

Research

Shaping sustainable solutions in fashion through design-led strategies, approaches, and practices

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Abstract

Today, growing concerns about the Earth's finite resources and escalating climate challenges have sparked a reassessment of industrial processes. This has led to a call for a more responsible and transparent approach across various sectors. The global conversation prominently revolves around sustainable development to foster diversity within a comprehensive framework to effectively address UNESCO's four pillars of sustainability: Environment, economy, society, and culture. The fashion industry, a highly significant and influential sector, has proven to be invasive due to resource-intensive processes that impact both the environment and the economy. Additionally, the industry's rich cultural content plays a substantial role in shaping social and cultural shifts. In this context, this article focuses on design as a catalyst for reform within the fashion industry's supply and value chain, steering it towards sustainability. The focus is on exploring emerging responsible practices aligned with evolving priorities, aspirations, and lifestyles to foster a systemic approach to sustainability in fashion. The discussion highlights design-led perspectives that support a sustainable transition, underscoring the necessity for a transformative mindset among designers. This involves adopting innovative strategies to promote responsible approaches and practices for contributing to a more sustainable future.

Keywords Fashion design for sustainability · Design-driven Innovation · Designers' role · Fashion industry transformation · Fostering sustainable transformation

1 Introduction

The decline in apparel prices, faster trend cycles, and the prevalence of low-quality items and planned obsolescence have resulted in a surge in global clothing consumption. This surge, however, contributes significantly to the environmental problem of apparel overconsumption and resulting waste, as a substantial portion of clothing and textile waste ends up in landfills instead of being recycled or repurposed [1, 2]. In 2000, global clothing sales amounted to US\$1 trillion, with Western Europe, North America, and Asia each accounting for a significant share [3]. This amplifies the scope of environmental impacts and intensifies challenges related to the disposal of vast quantities of textile waste the industry generates. The global fashion industry operates on unsustainable models, fueling a rise in product volume with abbreviated life spans and decreasing retail prices. It is a complex network of interconnected elements encompassing design, production, distribution, and consumption. Traditionally, the industry has been driven by trends, rapid production cycles, and a relentless pursuit of novelty. The perpetual shift in fashion trends fosters continuous design variations, fueling product sales, consumption, and subsequent underutilization and waste [4]. This fast cycle underscores the fashion sector's profound sustainability challenges, necessitating a harmonious blend of economic viability, social inclusivity, cultural

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preservation, and environmental resilience [5]. These challenges place the fashion industry at a crossroads as it grapples with intricate issues in its pursuit of transitioning to a sustainable paradigm. This transformative shift is imperative for mitigating environmental and social issues and sustaining the industry's performance and profitability. As discussed by Kozłowski et al. [6], the detrimental impacts of the fashion industry go beyond its ecoeconomic dimensions, encompassing significant adverse effects on both the environment and society, particularly affecting those situated at the lower tiers of the supply chain. Specifically, the fashion industry must address a dual challenge: (1) managing ecological issues such as substantial material and energy exploitation in production and (2) addressing economic and social-cultural sustainability aspects through supplier selection and monitoring.

At the core of the environmental problem lies issues such as the carbon footprint or the water pollution of the fashion industry, omnipresent forces that reverberate through every stage of the supply chain. From the initial extraction of raw materials to the final disposal of garments, each step significantly contributes to the alarming levels of greenhouse gas emissions plaguing our planet [7].

An example of such a polluting scheme is cotton cultivation, a fundamental pillar of the fashion industry and stands out as a significant reason for the Planet's degradation [8]. This particular cultivation requires a considerable amount of water, and the extensive application of pesticides disrupts our ecosystems, depleting water resources and creating imbalances in delicate ecological systems [9]. The inherent nature of this essential material sustains a pattern of environmental harm that reaches well beyond the confines of fashion production [10]. Of equal concern are synthetic fabrics, materials derived from petrochemicals that further intensify environmental degradation and account for most of the fashion industry's fibers [11]. The extraction and processing of these materials contribute to the industry's substantial carbon footprint, and their handling during use causes 35 percent of the world's microplastic pollution [12].

Beyond the ecological realm, the social and cultural consequences of the fashion industry add another layer of distress to the unsustainability narrative [6, 13]. The most vulnerable communities suffer as the search for cheap labor drives production to developing countries, impoverishing territories, and cultures connected to these areas. Workers in these regions often face precarious conditions and receive low wages, with constant reports of labor rights violations and instances of child labor [14]. These experiences deeply impact the industry's supposed commitment to ethical practices, revealing a sharp contrast between rhetoric and reality. The Earth and the communities engaged in the production process experience unwarranted pressure due to the fashion industry's practices. This creates a complex web of interconnected environmental and social challenges that demand urgent attention and systemic change. Accordingly, achieving an equilibrium is imperative for current and forthcoming generations [15]. Such transformation demands fundamentally reevaluating industry practices, encouraging longevity, responsible production and consumption, and resource stewardship [16].

In this context, several scholars highlight how fashion designers possess suitable knowledge and the capability to impact the product ideation, manufacturing, and management process [2, 17–19]. In their conventional role, designers influence aspects such as material selection, aesthetics, and manufacturing. Their significance becomes most apparent regarding sustainability, affecting sustainability at every stage, from ideation to the final product end-of-life management. The choices made during the design process reverberate through the entire supply chain, dictating the materials used, the production methods employed, and the overall environmental footprint of the garment. As consumer demand for transparency and ethical considerations grows, the designer emerges as a pivotal figure in guiding the industry toward a sustainable path. Designers can embrace responsible practices by rethinking traditional productive models, where garments are produced, consumed, and discarded. This means implementing reliable systems such as the circular economy by fostering innovative approaches such as recycling, upcycling, and sustainable sourcing to minimize waste and maximize the lifespan of fashion products. Designers can imagine solutions for achieving a harmonious balance between sustainability and economic feasibility, prompting stakeholders to reassess their business models and production methods. Effectively addressing these challenges is crucial for protecting the environment, advancing social responsibility, and securing the enduring resilience and profitability of the fashion industry in an era that calls for conscientious and sustainable practices.

According to those above, the authors present an interpretative framework outlining contemporary design approaches within sustainable fashion. This framework is conceptualized as a comprehensive idea, weaving together design-driven practices to cultivate a conscientious manufacturing system. The focus is intentionally decelerating, closing, and refining resource flows by design [15].

This article illustrates how designers can lead a transformation, aiming to optimize the utilization of resources, retaining their utmost value throughout use, and ensuring recovery and recycling after their life cycle [16]. Section 2 outlines the methodology, materials, and process employed in mapping the sustainability practices driven by design in fashion

companies, with specific attention to the European region. The research uses an iterative approach to model the data that informs the development of the proposed interpretative model. Despite the widespread integration of sustainability themes into the fashion industry's design, production, and sales processes in recent years, the decision to focus specifically on the European region is motivated by diverse factors. The fashion and high-end industries symbolize European cultural heritage and expertise, directly employing 5 million people in the fashion value chain and over 1 million in the high-end industries.¹ In the face of transformative shifts resulting from economic and climate crises, the industry strives to maintain competitiveness through a progressive transformation [20]. Additionally, the European fashion industry's global prominence is underscored, with European savoir-faire and craftsmanship enjoying worldwide recognition and 62% of products from European high-end brands being sold outside Europe. For personal high-end goods, European products constitute 74% of the global value in this category. European high-end exports are estimated at €260 billion, approximately 10% of all EU exports.² Also, the majority of the mapped cases are located in Europe. Furthermore, the decision is informed by the collective knowledge and experience of the research group, encompassing academic studies, teaching, networks, projects, and other research and practices related to fashion design and circularity conducted by team members. Section 3 presents results and discusses the analysis of current industry practices that integrate sustainability through a design-driven approach to reshape industrial creative and productive flows through investments in design and knowledge. In the present context, design-driven strategies involve the application of design thinking practices that leverage internal systems within a company, encompassing policies and procedures established by management [21]. These strategies go beyond customer-centric approaches and consider intermediaries with a profound understanding of their markets [21, 22]. In addition, adopting a design-driven perspective facilitates designers to preconceive a comprehensive approach to sustainability, assisting in the development of feasible and cooperative strategies supported by stakeholders, companies, and communities in equal measure [23]. Section 3.1. focus on strategies, which are ways of planning the fashion product by involving a systematic approach to organizing resources, making decisions, and implementing actions to attain sustainable development outcomes. Strategic planning involves identifying sustainability objectives and providing guidance for how the fashion industry intends to navigate sustainability challenges and capitalize on opportunities created by design [24, 25]. Section 3.2. illustrates the approaches, which are the way of designing products. This means adapting methods that prioritize long-term environmental, social, and economic viable process steps and priorities before proceeding with the development of the products. [26, 27]. Section 3.3. reports practices, which are the way of making products. Those are organizational activities or operations that support triple-bottom-line sustainability principles [28]. Section 4 demonstrates how the presented model opens up research opportunities to investigate how organizations can formulate innovative legitimization strategies to successfully embrace sustainable design solutions and adapt to the resulting changes in the industry. Lastly, Sect. 5 discusses the constraints and potential future directions of the research, indicating how the proposed conceptual model can organizational activities or operations that support triple-bottom-line sustainability principles to be tested in the subsequent phase of the study.

2 Materials and methods

2.1 Theoretical background

The study's theoretical background was constructed based on an initial systematic literature review [29], which aimed to investigate designers' approaches to adopting innovative strategies for fostering responsible practices in the fashion system. The goal was to inform a suitable model related to the study's findings and contribute to the propositions of the designed research model.

The review utilized Scopus and Google Scholar to ensure comprehensive coverage. Since Fashion Design for Sustainability is a relatively new and interdisciplinary area, the authors included review papers, conference proceedings, and book chapters. Preliminary research has highlighted the growing momentum of design principles and practices that investigate and apply the concept of sustainability in the global fashion industry, as highlighted by several scholars [25, 30–33]. The authors focused on the document published from 2013 to 2023 to ensure the most relevant information

¹ https://single-market-economy.ec.europa.eu/sectors/textiles-ecosystem/fashion-and-high-end-industries/fashion-and-high-end-industries-eu_en.

² https://single-market-economy.ec.europa.eu/sectors/textiles-ecosystem/fashion-and-high-end-industries/fashion-and-high-end-industries-eu_en.

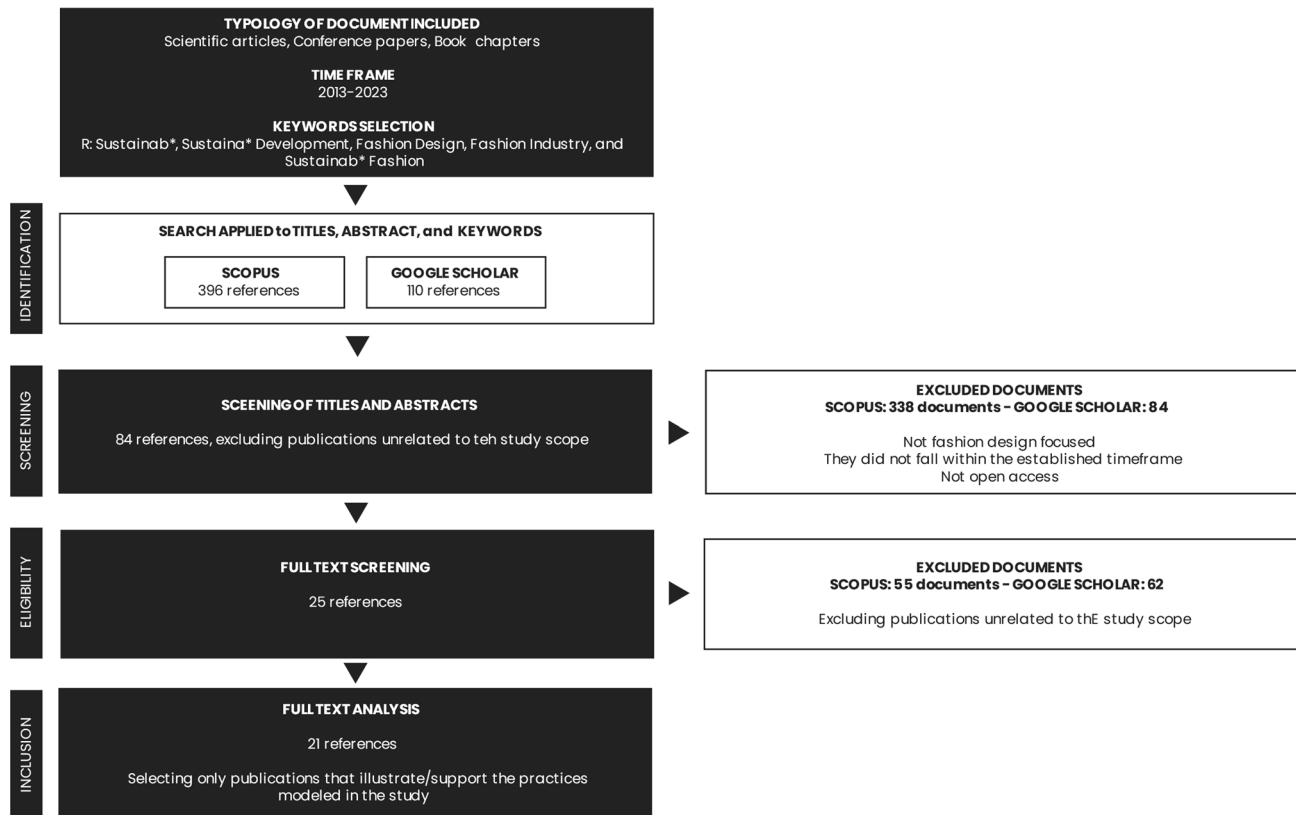


Fig. 1 Literature review process

was included. The specific timeframe was identified according to the increment in scientific publications, as reported by Scopus metrics. However, identifying keywords posed a challenge due to the cross-disciplinary nature of the inquiries, covering engineering, material, chemistry, and business. From this phase, five keywords were identified and researched: Sustainab*, Sustaina* Development, Fashion Design, Fashion Industry, and Sustainab* Fashion. About 500 articles from Scopus and Google Scholar emerged from this query.

The filtering process was complex, involving checking titles and abstracts to exclude publications unrelated to the study's delineation of materials production processes in/for the fashion industry. Additionally, the authors selected only open-source documents to ensure the replicability and availability of the sources for the relevant scientific community. Duplicates were then eliminated, resulting in 25 references. Full reading was conducted to define inclusion and exclusion criteria, revealing that almost all papers were related to technical fields. The authors included articles delivering overarching discussions on circularity and materials production, starting the codification of reported practices. A second reading round further narrowed the sample to 21 publications based on initial findings (Fig. 1, Table 1).

The initial thorough examination formed the basis for the study's structure, offering insights into the relationship between sustainability and contemporary design criteria. It scrutinized crucial aspects such as sourcing raw materials, designing, garment production, and end-of-life management [16, 18, 34–37].

Through a comprehensive review of the existing literature, the authors identified a specific gap and articulated this study's novel contribution to the scholarship of integration, which emphasizes the synthesis and contextualization of knowledge [38]. By focusing on deepening existing understanding by critically examining the authors delineating the boundary conditions of their identified theory [38]. Accordingly, in contrast to previous models, which often emerge from domains such as business engagement in sustainable design [25], educational initiatives [31], or supply chain management [32], this research offers a distinct perspective centered on the role of fashion designers. Specifically, this contribution holistically examines how the actions of fashion designers, shaped by strategic considerations and supported by conventional manufacturing practices, can be systematized within the modern fashion industry to promote sustainability. Such operationalization of knowledge serves to provide practical guidelines for designers seeking to integrate sustainability into their work. It enables the formulation of a strategy and its implementation through specific

Table 1 Final texts selection

Title	Type	Source	Year	Fashion Design For Sustainability	Designers' role
A practical guide to sustainable fashion	Scientific article	Google Scholar	2020	✓	
A Mixed-Method Study of Design Practices and Designers' Roles in Sustainable-Minded Clothing Companies	Scientific article	Google Scholar	2020		✓
Circular fashion: The new roles of designers in organizations transitioning to a circular economy	Scientific article	Google Scholar	2021	✓	✓
Current development and prospects of designing sustainable fashion	Scientific article	Google Scholar	2023	✓	
Designers' potential in sustainable fashion: a systematic literature review	Scientific article	Google Scholar	2023		✓
Designing fashion's future: present practice and tactics for sustainable change	Book	Google Scholar	2020	✓	✓
Designing for circularity: sustainable pathways for Australian fashion small to medium enterprises	Scientific article	Google Scholar	2023	✓	
Designing sustainable fashion: Possibilities and challenges	Scientific article	Google Scholar	2013	✓	
Fashion design industry impressions of current sustainable practices	Scientific article	Google Scholar	2014	✓	✓
Redefining, redesigning fashion: Designs for sustainability	Scientific article	Google Scholar	2014	✓	
Rethinking the fashion collection as a design strategic tool in a circular economy	Scientific article	Google Scholar	2017	✓	
Routledge handbook of sustainability and fashion	Book	Google Scholar	2014	✓	✓
Skills and capabilities for a sustainable and circular economy: The changing role of design	Scientific article	Scopus	2016		✓
Slow fashion: Tailoring a strategic approach for sustainability	Scientific article	Google Scholar	2017	✓	
Sustainable design: Circular economy in fashion and textiles	Scientific article	Google Scholar	2017	✓	
Sustainable fashion: New approaches	Book	Google Scholar	2013	✓	
The management of sustainable fashion design strategies: An analysis of the designer's role	Scientific article	Scopus	2020		✓
The reDesign canvas: Fashion design as a tool for sustainability	Scientific article	Scopus	2018	✓	
Tools for sustainable fashion design: An analysis of their fitness for purpose	Scientific article	Google Scholar	2019	✓	
What is sustainable fashion?	Scientific article	Google Scholar	2016	✓	

approaches and practices that are explicitly outlined in the proposed model. This systematization is then encapsulated in the model proposed by the authors, which operationalizes these practices. The focus is on insights derived from the literature and a critical issue within the fashion industry. Current discussions predominantly emphasize technical and material aspects that aim to reduce environmental impact in practice. Nevertheless, the study also considered economic and social factors in its preliminary theoretical investigation, acknowledging their significance despite not being the main focus. The literature delved into the benefits and untapped economic potential of efficiently utilizing design-driven resources [25]. While not the central focus, these financial considerations underscore the industry's importance in the broader context.

2.2 Methodology

The processed data originate from the Fashion in Process Research Lab at Politecnico di Milano, specifically derived from the authors' involvement in two international field studies in collaboration with a consortium of European academic and research institutions [31] and one of the authors' involvement in the MICS Project, an Extended Partnership between Universities, Research Centers and Enterprises funded by the Ministry of University and Research through funds made available by the European Union under the NextGenerationEU program. This has allowed for further refining of the focus and gathering additional information for the development of the study. Additionally, the dataset includes findings from the doctoral research conducted by one of the authors [39].

The research approach comprised four main stages to contribute to new knowledge. Following the preliminary desk research phase, the authors applied a case study approach to narrow down the extensive scope of their research into more manageable and easily searchable topics. This methodological decision was influenced by the intricate nature of analyzing existing knowledge on the subject. The selection of the case study methodology was considered appropriate for such complex analyses because it transforms individual cases into functional examples, enabling investigation within their original context while considering multiple variables and qualities [39]. As a bridge between quantitative and qualitative methods, the case study methodology supports inductive theory generation and generalization [40]. Considering the relatively unexplored nature of fashion design for sustainability, the case study methodology, while not generalizable, imparts practical knowledge that encourages interpretation through case-specific studies.

The study's first phase involved desk research for mapping international fashion companies' sustainability-related design and manufacturing practices. Approximately 50 companies engaging with sustainable practices worldwide have been identified (Fig. 2).

These companies present a diverse composition, encompassing both fashion and textile sectors actively striving to enhance sustainability across various production processes. This commitment extends beyond the design phase, encompassing manufacturing and technological aspects. In alignment with the industrial development trends, most of these companies were characterized as micro or small and medium-sized enterprises (SMEs) [40, 41]. The analysis of these companies' organizational practices allowed the authors to categorize the four macro dimensions that embed the different strategies to adopt for sustainability (Table 2, see *Planning a Sustainable Fashion Product: The Strategies* sect.).

After mapping these 58 companies, 9 initiatives were chosen as case studies for in-depth investigation of how they strategically direct sustainability through their approaches and practices. The research on case studies employed diverse data collection methods to conduct a comprehensive examination of the phenomenon. The researchers followed Yin's [42] perspective, considering a case study as a data collection method and a research strategy to investigate knowledge units. Specifically, case studies facilitate analytical generalizations wherein the previously gathered knowledge from the initial desk research is organized systematically and utilized to compare the empirical findings of the specific case under investigation. These generalizations enhance the explanatory capability of the presented case studies. Through these detailed case studies, the authors explored cases in varied locations and different periods, identifying similar processes and explanations at work. The criteria for choosing the cases rely on their approaches to incorporating sustainable practices into their systems (Table 3).

These companies adopt a design thinking approach to streamline the development and manufacturing of sustainable products. With a solid commitment to sustainability, these entities serve as eco-conscious alternatives to traditional materials and productions. By adopting innovative strategies, they embed methods, techniques, and materials to (1) design for low impact reducing resource consumption, emissions, and energy usage [43]; (2) design for low waste working on reducing waste generation [44]; (3) design for longevity working on extending the useful life of products [45]; and (4) design for perennity focusing on cyclically recover resources in the productive loops [4]. They all contribute ultimately to mitigate adverse impacts without sacrificing growth and prosperity (Table 3).

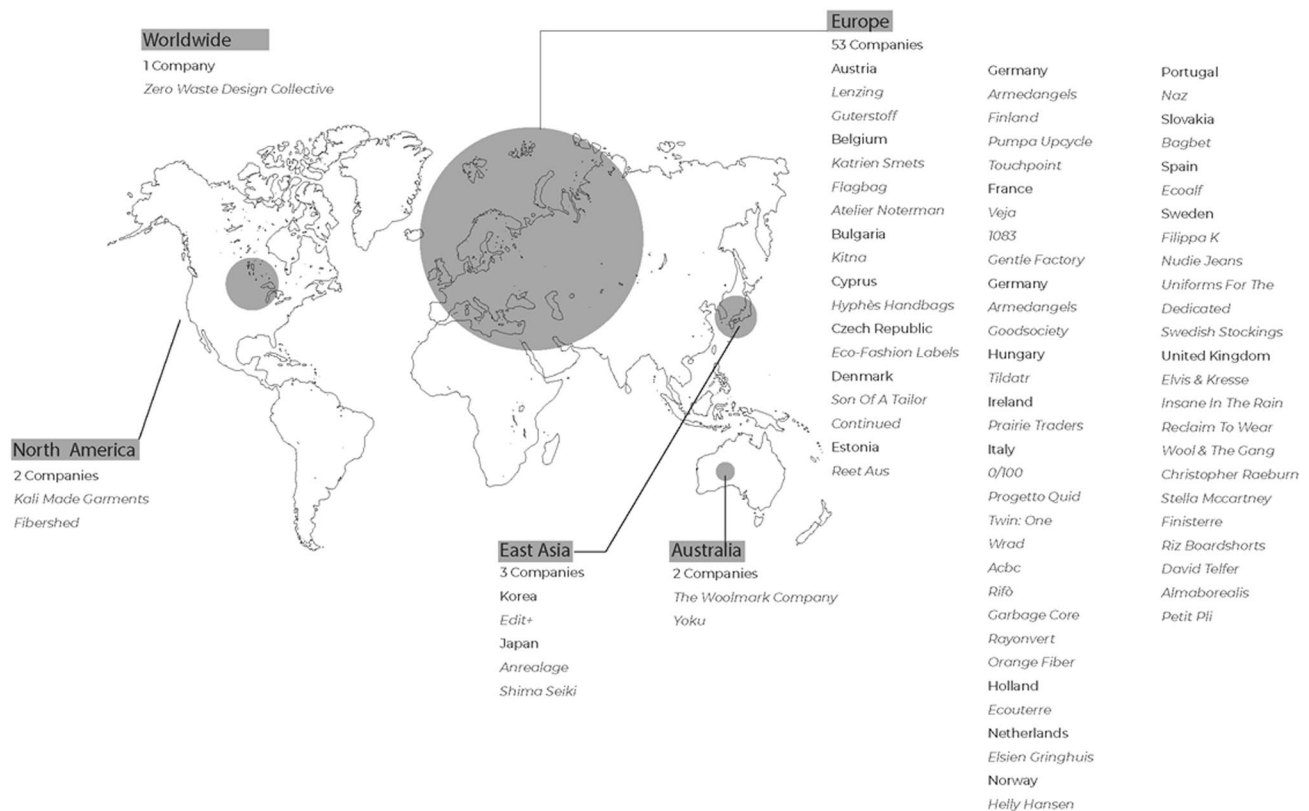


Fig. 2 Map of the Companies

The outcomes of this extended phase contributed to the identification of prevailing sustainable design and production strategies, approaches, and practices within the fashion industry. This delineation of elements represents an initial effort to comprehend the feasibility of transitioning to sustainable fashion by implementing specific design-driven aspects. The following section presents and discusses such aspects by illustrating the study's interpretative model.

3 Modeling design-driven sustainable innovations: strategies, approaches, and practices for fashion

According to what has been discussed, this paper attempts to model current sustainability strategies that support responsible approaches by designing sustainable practices in the textile and fashion industries. Such modeling process involved coding the case studies and concentrating on a specific case while incorporating insights from the wider context provided by the literature. This methodological approach included diverse variables and characteristics, enriching the model's robustness and applicability. According to Johnson [39], the approach adopted is an 'explicative' strategy. This strategy is particularly relevant for understanding complex phenomena where multiple variables interact within a broader context. It contrasts with the 'experimental' approach, which typically focuses on a single unit of analysis with a limited number of isolated variables, and the 'reductive' strategy, which examines many units of analysis but restricts the focus to a few variables. By employing an 'explicative' approach, the model aims to comprehensively understand the case while accounting for the broader theoretical and practical variables at play.

This section will discuss the results from the methodology on how these qualitative implementations take four main strategic paths of design lowering impacts and preserving resources.

In light of the above, this paper presents the identified strategic trajectories of the fashion context to determine how design approaches could inspire and promote new meaningful perspectives in sustainable textile and fashion design practices. This work aims to identify the potential pathways to new approaches, what they are made of, and how they should be implemented to create a more sustainable fashion industrial system. This is studied from a progressive perspective that traces the fashion design process according to Gwilt [46], focusing upstream in the fashion supply chain on

Table 2 Case studies full list

Country	Name	Description	Design for LOW WASTE	Design for LOW IMPACT	Design for LONGEVITY	Design for PERENNITY
Austria	Lenzing	Primary production of all three man-made cellulose fiber generations, from viscose to lyocell and modal. They developed a closed-loop model	✓			
Austria	Guterstoff	Ecological, fair, and climate-neutral T-shirts	✓			
Belgium	Katrien Smets	Made from bio cotton and printed with organic ink. For each item sold, the brand buys one m ² of nature	✓			
Belgium	Flagbag	Uses the cradle-to-cradle principle. Taking discarded flags, streamers, and sails and giving them a new life as a design object smartly and uniquely	✓			
Belgium	Atelier Noterman	'Detox Denim' collection. Using 80% less water, cutting energy consumption by 80%, and considerably reducing the use of toxic substances	✓			
Bulgaria	Kitna	Accessories are made of natural materials and hand-embroidered	✓			
Cyprus	Hyphês Handbags	Creates upcycled handbags from reclaimed material (predominantly denim but incorporates other fabrics offcuts as available)	✓			
Czech Republic	Eco-Fashion Labels	International multi-brand e-shop (and store in Prague) focusing on sustainable, organic, fair trade, and recycled clothing	✓			
Denmark	Son Of A Tailor	Custom-made clothing is made using technology to make it available everywhere	✓	✓		
Denmark	Continued	A platform for circular fashion through which brands can facilitate the take-back and reselling of products more than once	✓		✓	
Estonia	Reet Aus	They are dedicated to slow and ethical fashion, with an industrial upcycled collection made from production leftovers	✓			
Germany	Armedangels	Using renewable resources and recycled materials	✓			
Finland	Pumpa Upcycle	Unwanted textiles are received by Pumpa Design Oy and are upcycled into new products	✓			
Finland	Touchpoint	Workwear made of 100% eco-materials uses surplus materials, focusing on sustainability, the product's lifecycle, and no waste	✓			
France	Veja	Sneakers are made from organic farming and ecological agriculture materials, without chemicals or polluting processes. No advertising	✓			
France	1083	Produce apparel under the constraint that all procurements are situated within a 1083 distance from the firm's office	✓			
France	Gentle Factory	Using local production only, natural, organic, and recycled materials, and offering consumers a take-back scheme	✓			
Germany	Armedangels	Using renewable resources and recycled materials	✓			
Germany	Goodsociety	Do not use pesticide-intensive or genetically modified cotton crops. Local manufacturing is used, and all activities are traceable and transparent	✓			
Hungary	Tildatr	Upcycled fashion from bicycle tubes and curtains combined with organic and natural fabrics	✓			
Ireland	Prairie Traders	Producing ethically sourced 100% organic cotton t-shirts, hoodies, and sweatshirts made in fair working conditions for all employees at every step of production, from farm to consumer	✓			

Table 2 (continued)

Country	Name	Description	Design for LOW WASTE	Design for LOW IMPACT	Design for LONGEVITY	Design for PERENNITY
Italy	O/100	A zero-waste Fashion brand that works to eliminate unsustainable processes by design	✓		✓	
Italy	Progetto Quid	Cooperative producing handmade womenswear, using end-of-line quality textiles from prestigious Italian companies	✓		✓	
Italy	Twin: One	Digital collective specialized in photo-real 3D fashion design and animation. Their software allows the creation of the first digital twin of a product. With TwinOne, brands can create the content they need to virtually display a product, benefiting from photorealistic quality, unprecedented speed, and zero environmental impact		✓		
Italy	Wrad	Sustainable fashion brand/consultancy that implements awareness and responsible practices in the fashion system	✓	✓	✓	✓
Italy	Acbc	Sustainable fashion brand/consultancy that works to implement awareness and responsible practices in the fashion system by materials and design	✓	✓	✓	✓
Italy	Rifò	Circular fashion brand. Rifò creates quality clothing and accessories lines produced entirely in and around Prato using 100 percent reclaimed and regenerated fibers			✓	
Italy	Garbage Core	Garments made out of deadstock fabrics, second-hand clothes, and vintage treasures. They are based in Milan	✓			
Italy	Rayonvert	A sustainable fashion brand that provides digital files to their community to make their clothes according to the instructions provided or work with local seamstresses or repair shops and have them create clothes or pieces of equipment for them		✓		
Italy	Orange Fiber	Orange Fiber is the first company in the world to produce sustainable textiles from by-products of the citrus processing industry through an innovative process patented in 2014 in Italy, which was later extended to major citrus juice-producing countries worldwide	✓			
Holland	Ecouterre	Considers the product's disassembly strategy at the design stage as essential to facilitate efficient disassembly to reuse, re-manufacture, or recycle materials and components at the end of the product's first life			✓	✓
Netherlands	Elsien Gringhuis	The high-end, sustainable label is made 100% in the Netherlands, and all items are produced on order	✓			
Norway	Helly Hansen	Helly Hansen is a Norwegian manufacturer and retailer of sportswear and equipment and a subsidiary of the Canadian retail chain Canadian Tire				✓
Portugal	Naz	Working with local, raw, and quality materials without generating environmental impact has a positive social impact, inspired by the circular economy concept		✓		
Slovakia	Bagbet	Clothing upcycled from high-quality cotton, linen, and hemp	✓			
Spain	Ecoalf	It is made from recycled plastic recovered from oceans, tires, fishing nets, and more			✓	
Sweden	Filippa K	Longer technical life, lease, sharing own product take back			✓	
Sweden	Nudie Jeans	100% organic cotton denim, produced with social responsibility and transparent production. Offering free repair service, reselling second-hand products, and recycling worn-out products				✓

Table 2 (continued)

Country	Name	Description	Design for LOW WASTE	Design for LOW IMPACT	Design for LONGEVITY	Design for PERENNITY
Sweden	Uniforms For The Dedicated	Using organic, recycled, and bio-based materials			✓	
Sweden	Swedish Stockings	Produce pantyhose from recycled yarn. Factories they use engage in sustainable practices, including the use of environmentally friendly dyes, post-dyeing water treatment, and the use of solar power	✓			
United Kingdom	Elvis & Kresse	Rescuing raw materials, transforming them into luxury lifestyle accessories, and donating 50% of profits back to charities. B-Corp certified	✓			
United Kingdom	Insane In The Rain	Rainwear is made from recycled plastic, each using material from 17–23 plastic bottles	✓			
United Kingdom	Reclaim To Wear	Avoiding the use of any additional virgin plastic in all industrial processes The label is an ecological pioneer, the first to collaborate with fashion houses to upcycle production off-cuts to original creations	✓			
United Kingdom	Wool & The Gang	Yarn that is sustainable, recyclable, and biodegradable. In addition, the brand helps other companies eliminate their waste by transforming it into yarn	✓			
United Kingdom	Christopher Raeburn	The REMADE ethos, in particular, has pioneered reworking surplus fabrics and garments to create distinctive and functional pieces	✓	✓	✓	
United Kingdom	Stella McCartney	Stella McCartney is a British luxury fashion house founded in 2001 by its eponymous director and designer. It aims to be as sustainable as possible	✓	✓		
United Kingdom	Finisterre	Products that are fit for purpose cause as little environmental impact as possible, from materials, packaging, and supply chain transparency to a supplier code of conduct. B-Corp certified		✓		
United Kingdom	Riz Boardshorts	Every pair of our shorts is crafted from Eco-Friendly, 100% recycled, and recyclable fabric and digitally printed in the UK using earth-friendly inks. B-Corp certified		✓		
United Kingdom	David Telfer	David Telfer is a menswear designer specializing in sustainable pattern-cutting techniques such as Minimal Seam Construction and Zero Waste			✓	
United Kingdom	Almaborealis	They design items and experiences that invite children into clothes-making through playful products and imaginative workshops			✓	
United Kingdom	Petit Pli	Petit Pli is a modern and fit-for-purpose range of childrenswear that expands and contracts to grow as your child grows			✓	
USA	Kali Made Garments	Kali Made Garments produces limited-edition, locally-made luxury garments in Oakland, CA		✓		
USA	Fibershed	Fibershed is a non-profit organization that develops regional fiber systems that build ecosystem and community health		✓		
Korea	Edit +	They design items that can evolve by modularity according to their user needs	✓		✓	✓
Japan	Anrealage	Anrealage focuses on new uses for technology rather than on the newness of the technology itself				
Japan	Shima Seiki	Top manufacturer of knitting machines	✓	✓		

Table 2 (continued)

Country	Name	Description	Design for LOW WASTE	Design for LOW IMPACT	Design for LONGEVITY	Design for PERENNITY
Australia	The Woolmark Company	The Woolmark Company is the global authority on Merino wool. Its extensive textile and fashion industry partnerships highlight Merino wool's positioning as a natural fiber and critical ingredient in luxury apparel		✓		
Australia	Yoku				✓	
Worldwide	Zero Waste Design Collective	This global collective works at the intersection of education, practice, and industry. By connecting across boundaries, they harness the power of community to tackle textiles' most pressing problem: Waste	✓		✓	

Table 3 Case studies final selection

Country	Name	Approach	Practices
Estonia	Reet Aus	Upcycling	Cut&Sew other options: minimal seam moulage modules
Italy	0/100	Zero-waste	Zero waste pattern cutting Minimal seam Moulage Modules
Holland	Ecouterre	Disassembling	Minimal seam Modules
Norway	Helly Hansen	Monomateriality	Minimal seam other possible options:whole garment fully fashioned seamless Zero waste pattern cutting moulage modules
Sweden	Nudie Jeans	Recycling	Cut&Sew Minimal seam other possible options: moulage modules whole garment fully fashioned seamless
United Kingdom	Petit Pli	Physical durability	Cut&Sew other options: whole garment fully fashioned seamless Zero waste pattern cutting minimal seam moulage modules
USA	Kali Made Garments	Fibershed	Cut&Sew Other options: WHOLE GARMENT FULLY FASHIONED SEAMLESS Zero waste pattern cutting Minimal seam Moulage Modules
Korea	Edit +	Dynamic upgrade	Minimal seam Modules
Australia	Yoku	Emotional durability	Cut&Sew other options: whole garment fully fashioned seamless Zero waste pattern cutting minimal seam moulage modules

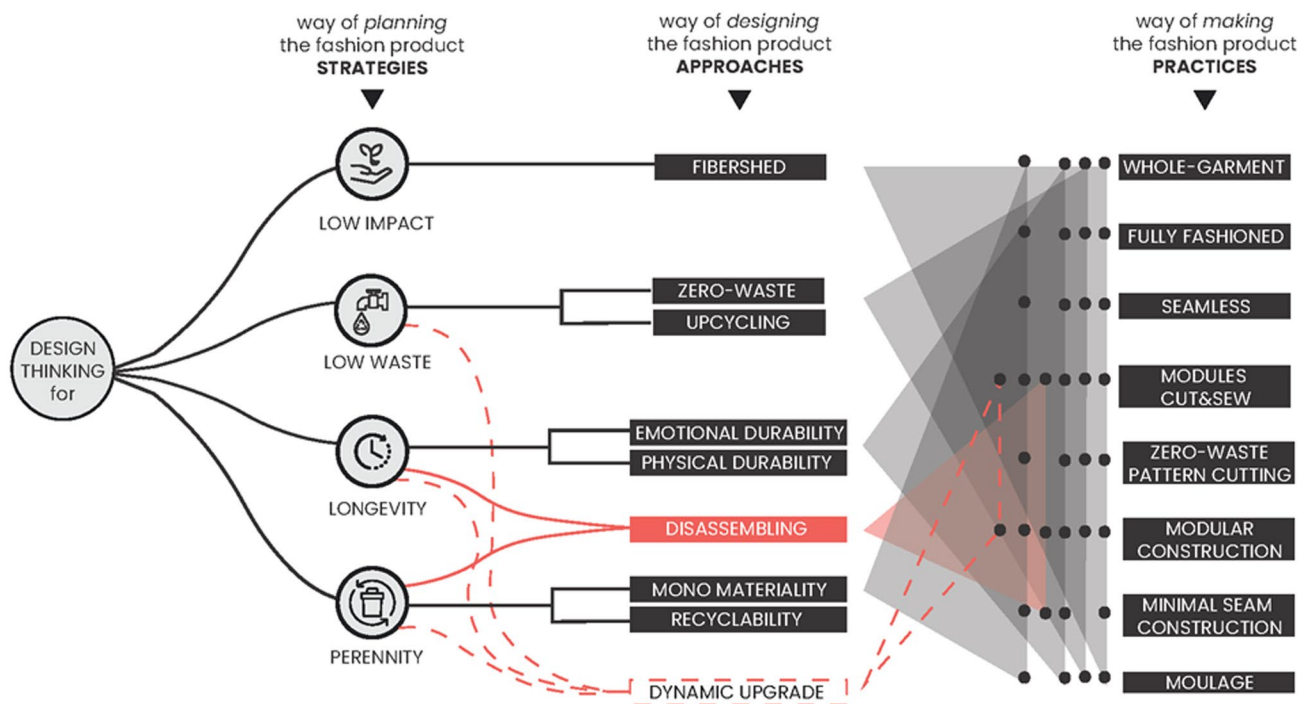


Fig. 3 The study interpretative model: Strategies, approaches, and practices

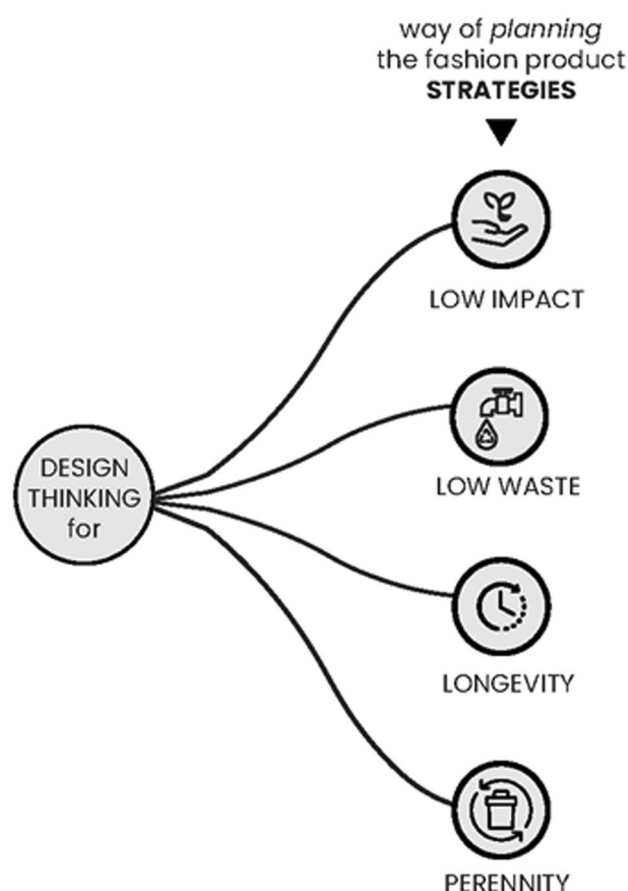
the planning, design, and implementation of a sustainable fashion product capable of taking into account a garment's life cycle, its end-of-life strategies or a sense of responsibility for textile waste generated through the analyzed phases such as pattern making or production [37].

Operatively, the study has identified four strategic dimensions – Design for Low Impact, Design for Low Waste, Design for Longevity, and Design for Perennity. These dimensions refer to design strategies that ensure that a particular sustainable characteristic, function, or quality criteria are reflected in the final design [47]. These dimensions serve as guiding principles for designers, directing them towards sustainability through eight distinct approaches: zero-waste, upcycling, fibershed, emotional or physical durability, disassembly, monomateriality, recyclability, and dynamic upgrade. Consistent with the implemented strategies, these approaches aim to lessen adverse effects and generate positive economic, environmental, and social outcomes that define sustainable fashion. They involve ecological and ethical practices designed to improve communities, cultures, societies, individuals, and the environment while promoting and respecting diversity [6]. Within this framework, success and profitability are deliberately separated from unchecked growth to establish a system capable of fostering perennity. These approaches prompt designers to reconsider their practices – from cut and sew to knitting – through a sustainable perspective, originating at the convergence of the explored paths. Accordingly, the model makes explicit the relationships between the identified dimensions underlying the connection among specific strategies, their related approaches, and the design practices adopted to act upon those specific sustainability characteristics (Fig. 3).

Operationally, the mapped practices of the case studies were classified into clusters corresponding to the four strategies identified in the literature. This classification aimed to define the approaches being employed and the associated practices subsequently performed. The case study analysis facilitated the specification and generalization of these practices through the model, which serves as a tangible representation of the knowledge produced by this study.

The following sections discuss Each model element – strategies, approaches, and practices—in detail, and through the help of case studies, one for each model component is presented. These cases are emblematic of the themes that represent approaching sustainability from a design-driven perspective. These companies promote innovative models supporting the development and adoption of design-driven practices to achieve sustainability in the fashion system.

Fig. 4 The study interpretative model: The strategies



3.1 Planning a sustainable fashion product: the strategies

Upstream of the fashion design process, we find strategies. These are defined here as the designer's long-term direction and purpose to help achieve sustainability through planning and configuration of resources within product creation to realign the current development path on a sustainable trajectory [48–50]. These provide a broad perspective rather than an exhaustive catalog, presenting various directions for fashion designers. The study codifies four strategies for embedding sustainability: Design for low-impact, Design for low-waste, Design for longevity, and Design for perennity (Fig. 4).

Design for low-impact is an umbrella term that involves an ecological perspective [51]. Designers actively minimize their environmental footprint [43] by tackling significant challenges encountered in the cultivation, processing, and coloring of raw materials and addressing concerns related to environmental pollution and the depletion of flora and fauna on our planet. According to Tkanko & Tkanko [52], the primary focus areas for designers in this context encompass principles like limited consumption, incorporating natural materials and colors, integrating waste-free production technologies, utilizing alternative eco-friendly fabrics, and similar considerations.

Designing with a focus on minimal waste, as Gupta and Saini [44] advocate, involves addressing overconsumption issues and actively working to reduce waste generation. The approach entails a strategic effort to minimize waste or explore the possibility of incorporating waste into the creation and manufacturing processes. Designers play a crucial role in conceptualizing garment designs, and pattern makers are tasked with creating patterns that can be cut from fabric rolls in the most efficient manner possible. However, it is acknowledged that current methods still have inherent inefficiencies [53]. Consequently, designers need to strategically structure their operations to control the quantity of waste generated during the production phase of their products.

Design for longevity focuses on extending the useful life of manufactured products [45]. Designers contribute to an elongated product lifespan, offering the wearer increased chances to derive utility from the item. Enhancing the endurance of existing pieces eliminates the necessity for additional acquisitions. This delay in new consumption conserves resources, reduces waste, effectively fulfills user needs, and aligns with sustainable practices. Nonetheless, as highlighted

by Fletcher [2], the investment in resources and efforts to extend product life may only prove effective if users capitalize on the extended lifespan, ultimately impeding the deceleration of new item consumption. Accordingly, designers must strategically embed these aspects to select the correct approach to sustainability.

Design for perennity focuses on recovering resources in the productive loops [4]. This approach encourages a perspective closely aligned with the principles of circular economy and closed-loop systems. It suggests a shift in the designer's mindset, where the focus is not on selling products to customers but on temporarily lending materials. These materials are then returned for reintegration into the design and manufacturing processes [54].

3.2 Designing a sustainable fashion product: the approaches

Strategies guide designers in selecting appropriate approaches to achieve their specific sustainability goal by allocating resources, identifying objectives, and formulating operational steps [28, 55, 56]. Such approaches are defined here as designers' overall structure that guides the process of designing, setting steps that they can refer to without constantly recreating the path from start to finish product embedding sustainable solutions for reaching the specific strategy scope. To achieve precision and consistency, the processed data are converted into groups to provide a picture of the investigated approaches resulting from the constant comparisons for similarities and differences [57]. What emerged are 9 approaches that embed sustainability in the design of fashion products. Seven pertain to distinct approaches and sustainable aspects: fiber-shedding, zero-waste, upcycling, emotional and physical resilience, mono-materiality, and recyclability. Meanwhile, three of these strategies operate at the convergence of two or more approaches – disassembly, for instance, can be associated with both longevity and perpetual existence, and dynamic upgrade may encompass low-waste, longevity, and perpetual qualities (Fig. 5).

As per the case of designers who strategically design for low impact, they mainly engage with fiber-shedding. The authors use this term to refer to initiatives that align with the Fibershed ethos. This association promotes natural fiber systems to foster enduring prosperity for local economies, the global climate, and the overall health and diversity of the ecosystem. Designers such as Kali Made Garments³ operate to establish strategic systems that make design and fashion active participants in environmental restoration. The brand engagement encompasses the entire garment lifecycle, from collaborating with actors who cultivate textiles in the soil to their eventual composting. They design planning the whole process from growth, processing, design, sewing, sales, and use while minimizing the environmental impact of such a system by exploiting aspects such as localism and regenerative agriculture.

Approaches related to low-waste strategies mainly adopt zero-waste or upcycling perspectives. The zero-waste design approach seeks to tackle the issue of textile waste by preventing its generation during the design phase. This method allows for the preservation of all resources through responsible practices in production, consumption, and the reuse and recovery of products, packaging, and materials. Importantly, it avoids burning and discharging into the land, water, or air that could threaten the environment or human health. Designers such as Camilla Carrara, who founded the brand 0/100,⁴ operate not for a revolutionary change but rather a restructuring of the fashion industry's values. The brand aims to eliminate the constraints of seasonal trends and age or gender restrictions, encouraging individuals to express themselves. The brand redefines the production processes and choices that contribute to creating a collection, as each element is designed to achieve zero waste, with a specific modeling approach and a 360-degree commitment. The products are made of single fibers and avoid accessories that are difficult to disassemble. The focus is on quality over quantity, uniqueness instead of seriality, and traceability and transparency rather than closure. In this case, the brand is characterized by a systemic ethos that embeds a value-driven choice through the Made in Italy label, representing a means to trace every step of production by collaborating with excellent suppliers open to change.

Upcycling is generally a design-based circular fashion approach, where post-consumer textile waste or deadstock materials are repurposed to create new garments. Producing goods through upcycling methods presents challenges for the mass production industry. However, designers are investing in experimentation to help save resources and prevent textiles from becoming waste, as in the case of Reet Aus.⁵ This designer is committed to responsible fashion and is a pioneer who introduced industrial upcycling principles to diminish the fashion industry's environmental impact. She achieves this by reintegrating fabrics leftover from mass production back into the production cycle through thoughtful

³ <https://www.kalimade.com/>.

⁴ <https://zerobarracento.com/it>.

⁵ <https://www.reetaus.com/>.

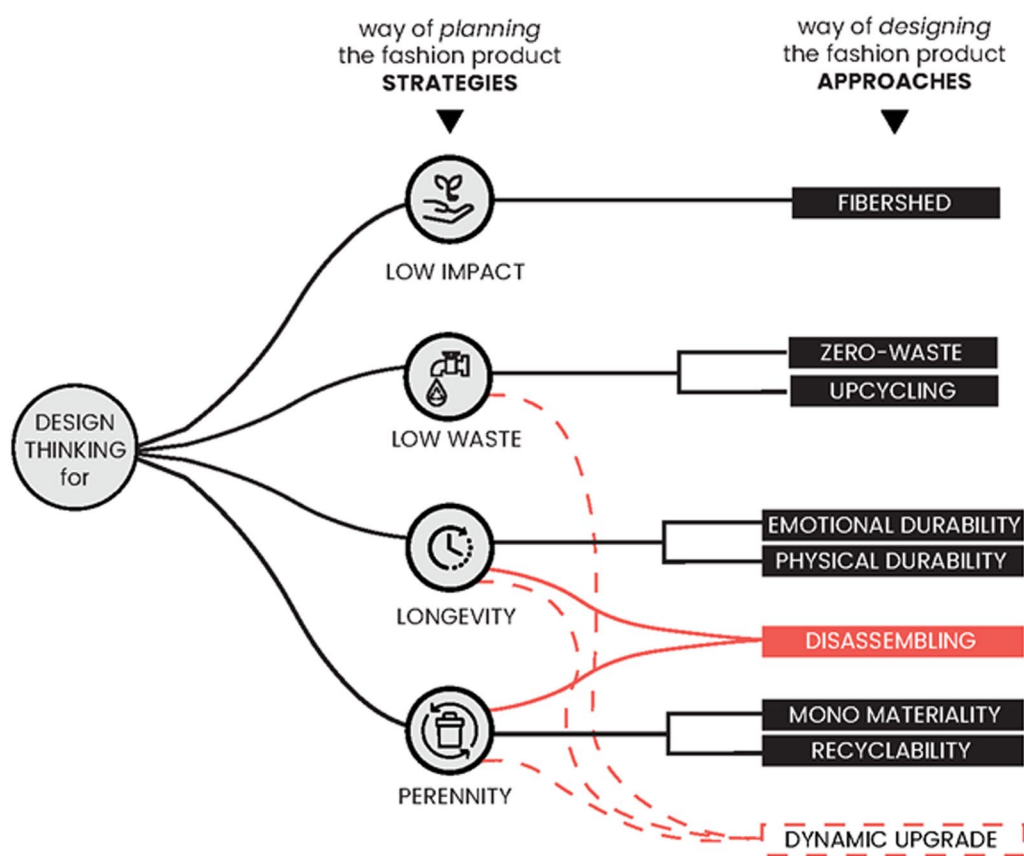


Fig. 5 The study interpretative model: The approaches

design. In typical mass production, around 18% of new fabrics become pre-consumer waste after cutting, often ending up in landfills. The brand's unique approach eliminates additional fabric production, rendering our clothing carbon-neutral. Furthermore, their virgin fabric ensures that any leftover material is free from harmful chemicals.

Design for longevity strategy engages designers with the notion of durability. This concept can be approached from two perspectives: physical and emotional.

Physical durability involves creating clothing focusing on longevity, considering aspects such as garment construction, fiber blend, color fastness, and resistance to abrasion, odors, and stains. On the other hand, emotional durability pertains to the psychological aspects associated with the user's feelings toward the garment throughout its lifespan. This includes considerations such as the garment's comfort over time, its appearance and feel as it ages (including surface damage and color changes), the continued relevance of its style, and the emotional connection developed with the garment.

Designers such as Ryan Mario Yasin, an aeronautical engineer turned designer, work to implement physical resistance through innovative material technologies. To address environmental concerns, he is adopting a comprehensive strategy encompassing every production stage, from the initial design to the finished product. The designer founded in 2017 the brand Petit Pli.⁶ The company has introduced a distinctive and patent-accepted material technology inspired by deployable satellites to minimize the waste produced by the fashion industry by prolonging the garment's life. Specifically, they adopt a holistic approach that considers various factors: Construction, physical resistance, functionality, and design to fit. This innovative perspective results in a specialized clothing line for infants that is waterproof, wind-resistant, and uniquely able to adjust to the wearer's body size as they grow. Taking inspiration from the traditional Japanese art of origami, each garment in the collection is crafted from fabrics featuring small folds that dynamically conform to the wearer's changing shape and movements in real-time.

⁶ <https://shop.petitpli.com/>.

Emotionally durable design offers a valuable framework for articulating the enduring significance of creating responsible, well-crafted, and tangible products to which users can develop a lasting connection with an attribute value over time. The Yoku⁷ brand embeds this approach in its products. Their archetypal item is the men's belt that exemplifies the personalized design of products, where the objects not only serve their primary functions but also serve as a means for the owner to make a statement or express their lifestyle and personal style. Specific design choices have been made in the material and construction of the men's belts to ensure that they age gracefully. Using solely brushed or polished metals, rather than coated or treated, results in the development of unique characteristics as they age. Opting for full-grain leather contributes to the belt's durability and allows the leather to absorb oils, developing a unique patina that makes each belt one of a kind. Over time, individual belts become easily distinguishable within a collection of otherwise identical belts, with any nicks or marks reflecting the wearer's life experiences.

Design for Perennity strategically offers insight into the compatibility of different elements of fashion goods to foster productive closed-loop systems and circularity. Specifically, it relies on two specific approaches: monomateriality and recyclability. Monomateriality focuses on a product composed of a singular material type or components, each crafted from a singular material that can be disassembled. The design philosophy involves using materials that are singular in composition or fiber, avoiding blends. This approach simplifies the recycling process, as garments made from a single material are more easily recycled than those requiring the separation of multiple materials for individual recycling processes. The Norwegian company Helly Hansen⁸ is embracing such an approach by designing a product composed of a singular material type, avoiding blends, that can be easily disassembled to simplify the recycling process. The brand always focused on designing products with long-lasting qualities, although the infrastructure to fully embrace a circular design process still needed to be implemented. With the advent of new technologies presenting new opportunities, the long-term goal is to incorporate considerations for end-of-life at the design stage for all products produced. Indeed, garments made from a single material are more easily recycled than those requiring separating multiple materials for individual recycling processes. When recycled to create new materials, they retain a superior quality to mixed fibers [58, 59].

The designer must consider that the garments they create will eventually reach a time when they no longer serve their initial purpose. Design for recyclability explores how designers can make this system extinct by aiming to achieve the ultimate goal of a closed-loop system, infinitely maintaining the value and quality of all materials. Nudie Jeans,⁹ established in 2001 in Gothenburg, Sweden, has become prominent in sustainable and organic denim manufacturing. Through the Nudie Jeans Recycle Project, the brand aims to repurpose old and worn-out Nudie jeans to recycle every fiber and component of the denim. Notably, 90%¹⁰ of each denim pair has been recycled, contributing to two distinct projects – creating new jeans or producing furniture and rugs.

The two last approaches that emerged from the modeling of design-driven practices merge different aspects related to two or more strategies.

Disassembling mix elements from longevity and perennity and dynamic upgrade works with low waste, longevity, and perennity.

Disassembling refers to a fundamental principle that informs decisions and material choices, changing how materials are joined together and how they are layered in a way that is accessible, reversible, and robust. Design for disassembly utilizes strategic material and construction choices to enable efficient disassembly for recycling, enhancing perennity, reuse, and remodeling into new products, fostering longevity. An example of designing for disassembly is the Refinity project. Dutch companies Ecouterre,¹¹ in collaboration with Dutchspirit, have introduced a conceptual raincoat designed with ease of disassembly in mind. The emphasis is on simplified disassembly for components, achieved through stitching the outer material instead of gluing it to the lining. Additionally, 'click-able' closures replace conventional options such as velcro, zippers, or buttons.

Dynamic upgrade focuses on integrating the existing design elements of a garment to prolong its life, enhancing longevity. This approach hacks the existing into different parts. It upgrades it at the wearer's will, fostering durability through material selection and component manufacturing to prevent waste generation and lessen the negative environmental impact of textile waste. Brands such as Edit + work in this category. The brand was established by Jean Sung,

⁷ <https://yokumensbelt.com/>.

⁸ <https://hellyhansen.com>.

⁹ <https://www.nudiejeans.com/>

¹⁰ <https://www.nudiejeans.com/info/we-want-your-jeans-back>.

¹¹ <https://ckh.wrap.org.uk/design/designForDisassembly?breadcrumb>.

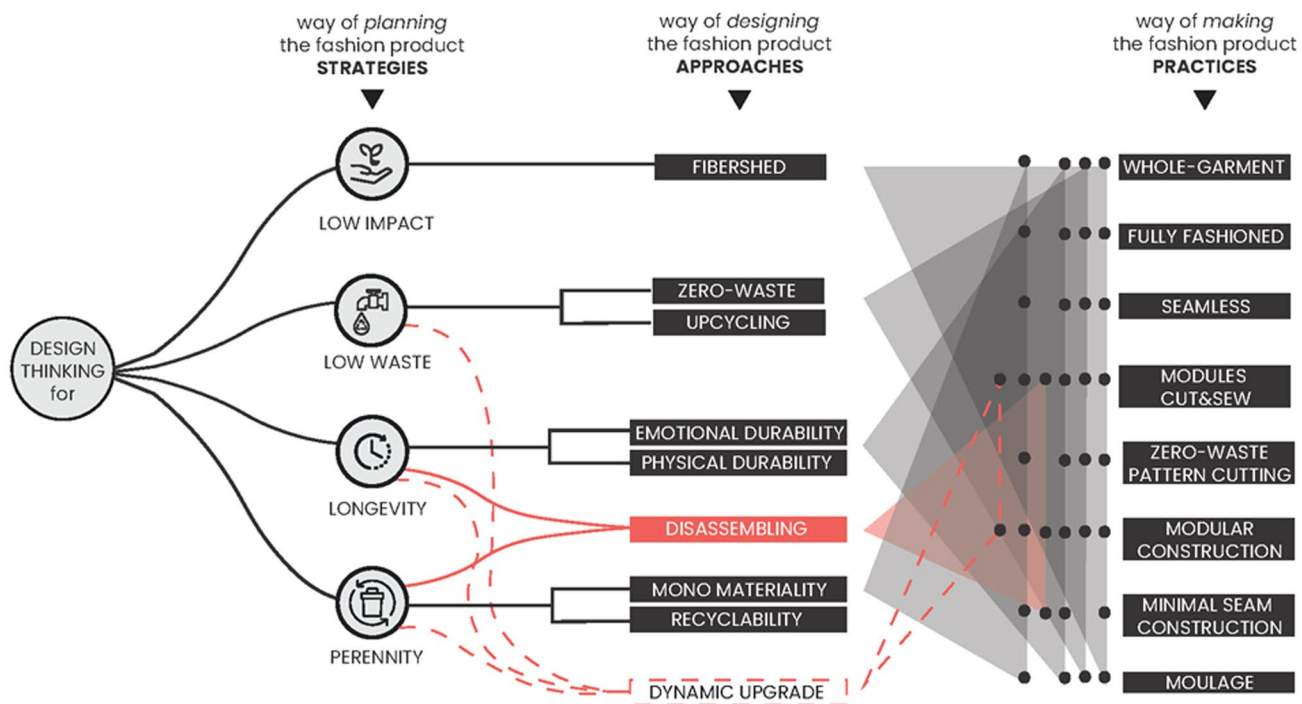


Fig. 6 The study interpretative model: The practices

who served as the Executive Director and CMO of North Face Korea. She believes in the practicality of modular fashion, aiming to produce versatile apparel that can be easily edited and changed according to individual preferences, reducing the number of garments while offering more outfit possibilities. Aligned with the "less is more" philosophy, Sung introduced Edit +, her genderless and modular clothing line. This line is customizable with removable parts, creating eight styles using just one piece.

4 Manufacturing a sustainable fashion product: the practices

The last part of the model tries to address the complex issue of how the fashion designer can practically engage with these approaches to operate according to the specific strategy scope (Fig. 6).

The modeling of how designers can make clothes to adopt the presented approaches for planning the sustainability of their goods proposes an interpretation that aims to offer a comprehensive vision rather than a definitive list for providing diverse options to fashion designers.

The two macro-categories of practices [60], knitting and cut and sewing, are modeled according to the specific approaches identified.

Knitting is related to designing and adopting solutions for zero waste by creating garments that come off the knitting machine fully formed and complete with zero makeup, cutting, or finishing required fiber shedding and physical and emotional durability. Mono materials and recycling are fostered by performing a conscious materials selection for manufacturing items that exude uniqueness, age gracefully, and transcend fleeting trends, significantly contributing to their enduring value.

- **WHOLE GARMENT:** Knitwear is produced in one piece, three-dimensionally, directly on the knitting machine, preventing and minimizing waste by design.
- **FULLY FASHIONED:** Knitwear is shaped by increasing or decreasing the number of loops made along the fabric length without alteration of the stitch. The product is shaped and seems to fit the body, creating the idea that the goods are distinctive or singular.
- **SEAMLESS:** The seamless technique encourages greater structural diversity and comfort along with reduced fabric wastage, using circular and flat-knitting technologies.

Cut and sew practices are associated with developing solutions for zero waste by creating patterns that maximize the use of resources, minimize the production of leftover waste, or reuse the waste by design in the manufacturing process. These practices promote fiber shedding and physical and emotional durability, focusing on high-quality materials. Furthermore, they foster mono materials and recycling by deliberately adopting design and assembly solutions [61].

- Zero waste pattern cutting: This design practice uses a flat pattern-cutting system to realize a design and achieve maximum fabric usage, preventing waste.
- Minimal seam: This design practice reduces the number of seams required to sew together a garment. It makes manufacturing much quicker, can save on materials, and impacts the disposal phase. It can also give the garment greater freedom of movement and increase comfort for the wearer, fostering an emotional attachment to the product.
- Moulage: This is a manual practice by which fabric is sculpted directly on a sartorial mannequin through the use of cloth or fabric, pins, and a scissor with which a garment can be made in one piece, transforming it into geometric shapes and fluid, perfect creations establishing the concept that the products are unique or one-of-a-kind.

Common to both categories is the concept of a module. That can foster all the approaches embedded in the two categories, adding the dynamic upgrade dimension.

- Modular fashion refers to knitting or clothing items with detachable pieces so that one can easily alter the clothing item to suit changing needs and tastes over time. This prevents precious materials from becoming waste and creates a connection between the user and the garment.

5 Conclusions

The study focuses on how the fashion system is undergoing a significant transformation, with designers reclaiming their pivotal role as leaders of a fashion revolution. Beyond traditional creative duties, designers actively engage in education, advocacy, and challenging established norms (De Casto, 2021). Their impact extends to shaping a future where the fashion industry is synonymous with responsible practices, mindful consumption, and harmonious coexistence with the planet and its diverse systems. The article explores emerging responsible practices aligned with evolving priorities, aspirations, and lifestyles. The aim is to encourage a systemic approach to sustainability in fashion by adopting innovative strategies that promote responsible practices. These efforts optimize resource utilization, ensure maximum value retention throughout the life cycle of fashion products, and facilitate recovery and recycling at the end of their usage by design. The article codifies transformative and sustainable paths led by designers, inspiring a global shift towards conscious and responsible practices in the fashion industry for fostering sustainable production ecosystems.

6 Limitations and future scope

The authors would like to draw attention to a few limitations of this study. Although this work acknowledges the limited scope of the data, it does not seek to put forth novel knowledge. Nevertheless, it offers comprehensive insights that distinguish the particular perspective in investigating design-driven strategies, approaches, and practices for promoting sustainable fashion. This research was done in the context of the fashion systems in industrialized nations, such as the United States, Japan, and Europe, with distinct social and economic traits. Additionally, as some of the studies in this work are rooted in Europe, it makes sense to concentrate mainly on this region. The mapping of the cases demonstrated how various approaches to conceptualizing, creating, and producing fashion products have or are rapidly acquiring a great degree of awareness of sustainability challenges and readiness to enhance efforts and activities. Accordingly, the results should be considered according to the proposed perspective.

Examining the proposed model made it clear that systematically implementing design thinking can close the current gap in the sustainability abilities of the fashion sector. These strategies make it easier for industries to acquire and develop the necessary resources and competencies.

The companies and brands examined in this research demonstrated a range of sustainability strategies, indicating the critical characteristics required to obtain the know-how and abilities needed to advance toward design-driven sustainability:

- The internal integration of strategy-related approaches in organizations, integrating crucial components for demonstrating an innovative design-thinking asset targeted at attaining sustainability.
- Establishing collaborations with other organizations and combining traditional techniques with environmentally friendly solutions to create synergies that advance cooperative efforts toward responsible production initiatives.

Future research should scrutinize the precise elements influencing sustainable organizational development through design. This could pave the way for diverse research avenues, such as:

- Identifying the specific barriers to adopting strategic design-driven approaches sustainably.
- Assessing the impact of integrating sustainable fashion through design at a systemic level, particularly in nurturing industrial ecosystems.

Finally, the authors recognize that, from a sustainable development perspective, as discussed in the introduction, the social dimension is crucial. However, the current discourse predominantly emphasizes insights derived from the literature and industry investigations concerning technical or material aspects aimed at reducing environmental impact in practice. This focus is balanced with enhancing social value, primarily through deliberate approaches and practices, which can significantly contribute to the broader ethos of sustainable development. Future iterations of this study should investigate how the proposed model can effectively address social issues [62, 63].

In conclusion, design-driven thinking is crucial to fostering sustainability within the fashion sector. This research offers initial insights into implementing strategies, approaches, and practices rooted in inherent design capabilities, technological proficiency, and organizational strategy. Additionally, collaboration among fashion industry participants and other stakeholders is recommended for fostering incremental innovations beyond individual strategy. Integrating stakeholder involvement into the proposed model is a strategic consideration that significantly enhances its applicability and impact. While the model primarily focuses on the role of designers, acknowledging and incorporating contributions from other vital actors within the value chain—such as enterprises, agricultural industries, recycling sectors, and public institutions—can greatly enrich its effectiveness. For instance, enterprises producing and distributing fashion items can work in tandem with designers to ensure the use of sustainable materials and implement environmentally friendly production practices [64]. Agricultural industries can collaborate with designers to provide eco-friendly materials, such as organic cotton or biodegradable textiles, aligning with sustainable design principles. Recycling sectors can be integrated into the model by developing systems for recovering and repurposing textile waste, thus contributing to a circular fashion economy [65]. Public institutions, including regulatory agencies and educational bodies, can support the model by establishing guidelines, endorsing sustainable practices, and promoting awareness throughout the industry. The successful implementation of the model relies not only on the actions of designers but also on the cooperative engagement of all relevant stakeholders. By incorporating these actors, the model offers a more comprehensive framework that addresses the complexities of sustainable fashion. This approach ensures that the model addresses the design process and aligns with the practices and needs of various sectors within the value chain. Including these interactions within the model fosters a more holistic approach to sustainability, reflecting the interconnected nature of the fashion industry [66, 67].

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Data availability The article contains all the related data (see Sect. 2 Materials and Methods).

Declarations

Ethics approval and consent to participate “Not applicable”.

Consent for publication “Not applicable”.

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