Instagram and Facebook. The donation was arranged via social media. On the other hand, older people were contacted via word-of-mouth among family and close friends. In the first case, the donation was made to do a good action for the planet (avoiding accumulating waste and supporting a slow-fashion business). In the second case, the reason for donating was mainly as a personal favor and curiosity towards the creativity of the upcycling process.

Learning an upcycling design process

During the past couple of years, many products were designed with different methods to understand better how to manage the wide variety of materials I had collected smartly and sustainably – to avoid creating more waste. One design process may create waste, so a methodology must be designed holistically considering all by-products. Having by-products may enable another design process, so by-products themselves must be carefully designed.

The bag archetype

Tote bag. Tote bags are among the most straightforward products to design and manufacture because their basic shape does not have any tridimensional volume – although more advanced versions can be designed. More than 80 tote bags were commissioned from a client who needed merchandise for a non-profit organization **(Image 5.30)**. Bed sheets were raw material for the bags, and the logo was embroidered by cutting the shapes out of fabric scraps and placing them in the center of the tote bag. The logo cutouts were assembled by sewing the hems with a decorative zig-zag stitch.

Image 5.30 - *Shopper bags created by Offbeat District for the Understanding Europe organization (next page).*

Shoulder bag/handbag. A pair of pants can be upcycled into one or more handbags – depending on the fabric available and the desired bag size. All sorts of handbags were created by deconstructing pants, such as from this vintage Moschino pants (**Image 5.31**) (size IT42), from which two bags can be made. If the top front part of the pants is used in the first bag, the second bag will necessarily be different. Using this part allows for having ready-made functional pockets (**Image 5.32 & 5.33**).

Image 5.31, 5.32, 5.33 - *Vintage Moschino pants disassembled and upcycled into a handbag.*

A pair of pants (size IT44) created three shoulder bags of the same kind. Each upcycling approach and each product need more than just one material to be fully functional and durable. In this case, the bags needed adhesive canvas for reinforcement and a lining of matching color – plus a button for the closure (**Image 5.34**). The adhesive inside the bag for reinforcing its components was a questionable choice. There is no information about whether that specific glue prevents the fabric from being recycled at the end of its life; therefore, using it may result in a non-circular product. From this thought, another technique for reinforcement was designed for future products.

Image 5.34 - *Handbag made of a pair of printed pants.*

Padded piping handbag. This product was designed with fabric cutouts in mind and the need to create a more structured product, enabling a more practical use (**Image 5.35**). Both the bag and the piping handles that encircle the bag are made of cutouts embedded in one or two fabric layers. The pattern pieces of the bag shell are made of 2 layers of fabric, between which some cutouts are quilted. The piping handle is also filled with cutouts but much dense to stretch the bag shell into a tridimensional shape.

Two key aspects must be considered to design the padding keeping circularity in mind. First, the nature of cutouts employed in the padding may reduce the recycling or upcycling potential of the bag at the end of its life. Mixing tiny pieces of fabric is not a good idea because their size does not allow for fiber-type separation when disassembling for recycling. The padding must consider fabric composition. Secondly, the final design needed to consider the possibility of disassembling the product in the future. Therefore, the quilting stitches – not structural but simply for distributing the cutouts evenly – must be as large as possible to enable a faster disassembling process.

Image 5.35 - *Handbag with fabrics cutouts as padding.*

Tops

When designing tops, many techniques and upcycling methods come into play. Generally, this process does not require a rigid structure such as the padded quilt of the handbag – which will be used again in coats and jackets later. Instead, this product category allows the designer to explore all possibilities that lightweight fabrics provide. Therefore, tablecloths, curtains, bed sheets, laces, and scarves are the most suitable raw material.

Tablecloth shirt. Specific raw material features, such as embellished hems, highly drove this design process. They are frequently found in tablecloths and include laces and embroideries – sometimes of many colors. This aspect was considered when designing the patterns and placing them so that the decoration would become the main focus of the final product (**Image 5.36**). Moreover, repurposing hems is a time-saving opportunity when manufacturing since the product will not require to be ironed and sewn at the bottom. The original tablecloth was slightly stained in some parts, so it was given away, although in perfect conservation conditions, requiring different coherent design solutions. The leftovers from the cut pattern included a few lace parts placed on the garment to cover the stains. Embedding parts of the leftovers into the garments is an excellent solution to mend or cover imperfections without worrying about finding a matching fabric. Moreover, when the randomness of the imperfections drives the placement of the leftovers, it results in unique designs that fit the brand's aesthetic identity. (foto camicia)

Image 5.36 - *Upcycled shirt.*

V-neck tank top. This design process was driven by the necessity of repurposing a trimming in a V-shape. Many collected embellishments have this shape and serve as neck decorations. An intelligent solution was needed for them to be upcycled. The choice of raw material was driven by the color of the cotton lace (a dark yellow), which matched a piece of deadstock knit cotton fabric. The tank top pattern was designed after the V-neck lace, and the margin was added for assembly. When using such embellished pieces, using deadstock fabric seems to be a good solution rather than patchworked or decorated pieces so that its simplicity highlights the trim (**Image 5.37**). This choice keeps the garment's aesthetic appearance consistent.

Image 5.37 - *Upcycled tank top.*

Bottoms

A-Line Skirt. This skirt was designed using a bed sheet with evident signs of use. About 8 cm wide brownish stains signed the fabric in a way that seemed like it was used as a cover or container and sealed with brown tape. The brown tape had ruined the white cotton permanently. This kind of stain suggested using linear pieces of lace or crochet trimmings – which were abundantly collected from the donors. Other textiles used to cover these signs were some yellow-brownish canvas stripes repurposed from the inside of pants belts and men's ties. They happened to be already cut in the perfect shape for this purpose – plus, the color variation of these pieces matched the laces and crochets. These trimmings were placed to cover the stains creating a unique asymmetrical decoration on the skirt. The fabric had other issues, such as some round stains covered with rounder crochet embellishments (**Image 5.38,** check **further photo documentation at pp. 203-211**).

Image 5.38 - *Upcycled skirt.*

Linen pants. Many people donated men's suits with matching pants and jackets for the summer and winter. When the garments were tailored-made, it was possible to understand the fiber composition because there were multiple labels – both from the tailor's shop and the fabric manufacturer. These garments were not being used because of being way oversized and tailor-made for a specific body type. The transformation of the tailored pants considered parts of the original garment to maintain some details of tailored quality when possible. For instance, the belt was adjusted to another size, but its components were kept – such as the inner white strip for finishing and the strengthening canvas, which was placed between these two layers. Front and back pockets were preserved, while the side was slightly adjusted in size. The crotch was cut according to the desired pants' pattern, while the bottom part of the pants needed to be widened. Therefore, the missing part was completed with a matching patchworked piece of fabric. These bottom inserts downplayed the pants from formalwear to a more casual everyday style (**Image 5.39**).

Image 5.39 - *Upcycled pants.*

Outwear

Summer coat. The deadstock fabric that was collected had not been used by its previous owner because of flaws in the weave or knit. Moreover, by being stored for many years – some fabrics were more than 40 years old – some pieces started showing stains caused by sunlight or holes made by moths. This issue was the starting point for designing a summer coat by repurposing a heavy cotton fabric. Apart from the visible flaws, the fabric structure was still perfect, and its functionality was preserved. Once again, imperfections were the starting point for upcycling the fabric. Stains and holes were covered by applying a cotton yarn with a zig-zag stitch with a functional decoration. These contrasted embroideries draw attention away from the imperfections, which are covered and moved to the background (**Image 5.40,** check **further photo documentation at pp. 203-211**).

Image 5.40 - *Upcycled coat.*

Quilted bomber jacket. This product replicates another bomber jacket that needed an invasive mending process because of very intense use and evident signs of wear. The outer fabric was stained, and the pockets were frayed. Moreover, because of the old age of the garment, much dirt had deposited inside the seams. Nevertheless, some trims were still in perfect condition – such as the zipper and the eyelets – and the pattern pieces were well preserved. These conditions suggested the design of a replica of that garment, which allowed the reuse of specific components that would necessarily be of the perfect size. There was no need to buy a zipper of a specific size or apply new eyelets. Repurposing these items avoided questionable actions, such as using the zipper for another garment which may result in the need to shorten it or not being long enough. The garment was redesigned with a cotton canvas for the outer layer, while the inner layer was quilted. The padding design was inspired by the quilt made for the padded handbag but with different kinds of cutouts. Considering the jacket was meant to be a mid-season garment, there needed to be a certain degree of warmth created by the padding in the quilted lining. The surface was designed with synthetic cutouts instead of cotton ones to achieve warmer padding – especially with fabrics capable of generating an air volume, such as actual padding, fleece, jersey, and fluffy fabric (**Image 5.41,** check **further photo documentation at pp. 203-211**). If the designer needs to make a winter garment, a synthetic or woolen outer layer can be used instead of cotton canvas – for better insulation.

Image 5.41 - *Upcycled bomber jacket.*

Fabric leftovers and cutouts

This product category was born inevitably because of the prototyping and fitting processes' by-products. Understanding how to repurpose smaller pieces was challenging, but it helped reach zero-waste production **(Image 5.42, 5.43, 5.44)**.

Part of the cutouts was repurposed to create functional decoration with figures embroidered on top of the pattern pieces. When sewing a piece of fabric on top of another, a few things must be kept in mind:

Using a stretchy fabric on top of a non-stretchy one might result in unwanted deformation of the original shape of the cutout. Contrarily, sewing a non-stretchy fabric on top of a stretchy one will make it stiff, compromising the stretch of the garment. Both these issues can be created on purpose. In the first case, the cutout can be stretched or bent to create a different shape (but if pulled too much, it can pull the non-stretchy fabric with a shirring effect). In the second case, the non-stretchy fabric can be used to reduce the stretch of a knit, for instance. When decorating with cutouts and scraps of fabric, we need to remember that we are combining different materials and might compromise their end-of-life potential. This also applies to the sewing thread, which should be made of the same fiber as the fabric to optimize recycling – or be easily disassembled from the product. To ease washing and ironing, we should combine materials with similar care instructions (washing and ironing temperatures and chemicals allowed) – for instance, not having to wash nylon and wool or iron cotton and polyester together.

Image 5.42 - *Upcycling cutouts.*

Similarly, to stretchy fabrics, sewing on the bias of a piece of fabric on top of another will deform the pattern piece, compromising the fitting of the final product. This issue can be corrected by ironing the piece once the decoration is complete. However, in some cases, the deformation will cause unwanted volumes to be too big to be corrected through ironing. It can only be used in the second case if the extra volumes are hidden in the decoration.

Fabric weight and type are crucial in this process. Embroidering scraps of one fabric on top of another will increase the pattern's weight and stiffness in certain areas. This can be a downside, especially when working with lightweight fabrics because the difference in weight will be immediately visible. On the contrary, reinforcing certain parts of a garment or accessory can become an advantage – such as bag bottoms and more structured garment pieces.

Image 5.43 - *A second-hand nightgown decorated with fabric cutouts.*

Image 5.44 - *A second-hand nightgown decorated with fabric cutouts.*

Repurposing yarn

Knitting yarn of many types was collected in large amounts. Upcycling this material with a knitting technology is outside of the scope of this research. Although, it was employed in the upcycling process of second-hand garments by applying the yarn with a zig-zag stitch creating a decoration (**Image 5.45 & 5.46**).

The decoration was realized for two different reasons. The first reason is to restyle a garment after the owner had become tired of wearing it. This can postpone the end-of-life of the garment. The second reason the decoration was applied was to cover stains that were preventing the pants from being used by the owner.

Image 5.45 & 5.46 - *Second-hand garments decorated with cotton yarn.*

Digital technologies involved in the upcycling value chain by Offbeat District

This case study proved the accuracy of the hypothesis that upcycling designers can benefit from digital technologies in multiple steps. First, digital technologies enabled and powered the design processes described in the previous paragraphs. The designer has used various tools to acquire higher precision and creative experimentation while digitizing patterns and fabrics.

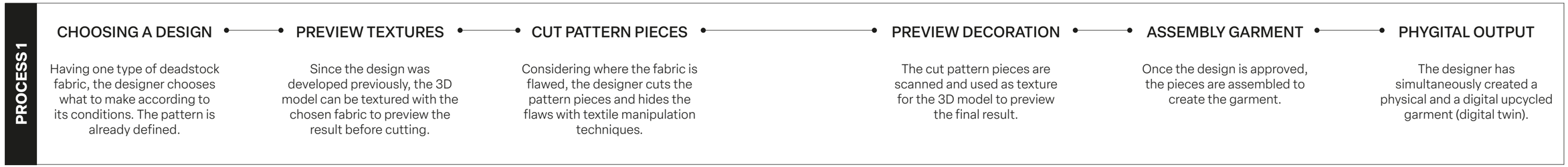
The digitized material is a multi-purpose tool. Apart from designing, the front end of the value chain can benefit from textured 3D models and digital content. Furthermore, the brand's online presence through social media and a website can use 3D models and digital content to create augmented product presentations and shopping experiences for the customers. Lastly, digitizing products' information in digital IDs accessible through NFC labels on physical garments improves the chances of an end-of-life management fit for circularity. Digital IDs are of specific interest for upcycled products since it is required for brands to communicate the high value derived from slow-fashion manufacturing embedded in each product to the customer.

Digital technologies involved in the collection and sorting of raw materials

The textile collection phase lies at the beginning of the upcycling design process. Most upcycling brands do not disclose the origin of the raw material they use, usually thrifted from second-hand stores and street markets. Some upcycling brands use dead-stock materials, which is not enough to create a circular upcycling system by itself due to fabric manufacturers' production of deadstock on purpose. Using an online raw materials database with data about the time and place of collection and fabric type allows for smart management of resource inventory and the possibility of disclosing sustainability data to the public, improving transparency. In this phase, social media are crucial for contacting donors and supporters who can contribute by giving their old clothes or household textiles.

Digital technologies involved in the brand's upcycling process

The case study provided valuable data confirming how digital technologies affect the upcycling design process, as found in the literature in chapter three. The design process can be called phygital because of going back and forth between the physical and digital worlds. It is not possible to define one general phygital upcycling process. There are crucial differences in each product's development because of using different methods, raw materials, and different goals. However, all processes have in common the digitization of patterns through avatar-based CAD software such as CLO3D, digital sampling and fitting, and image textures for previewing fabric combinations before cutting the real one.



Map 5.3 - *Phygital upcycling design process 1*

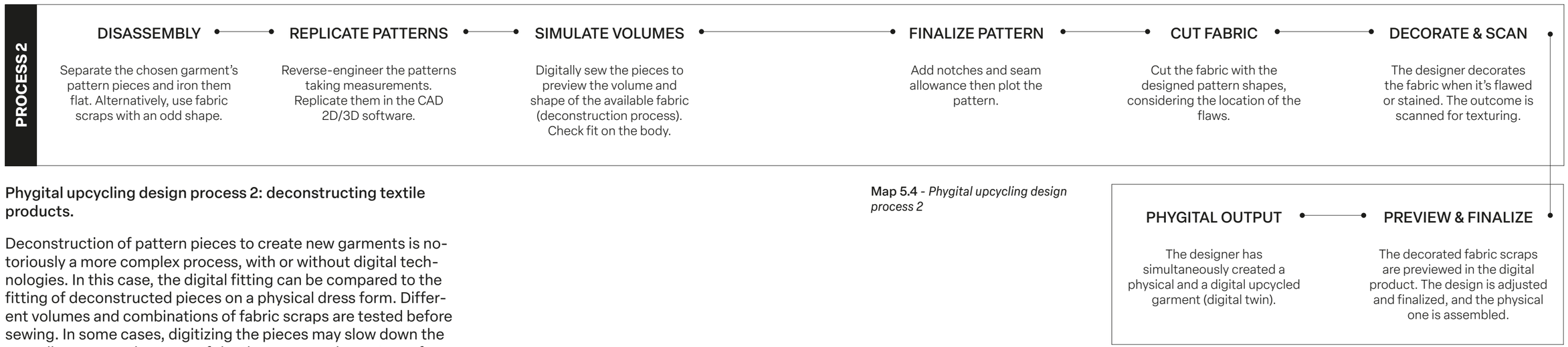
Phygital upcycling design process 1: using deadstock fabrics.

Using deadstock fabrics does not branch off the standard fashion design process because it can follow similar steps when patternmaking and assembling due to the availability of full-sized fabric pieces (**Image 5.47**). Nevertheless, it limits the design in terms of colors and fabric type. Furthermore, digitized patterns can help achieve the pattern shapes more quickly, avoiding patternmaking on paper and the need to trace and adjust the pieces to improve the fitting. Moreover, the software allows us to check for inaccuracy in measurements which would result in textile waste for prototyping the wrong piece.

The process starts with a fully digital pattern which is digitally sewn together and fitted to an avatar with the desired measurements. The software allows one to render specific fabric properties – such as weight, stretch, and stiffness – and understand how the garment fits and feels through stress/strain maps. The product does not exit the virtual space until the best results are achieved. The final pattern is then plotted or printed, and the pieces are cut. The physical result is correctly achieved in a short time.

To create a digital twin – which resembles the physical garment in all its features – the digital garment can be resumed after assembling the physical one, and trims and details can be added—for instance, specific material textures, topstitching, lining, labels, buttons, and custom zippers.

Image 5.47 - *Deadstock denim with flawed weave.*



Map 5.4 - *Phygital upcycling design process 2*

Phygital upcycling design process 2: deconstructing textile products.

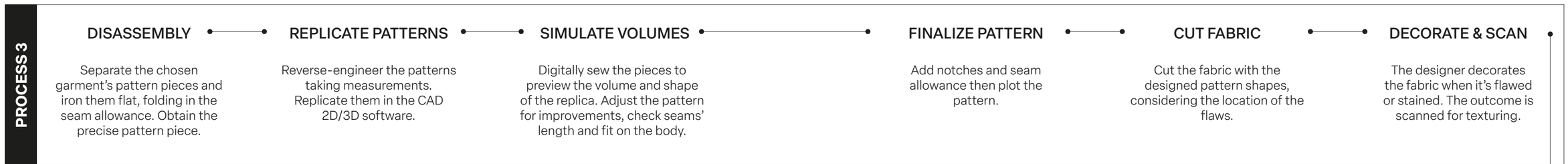
Deconstruction of pattern pieces to create new garments is notoriously a more complex process, with or without digital technologies. In this case, the digital fitting can be compared to the fitting of deconstructed pieces on a physical dress form. Different volumes and combinations of fabric scraps are tested before sewing. In some cases, digitizing the pieces may slow down the upcycling process because of the time-consuming nature of replicating scraps and pattern pieces with the exact measurements as the real ones. On the other hand, digitization of the deconstruction process can help the designer achieve more accurate fits by testing different cutting and sewing options before doing it on the physical textile scrap and creating a digital twin.

For instance, if a tablecloth is used to create a shirt, the designer may need to cut a hole in it as a neckline. If the hole ends up being in the wrong place, or the shape is wrong for the desired fit, repurposing that tablecloth will be incredibly hard for having that cut as a new constraint. This downside can be avoided thanks to digital technologies. The available fabric can be replicated digitally with CAD software, then cut digitally to achieve the desired fit. In this case, the designer can understand the exact place and entity of the cuts necessary to create the garment.

To digitize pieces of fabric not cut in simple shapes – such as rectangles, squares, circles, and ovals – the designer needs to reverse-engineer the patternmaking process to obtain precise measurements to replicate on the CAD software. The garment they decide to deconstruct must be carefully disassembled, avoiding ripping it accidentally or deforming its shape by pulling or ironing. Once the pieces are split apart, they need to be ironed flat. Since the pattern pieces include the seam allowance, better results are achieved by ironing it towards the inside of the piece so that the original shape emerges. This workflow allows for more precise digitization and easier pattern editing on the software. The pieces are then placed on paper, and orthogonal lines are drawn around them to frame them in a rectangle. Lastly, measurements must be taken between the pattern and the previously drawn rectangle at the meeting points. The references from this process allow for an accurate replica of the pattern pieces on the CAD software.

Next, the digitized pieces can be placed, cut, and sewn around the avatar to test the best deconstruction option. Once the desired fit is reached, the designer can replicate the process for the physical garment. The advantage of having a digitized version of the deconstruction process is that the designer can quickly go back to it and understand how the pieces have been combined – which is not always understandable once the garment is assembled. This tool provides crucial learning opportunities for the designer and, eventually, the public to consult what has been done.

The digital twin can be easily created, used for the digital ID, and shared online.



Map 5.5 - *Phygital upcycling design process 3*

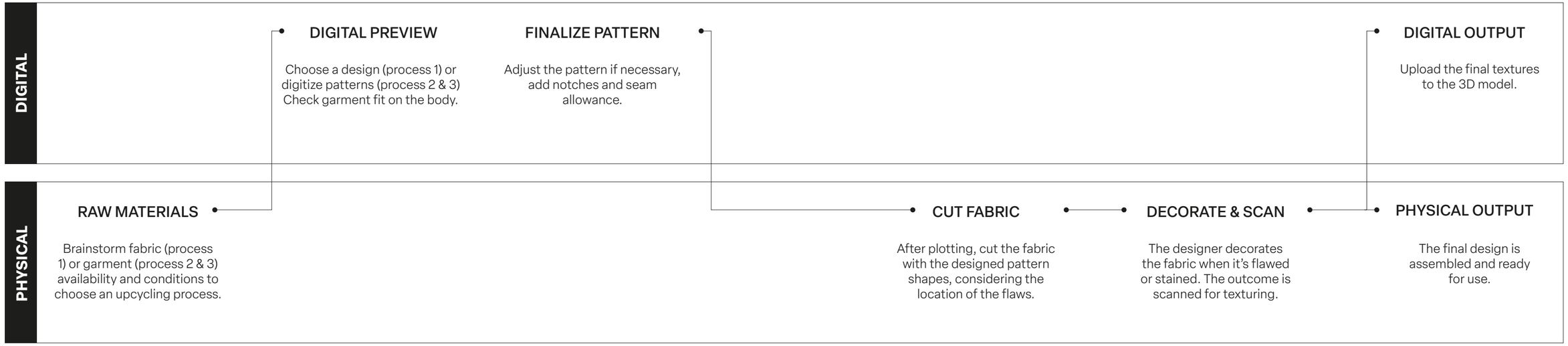
Phygital upcycling design process 3: creating garment replicas.

Replicas are a crucial part of the upcycling process because they embody one of the most critical aspects of this practice – the re-interpretation of the old in the new. Garment replicas are vital for circularity because they allow one to obtain a digitized version of a garment, improving the opportunity to mend it in the future by substituting pattern pieces if necessary. An augmented garment enriched with meta-data is born from an unwanted second-hand garment. The designer can create a renovated and improved version of a garment by following this process: disassembling a garment after use helps understand its flaws and virtues, enabling the design of a more durable product.

This process starts in the physical world when the garment is disassembled; its components are ironed and reverse-engineered as described in the Phygital upcycling process 2. Next, the basic shapes are inscribed in a rectangle with measurements and references to be replicated with the CAD software. In this case, the pattern is not deconstructed but is replicated to achieve the original fit of the garment. The necessary improvements to the pattern are made in this part of the process. Plotting the pattern and cutting the shapes with high-quality fabric is the next step for creating the replica. During assembly, the designer may consider upcycling components or fabric from the original garment.

Generalization: a phygital upcycling design process

Map 5.6 - *General phygital upcycling design process*



The three processes can be generally described by visualizing when the process is physical, when it is digital, and when it is a combination of both. As proof of the material-driven nature of the upcycling practice, the first milestone is the availability of fabrics and second-hand garments for upcycling. The nature of the raw material then drives the choice of one process among the three (using deadstock when the fabric is not yet cut, deconstructing when using garments in good condition, and replicating garments when they are in no condition to be repurposed). All three cases rely on digitally previewing the result twice. First, the designer previews the color and fabric combinations outcome to understand whether the raw material suits that product. Second, the designer previews any embellishment and decoration on the 3D model. Between these two steps, the pattern is plotted, and the fabric is cut. Next, the cut and decorated pattern pieces are scanned for digitization, creating the digital twin. Simultaneously, the physical garment is assembled. Finally, phygital products are available for distribution and use.

Digital technologies involved in retail, archives, and the products' end-of-life

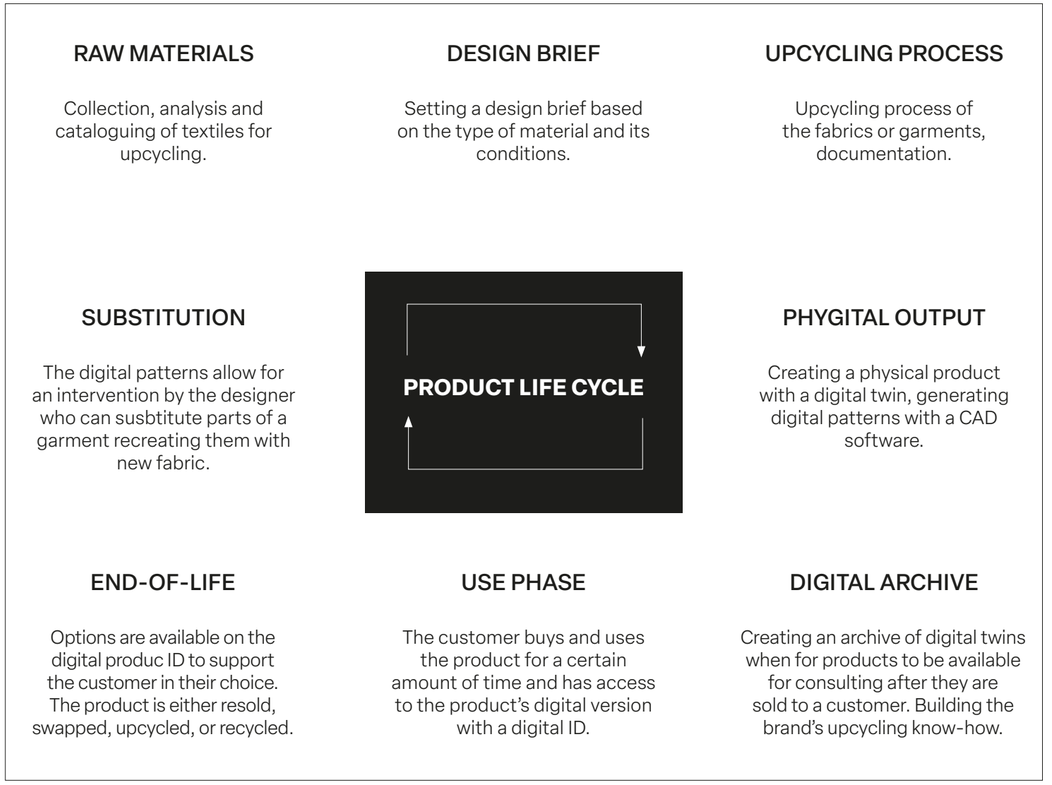
All three design processes are aimed at creating digital twins for multiple purposes. The textured 3D models are not just tools for the designer to achieve higher creative freedom and streamline the prototyping process but also enablers of a revolutionary approach when showing products to customers is the use of AR technology on social media and dedicated mobile apps. There are two main ways for brands to show their products with AR. One way is using the world object template, with which the 3D model is virtually placed on the user's surroundings using the front camera. Another method that is widely used by digital fashion designers and digital creatives worldwide is using the body tracking template. The second method allows rendering a garment or an outfit on the person's body following their movements. While the second type is perfectly suitable for trying on garments virtually, accessories are better previewed with the first type.

3D models should differ according to their purpose. For example, creating AR filters with the 3D garments and accessories designed with CLO3D requires reducing the polygon count and the texture size to have a smaller file size. On the other hand, to render images and animations containing 3D models for social media, it is better to have a highly detailed 3D model and texture.

Another focus for the brand involving textured 3D models was the creation of a digital archive of upcycled products. The digitized patterns and textures are crucial tools for building a brand-know-how database for future consultation. The great variety of raw materials and the simultaneous use of different design processes and methods makes every product very time-consuming in terms of labor. Once an upcycled product is sold, there cannot be another of the same kind and appearance. Therefore it would be hard to recreate a similar design with a similar process. Digitizing upcycled products with a detailed digital ID allows the designer to improve the design process in the future by building upon the internal know-how of the brand and being inspired by previous solutions that may apply to other contexts.

Map 5.7 - *Circularity of upcycled products.*

The digital ID is a multifaceted tool that allows one to know how to take care of a product and manage its end-of-life phase. The user needs to have the chance to preserve it as long as possible in good condition. It is helpful for a designer who wants to upcycle it, as well as for a hypothetical recycling facility. The brand designed access to a digital ID through NFC labels, which are waterproof and long-lasting. The labels are embedded in a removable patch in case they need substituting.



Discussion: case study of an upcycling methodology

The Offbeat District case study provided a practical insight into the application of different upcycling methods and the definition of priorities to achieve a circular design methodology using textile waste. Moreover, it helped explain how digital technologies affected the definition of the design process and the overall value chain, including the brand's user experience.

The emerged methodology is suitable for upcycling garments, accessories, houseware textiles, trimmings, embellishments, and deadstock fabrics of all types. The product outcomes include tote bags, shopper bags, handbags, shoulder bags, tops, bottoms, coats, and jackets. In addition, it allows the repurposing of full-sized fabrics and smaller pieces, cutouts, yarns, and threads into new raw material.

Hierarchy of solutions for smart upcycling

The project aimed to provide more durable products with traceable labels and a complete product ID for end-of-life management. Consequently, the upcycling process was characterized by a hierarchy of solutions prioritization for each type of raw material. The following statements are the starting point to define the best hierarchy of solutions for upcycling:

Low-quality materials are available in larger amounts than high-quality garments and deadstock fabrics.

An upcycled garment should be fit for circularity (more durable, easily disassembled, and recyclable.)

Durability is achieved by using high-quality fabrics for structural parts.

The smaller a piece of fabric, the harder it is to upcycle it and to repurpose it after a hypothetical garment disassembly at the end of life.

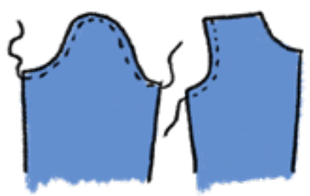
Not all necessary materials can be sourced from textile waste.

Upcycling inevitably creates leftovers and cutouts: a zero-waste patternmaking method is not always possible, especially with irregular fabric scraps.

Based on these facts, new design dogmas for smart upcycling can be listed:

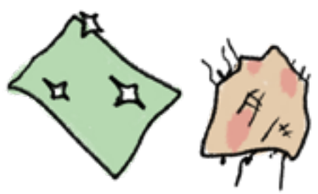
1.

Find a way to repurpose both low- and high-quality raw material in a way that doesn't undermine the durability of the final products.



2.

Design upcycled products for an easy disassembly and consider fiber composition when sewing different fabrics, to allow recycling at the end-of-life. Provide a detailed label.



3.

Assign different purposes to the raw materials according to their condition. High-quality fabrics should be used for structural parts, such as the base pattern shape, while lower quality fabrics can be repurposed as aesthetic or functional decoration.

4.

When using scraps of fabric, don't cut them into smaller ones unless it's essential for a specific design.

5.

Avoid designing products that require to buy a lot of new items to be assembled, such as new zippers, buttons, linings, or buckles. If possible, upcycle them from other garments. If a raw material is not available, try to create it from textile waste.

6.

When upcycling there can be a certain degree of improvisation when placing or cutting pattern pieces, according to the fabric that is being used. If there are leftovers, they can be repurposed in the same product or in associated products (for instance, in the same outfit).

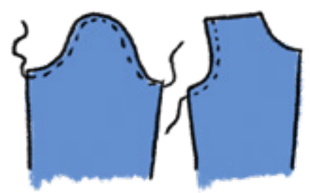
1.

Find a way to repurpose both low- and high-quality raw materials in a way that doesn't undermine the durability of the final products.

Discussion. (1) Addressing textile waste requires thinking about the problem holistically and understanding how the domination of the fast-fashion business model has flooded our planet with low-quality garments. International trade routes of second-hand clothes and those who buy them are negatively impacted by the high volumes of fast fashion that people give away globally. These products are made of cheap fabrics that are not durable enough to be upcycled as they are. For instance, a pair of leggings manufactured for fast-fashion companies show signs of wear after a few weeks of use and easily rips off after a few months. This issue does not mean that designers should ignore fast-fashion products when upcycling – instead, they should find alternative repurposing solutions. One option can be cutting the fabric into shreds and using it as padding for quilted surfaces (which can be used for bags or coats), padded bag handles, and padded shoulders. Of all cheap materials, synthetic leather has proven to be the hardest to upcycle. First, it cannot be used as a structural piece because it tends to peel. Second, the combination of fabrics, glues, and finishing treatments in this fabric may change over time and become unsuitable to wear (for instance, it can become sticky).

2.

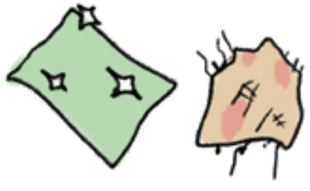
Design upcycled products for an easy disassembly and consider fiber composition when sewing different fabrics, to allow recycling at the end-of-life. Provide a detailed label.



(2) Easing the disassembly and controlling the fiber composition of the upcycled product are essential aspects of circularity. As seen in this case study, when collecting second-hand and deadstock raw material, it is possible to catalog it according to the type. Unfortunately, the designer is never entirely sure of the composition – when a label is unavailable. It is possible to make a test by burning part of the fabric, which will smell differently according to its composition. This technique is primarily helpful to distinguish larger pieces of natural and synthetic fibers or yarns – while burning small embroideries or laces is undoubtedly not an option. There is the chance that a designer assigns the wrong composition to a label, preventing a correct sorting-recycling process at the end of life. Considering the aleatory nature of the composition labeling process, the brand should first prioritize distinguishing natural and synthetic fibers since the latter are biodegradable. Combining them will be less of an issue when landfilling. Due to their non-degradable nature, synthetic fibers should be labeled carefully. Although they are often found in fabric blends, therefore cannot be recycled. Consequently, fabric blends with synthetics can be combined in the same product – there was never a recycling opportunity, to begin with.

3.

Assign different purposes to the raw materials according to their condition. High-quality fabrics should be used for structural parts, such as the base pattern shape, while lower quality fabrics can be repurposed as aesthetic or functional decoration.



(3) Considering the variety of raw materials collected, the designer should prioritize using the best fabrics for structural parts, such as deadstock full-length pieces, larger scraps, and deconstructed high-quality garments. Grading fabrics from the best to the least quality type, assigning different purposes to each is possible. As before, cheap materials such as jerseys from fast-fashion products should ideally be repurposed for a non-structural part.

4.

When using scraps of fabric, don't cut them into smaller ones unless it's essential for a specific design.

(4) To create the basic pattern shapes, using a single piece rather than a patchworked piece of fabric is better because its durability can be easily compromised. The smaller the pieces, the higher the chance for them to unstitch and the slower the garment disassembly process. Moreover, having more cuts will result in a larger area for the fabric to fray. Therefore the remaining fabric for the following upcycling process will be much less than the original amount.

5.

Avoid designing products that require to buy a lot of new items to be assembled, such as new zippers, buttons, linings, or buckles. If possible, upcycle them from other garments. If a raw material is not available, try to create it from textile waste.

(5) To achieve certain production standards, each design needs specific trims to be finished, which an upcycling designer does not easily source. For instance, a bag or a coat typically needs a matching lining to hide the internal seams. Moreover, bags need buckles and buttons or zippers for the latch in a precise size. Designing products that require a lot of virgin raw materials to be assembled is not exactly a best practice for circularity. For this reason, the upcycling design process must cross all functions and features and favor a design whose components can be sourced from what is already available.

6.

When upcycling there can be a certain degree of improvisation when placing or cutting pattern pieces, according to the fabric that is being used. If there are leftovers, they can be repurposed in the same product or in associated products (for instance, in the same outfit).

(6) When cutting the fabric to create a garment or a bag, part of the pattern can be adapted to the available fabric. Dynamic pattern cutting is a best practice for upcycling since it can substantially reduce the waste generated. The concept is easily explained with tote bags, whose shape can vary in height and width without compromising the final product's functionality. When producing large amounts of shopper bags with a bed sheet, the designer can subdivide the fabric into equal parts according to its size instead of having a strict pattern shape which may result in leftovers. In conclusion, tote bags are efficiently designed as a zero-waste pattern. When applying this concept to garments, there are far more complications since a slight change in the pattern measurements will result in unpleasant fit or wrong sizing. However, some garments can be designed to be more dynamic regarding the overall length of the sleeves and the front and back parts. This flexibility can easily be supported by using the 3D CAD software to preview the final result.

Conclusions and future perspectives

The dissemination of industrial processes for manufacturing fashion products has created a globalized system that includes agricultural, petrochemical, manufacturing, and assembly processes. Moreover, the impact of logistics and retail needs to be tackled, and the impact of the use phase needs to be deeply investigated. The production of virgin raw materials is responsible for carbon emissions, water, and energy consumption, as well as being harmful to people worldwide. Current trends in the literature have highlighted how the circular economy is considered the best way to innovate the industry for a more sustainable future. Therefore, there is a need for alternative models for fashion capable of limiting production and consumption growth. Transiting to a circular economy is a complex task because it needs to consider all steps of fashion's value chain, from the extraction or cultivation of resources to the retail, use, and disposal of a product. In this context, material selection is crucial because it is the main reason a product can or cannot be recycled at the end of life. Ahead of the use phase, by-products of fashion design and production are a core issue, for which solutions such as zero-waste pattern cutting have been proposed. Trims, accessories, and packaging are a core issue preventing the achievement of a circular model because not enough research is being carried out on the topic. 70-80% of the waste is generated during the product design. Therefore, improving this aspect is critical, although impossible in large-sized brands because the designers do not have enough responsibility and have strict design guidelines. This situation suggests that a fundamental change is more likely to happen in smaller-scale brands where the designer's role is more crucial than in large brands. The fashion system is profoundly transforming towards the digital world, where many opportunities for sustainable development and circularity exist. Upcycling is considered among the best practices for circularity, and it creates high-quality and high-value products from textile waste. Born from the slow fashion movement and tied to traditional crafts and know-how, upcycling has become one of the leading fashion trends of today. The main innovation brought by upcycling is that the materials, and not vice-versa, drive the design. As for standard fashion design, it can benefit from digital transformation in multiple ways. 3D technologies enable a dynamic upcycling design process, while real-time technologies allow the visualization of multiple product variations through AR and VR. A digital label or product ID is crucial for upcycled products to be transparent regarding raw material origins and composition, enabling end-of-life options such as recycling or further upcycling. If digital transformation brings apparent benefits to traditional fashion design, upcycling can enable small businesses and slow-fashion brands to stand out.

Upcycling as a practice exists outside of business logic and is an exciting field of research from a designer's perspective. This practice is characterized by the deconstruction philosophy that transforms the structures of society, intending to disrupt traditional interpretations. It questions why and how things are structured, showing new possibilities of meaning and new points of view. The design case of Martin Margiela was an exemplar to understand this concept since he and his team could expose the secret language of fashion, questioning its mechanisms of fascination.

One of the main issues preventing upcycling from thriving in the fashion system is its labor-intensive nature, which becomes a barrier when upcycling designers must price and sell their products. This barrier was created by the division between the production and consumption of fashion products, creating a society where people must be aware of how long and complex the fashion manufacturing process can be. The current fashion system - both brands and customers - undervalues manufacturing in favor of design. The upcycling practice - as thought by Martin Margiela - brings production and consumption back together by being material- and design-driven instead of trend-led. The focus goes entirely back to the design process and the designer's creativity by showing where materials come from, how they are sourced, how they are reinterpreted, and how products come to life, maybe saying how many hours it took to assemble that garment, exposing human labor as fashion's primary source of value.

The upcycling design process is unique for each designer and each brand, sometimes even for each garment. It is based on a combination of techniques with varying degrees of complexity. The easiest one is using deadstock, which does not require deconstructing a garment or repurposing an already-cut piece of fabric. Although considered an upcycling method, deadstock is not always a sustainable solution since the raw material can be manufactured on purpose by weaving factories if the demand rises. Therefore, how deadstock is sourced is crucial to understand whether it can be an excellent solution to kickstart an upcycling process.

Moreover, using deadstock does not require questioning design, patternmaking, pattern cutting, and material selection - fundamental steps to repurpose textile waste successfully. If upcycling is an intelligent methodology for repurposing textile waste, it needs to deconstruct traditional fashion processes and methods since the textiles harming our ecosystems are clothes and accessories rather than deadstock fabrics. Actual upcycling methods include subtraction, deconstruction, addition, and refunction - and the creative combination of these.

Three upcycling brands were analyzed: Freitag, Studio Mend, and MutaWear. These design-driven businesses have adopted the upcycling philosophy developing different methodologies and generating different types of business models. Freitag is proof that upcycling can be scaled up for mass production. This choice can be questioned since upscaling can quickly end up pushing overproduction. The brand has successfully communicated the high value of its products, keeping a higher price point and choosing a timeless design. Studio Mend is a luxury-upcycling design studio based on the visible mending technique applied to thrifted minimalistic designer clothes. In this case, there is an emphasis on slow fashion and timelessness as the brand's core values. MutaWear, on the other hand, focuses on a service-based model involving upcycling as a customization technique carried out with the customer. Contrarily to Freitag's digital customization tool (where customers can place pattern pieces freely on a tarp and customize their bags, resulting in an ugly

amount of wasted material), the slow-fashion model of this latter case study highlights how small-scale customization involving upcycling is much more functional and can quickly achieve a zero-waste production. Moreover, the 1:1 relationship between the customer and the designer creates a unique bond between them and the textiles, creating an emotional attachment to the upcycled product.

The real innovation of upcycling businesses is the possibility of relocating the value chain or building one from scratch in a territory leveraging the local community as the stakeholder and enabler of the project. Upcycling methods were only briefly described in the literature; in fact, they were deeply studied through practical research in the case study of Offbeat District. Through upcycling, the designer assigns new meaning to a product with a transformative process characterized by deconstruction and reinterpretation. For the most part, no further virgin resources are needed – with a few exceptions, such as trims that cannot be sourced from second-hand material.The users' involvement is crucial for the brand to create a network through which it can thrive, finding models, collaborators, customers, co-creators, and donors. The project is highly driven by the contribution of the local community, which enables the collection of raw materials and provides general support. All value chain steps are found in a specific area, localizing one hundred percent of production in Pordenone. On the other hand, customers come from a broader area in northern Italy.

The raw materials found in the area include deadstock fabric, second-hand garments, second-hand accessories, houseware textiles, underwear trimmings, lace, embellishments, crochets, zippers, and buttons. The materials were cataloged digitally on a spreadsheet keeping track of the inventory, time and place of recovery, fabric type, fabric size, weight, and the presence of flaws. Among the collected textiles, many represented the local textile heritage which was investigated to understand its value better. Once the raw material was stored, the upcycling methodology slowly built, and the internal know-how of the brand started to take shape. Different workflows were identified

according to the material and the goal at hand. Different types of products have been designed, allowing the definition of three possible design processes. First, the bag was an archetype to repurpose and recreate different structures, such as linings, rigid surfaces, and handles. Afterward, tops, bottoms, and outwear were designed transferring solutions and concepts.

The influence of digital technologies was crucial for the project outcome and the definition of design processes. The findings of this research suggest that the upcycling design process can benefit from digital transformation as much as the standard design process. It can help build a local value chain and foster slow-fashion practices. On the one hand, it connects people with local textiles. On the other hand, it provides tools for rapid prototyping helping small studios or individual designers to design and produce garments and accessories in reasonable time frames. This finding suggests creating a dynamic upcycling process relying on real-time technologies for rendering digital products and visualizing multiple variations of that item. Implementing an NFC-powered digital ID for the upcycled product is the ultimate connection between the physical and digital worlds, fostering transparency and traceability of raw materials and manufacturing and empowering the consumers with end-of-life options to achieve a circular value chain.

Is upcycling good for improving the circularity of the fashion system today? Generally, it is. Although, this depends on many factors that may cause a brand or a supplier to do more harm than good. Testing what was analyzed in the case studies, this research confirms that upcycling can successfully foster circularity by adopting strategies of intermediate-to-high impact from the 9Rs' principles framework. These strategies include refurbishing (R5), repairing (R4), and reusing (R3). On the other hand, upcycling without an intelligent and local supply chain may generate high carbon emissions through logistics for raw material shipping.

Moreover, it was discovered that textile manufacturers have been producing deadstock on purpose, knowing that there was

rising demand from upcycling brands. Large-scale upcycling can quickly become a controversial business from a sustainability perspective since it is impossible to know whether the brand is overproducing instead of being driven by the actual availability of the raw material. Moreover, there is not enough data to understand whether large-scale upcycling's value chain is more impactful than a standard one (similarly to how fiber-to-fiber recycling can be more energy-intensive than sourcing new fabrics). On the other hand, small-scale upcycling is an entirely different phenomenon, tied to the designer's specific methodology that generates unique solutions. This type of upcycling practice is the one that can suggest the most significant amount of options with different raw materials and different interpretations. In this case, products are more artisanal and less perfect because they represent an attempt ad questioning standard structures rather than providing a highly engineered scalable product. This activity provides a fertile place where designers can connect to customers through textile culture and creativity. Moreover, it allows people to rebuild the material know-how lost during the past century's shift to a throw-away society, empowering people with the tools to take care of products and understand their embedded material culture. If fashion is profoundly transforming its processes towards the digital landscape to analyze and address the impact of its value chain, upcycling designers and brands, need to adopt similar solutions.

If upcycling is a circular practice, it can and will improve its impact by adopting digital solutions. Many of the difficulties that small businesses and individual practitioners find in thriving within the fashion landscape can be overcome by digitizing products and enhancing their value through digital IDs. They allow us to control the product life cycle and share precious knowledge to improve end-of-life management. Accessing this data is vital for upcycled products since the value embedded in them – generated by unique interpretations and ad hoc design solutions during the manufacturing process – often goes unnoticed.

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AENRMOUS: https://www.aenrmous.co/shop

POLYHEDRON Denim Wrap: https://apoc-store.com/products/denim-wrap

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ANNEX | BEHIND THE SCENES PHOTO DOCUMENTATION

Phygital upcycling design process 1: using deadstock fabrics

(1) Flawed deadstock fabric.

(2) The flaws were covered by embroidery with cotton yarn.

(3) The decorated patterns were scanned to create a digital texture.

(4) The digital twin was created.

Phygital upcycling design process 2: deconstructing textile products

(1) A bunch of ties was disassembled and the inside layer was removed.

(2) The inner part consised of a heavy fluffy canvas of many shades of yellow and grey.

(3) This canvas was used to cover stains on a piece of fabric and create decorations for a skirt.

(4) Before sewing, the skirt was scanned to create digital textures.

(5) The digital twin was created.

Phygital upcycling design process 3: creating garment replicas.

(1) Original garment and pattern deconstruction.

(2) Creation of the padded lining with fabric cutouts, quilted between two layers of fabric.

(3) Final result of the quilted lining - inside and outside.

(4) Inserting the NFC tag in the removable label placed on the back of the garment.

(5) Creating the digital twin, matching the real garment.

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