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EDITED BY
Giovanni Maria Conti,
Polytechnic University of Milan, Italy

REVIEWED BY
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Instituto Politécnico do Cávado e do Ave (IPCA), Portugal
Nkumbu Mutambo,
Northumbria University, United Kingdom

*CORRESPONDENCE
Flavia Papile
✉ flavia.papile@polimi.it

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Ecodesign-driven material selection in fashion design: a methodological proposal and a mock-up tool

Flavia Papile[1]* and Barbara Del Curto[1,2]

[1]Politecnico di Milano, Department of Chemistry, Materials and Chemical Engineering "Giulio Natta", Milano, Italy, [2]National Interuniversity Consortium of Materials Science and Technology (INSTM), Firenze, Italy

The textile sector is widely recognised as one of the most environmentally impactful industries, contributing substantially to greenhouse gas emissions, water consumption, and chemical pollution. A significant share of these impacts stems from the production, use, and end-of-life of the materials employed in fashion garments. Extending garment lifetimes thus represents a central challenge in the fashion industry's transition toward circularity. Although durability is acknowledged as a key principle of the circular economy, design practice often struggles to translate material performance into actionable ecodesign strategies to promote "use for longer" behaviours. In this context, ecodesign, understood as the integration of life-cycle thinking into product development, is increasingly emerging both as a regulatory requirement and as a strategic opportunity for textile manufacturers. This paper analyses the main regulatory frameworks for ecodesign in textiles. It examines relevant certification schemes, outlining key design principles through their integration with material-related information and material selection methodologies. By investigating how technical and sensory attributes of materials are addressed in fashion design practice, the study explores how these insights can inform ecodesign strategies that support both physical and emotional durability in fashion garments, ultimately guiding practitioners toward a more informed material selection process. Finally, the paper proposes a structured methodology for integrating ecodesign-driven material selection into industrial practice and presents a mock-up tool to support its implementation. The discussion highlights the opportunities and challenges associated with the proposed approach.

KEYWORDS
circular fashion, durable fashion design, material selection, material selection tool, material sustainability

1 Introduction

The transition toward sustainable and circular textiles production and consumption is a central priority for the European Union (European Commission, 2022). The textile industry is widely recognised as one of the most impactful sectors globally: conventional textile production is highly resource-intensive, generating environmental impacts across energy consumption, chemical use, waste generation, and post-consumer disposal (Niinimäki, 2020; Allwood et al., 2006), as well as social impacts related to fair work conditions and the health and wellbeing of textile industry employees.

Ecodesign represents one of the most developed frameworks for embracing a holistic design strategy that integrates environmental, social, and economic parameters at the design stage across the entire product life cycle (ISO, 2006). The Ecodesign for Sustainable Product Regulation (ESPR), which entered into force on 18th July 2024, establishes legally binding ecodesign criteria for nearly all product categories, including textiles. These requirements encompass durability, repairability, recyclability, the use of recycled content, and chemical safety. The regulation also introduces the Digital Product Passport and prohibits the destruction of unsold textile products (European Commission, 2024a). Adopted in 2022, the EU strategy outlines a 2030 vision for textiles that are long-lasting, recyclable, largely free of hazardous substances, and partly produced with recycled fibres. It highlights Extended Producer Responsibility (EPR) as a key instrument for shifting end-of-life responsibility to producers (European Commission, 2022). ISO 14006 provides guidelines for embedding ecodesign within environmental management systems (ISO, 2020), while UNI-ISO 14009:2024 underscores the integration of life-cycle thinking into product design (UNI, 2024). Eco-labelling schemes, such as the EU Ecolabel, OEKO-TEX, and GOTS, provide standardised methods to communicate product sustainability attributes and enhance consumer trust (European Commission, 2014).

These new rules establish transparency, accountability and conscious design from the initial product development stage. According to the EU Strategy for Sustainable and Circular Textiles (European Commission, 2022), the production and consumption of textiles must incorporate ecodesign strategies in the design phase, with this step accounting for approximately 80% of a product's life-cycle impacts (European Commission, 2020). This aligns with the commitments made in the European Green Deal (European Commission, 2019), the Circular Economy Action Plan (European Commission, 2020), and the European Industrial Strategy (European Commission, 2020). Focusing on the fashion and textiles sector, the implementation of these regulations and international standards now imposes significant constraints (a comprehensive table of Textile International and European Standards and Norms is provided in the Supplementary material).

Due to the complexity of the production and value chain of the textiles and clothing ecosystem (European Commission, 2022; Niinimäki et al., 2020; Fletcher and Tham, 2019), several normatives have been introduced to guide companies in monitoring several aspects affecting the life cycle of a new garment. These normatives generated standards and certifications that arose to direct the industrial work. Recurring principles derived from regulatory frameworks include diverse parameters directly or indirectly conducive to materials and their selection:

- Durability: Enhanced material strength and product longevity.
- Repairability: Design enabling maintenance and part replacement.
- Recyclability: Preference for mono-materials or separable fibre blends.
- Resource Efficiency: Minimisation of water, energy, and chemical use.
- Non-toxicity: Compliance with REACH and eco-toxicological standards.
- Transparency: Use of labels and digital product passports.
- Producer Responsibility: EPR compliance for post-consumer waste.
- Life-cycle Integration.

A substantial portion of these environmental and social impacts arises from the materials used in this industrial sector throughout their life-cycle, including production, use, and disposal (Fletcher and Tham, 2016). In this context, extending the lifetime of textile products is represented as a central challenge in advancing the transition toward circularity in the textiles and fashion industry (European Commission, 2020). Not all regulations/certifications directly refer to textiles, but several have clear implications for fibres, chemicals, and recycled/organic content. Therefore, Table 1 summarises the regulations and information about textile materials that need to be taken into account when designing aware fashion products.

It follows that material selection, also in the fashion sector, represents a crucial step in the design process of physical products. Inadequate material selection, often driven exclusively by aesthetic considerations, can compromise a product's potential to remain in circulation, regardless of subsequent design strategies aimed at enhancing its emotional or symbolic value. Several studies (Fletcher and Tham, 2019; Chapman, 2015) emphasise that systemic durability is essential for extending product lifespans, including emotional, symbolic, and cultural dimensions. However, these forms of durability cannot exist without a robust foundation of material-related choices. A garment that deteriorates rapidly due to underperforming materials loses both its functional and aesthetic value, inevitably breaking the connection with the user, despite any emotional or symbolic attachment it may hold. Consequently, premature disposal of garments, coupled with changes in fashion styles, results in significant resource loss.

Material selection is therefore a key factor in achieving both physical and systemic durability. Natural fibres, such as wool, cotton, and silk, generally offer superior durability when adequately processed. In contrast, synthetic fibres widely used in fast fashion, such as polyester and nylon, tend to degrade more quickly, often exhibiting issues like pilling and loss of appearance after repeated washing (Niinimäki and Hassi, 2011). These material choices also affect the potential for recycling, repair, and reuse, which are essential elements of circular design and ecodesign strategies.

The central role of material selection in achieving sustainable fashion design is widely acknowledged. The extraction and processing of raw materials are significant drivers of greenhouse gas emissions and resource consumption, particularly in the early stages of the supply chain (i.e., tiers 2, 3, and 4). Tier 2 processes, such as fabric preparation and dyeing, alone account for 53% of the industry's GHG emissions (Apparel Impact Institute, 2023).

Despite growing awareness of textiles and fibre recycling, available technologies remain limited and fragmented, thereby reducing the circularity of materials at the end of their life (Allwood et al., 2006; Ellen MacArthur Foundation, 2017). Furthermore, the long-term consequences of designers' material choices, especially their influence on circular strategies, remain underexplored. Previous research (Papile and Del Curto, 2021; Mazzitelli et al., 2024) has shown that material repositories and selection frameworks can support designers' decision-making; however, they often fall short in holistically integrating circular and durability-oriented criteria.

This research, therefore, builds on these findings through a critical and comparative review of existing methodologies, material selection frameworks, and sustainability assessment systems used in fashion design, to understand how material properties are currently represented and where integration gaps persist. Within the circular economy framework (Ellen MacArthur Foundation, 2020), material

TABLE 1 Analysis of textile international and European standards and norms from the perspective of material-related information and implications for textiles.

Reference	Focus on materials	Implications for textiles
EU Regulation No. 1007/2011	Fibre names, textile composition	Regulates the naming of fibres and the labelling of textile composition
EU Textile Labelling Rules	Textile composition, labelling of fibres/fabrics	Ensures mandatory labelling of fibre content for textiles
ISO 3688	Fibres, yarns (definitions and terminology)	Standardises terms for fibres and yarns
ISO 13986-1	Generic fibre names	Provides consistent fibre identification
ISO 18334-1	Fibre composition of textile products	Specifies quantitative fibre content
ISO 2060	Yarn structure (twist per unit length)	Measures yarn twist affecting textile properties
ISO 11092	Yarn mechanical properties	Measures breaking force and elongation of yarns
ISO 13934-1/2	Fabrics	Tensile strength testing (strip and grab methods)
ISO 13937-1/4	Fabrics	Tear resistance testing
ISO 13938-1/2	Fabrics	Bursting strength testing
ISO 13935-1/2	Fabrics	Seam strength testing
ISO 12945	Fabrics	Pilling resistance (surface wear)
ISO 105 series	Fabrics	Colour fastness to washing, light, and rubbing
ISO 3071	Fabrics	Measure the pH of textile aqueous extracts
ISO 20743	Fabrics	Antibacterial activity testing
ISO 13943	Fibres, yarns, fabrics	Standardises textile terminology and vocabulary
ISO 5232/ISO 5234/ISO 5247	Yarn, fabrics	Reference for textile machinery parts affecting yarn/fabric processing
ISO 11612	Fabrics (protective clothing)	Performance against heat and flame
ISO 11611	Fabrics (protective clothing)	Performance for welding protection
ISO 1149	Fabrics (protective clothing)	Electrostatic dissipative properties
ASTM D-series	Fibres, yarns, fabrics, finished textile products	Provides methods for mechanical and physical testing
ASTM D5034	Fabrics	Break strength and elongation testing
ASTM D4966	Fabrics	Abrasion resistance testing
ASTM D1776	Fibres, yarns, fabrics	Standard conditioning and testing atmospheres
ASTM D7017	Fabrics	Rainwear performance testing
OEKO-TEX® Standard 100	Fibres, yarns, fabrics	Chemical safety certification
OEKO TEX® Made in Green/STeP	Fibres, yarns, fabrics	Ensures sustainable and responsible production
GOTS	Fibres (organic), fabrics	Organic content, environmental and social compliance
GRS	Fibres (recycled), fabrics	Recycled content, traceability, and social criteria
SA8000	Fibres, fabrics	Social accountability in textile production
Fair Trade	Fibres, fabrics	Ethilabourabor and trade practices
WRAP	Fibres, fabrics	Responsible apparel manufacturing program

information management plays a key role in enabling reuse, repair, and recycling strategies. However, such considerations must be embedded at the earliest stages of design, when material decisions are defined. The study, thus, discusses how technical and sensory material attributes can inform eco-design approaches that support both physical and emotional durability, while addressing the gap between analytical sustainability data and creative design practice. To address this gap, this study investigates how digital tools can promote circular material selection in fashion design. Specifically, it explores:

1 how existing material selection tools integrate (or neglect) circularity criteria;
2 how the material selection process is currently performed in textile selection and application;
3 How a new digital tool can help designers align material choices with circular design principles.

To address this gap, the authors propose a methodology that bridges textile material information (technical and sensory) with ecodesign criteria for fashion designers. A mock-up tool is presented here to assist fashion designers in making informed material choices that can enhance durability and support circular product design strategies. Its development is grounded in a state-of-the-art analysis of existing material selection tools and databases, evaluating data accessibility, usability, and the integration of circular metrics. Ultimately, it offers a replicable framework for embedding sustainability and circularity criteria into material selection processes, bridging the gap between scientific data and creative design practice.

2 Methodology

The standardised language of product design, functional for characterising materials, cannot always be directly applied to the fashion industry due to its unique constraints and the complexity of textile products. However, structured material selection methodologies from product design can still inform fashion applications (Italia et al., 2023).

According to the literature, material selection activities oriented towards product design are supported by a variety of tools (Van Kesteren et al., 2008; Sörensen, 2016; Papile and Del Curto, 2021). The main categories include material libraries, material selection tools, and methodologies that assist designers in choosing materials based on different kinds of properties—namely, functional, hedonic, and ethical attributes. While in product design practice, the material selection process has been structured and formalised for many years (Sörensen, 2016, for industrial design education), the state of the art in fashion design is comparatively less structured and standardised (see Mazzitelli et al., 2024).

To investigate and set up a structured state-of-the-art of existing sources that can support material selection activity in fashion design practice, the following tables have been structured to systematise:

a A selection of material Libraries for Fashion Designers
b Methodologies of Material Selection for Fashion Designers
c Tools Specific to Material Selection for Fashion Designers.

Therefore, to explore and analyse existing case studies, web research with the following queries:

- "Material Libraries AND Fashion Design"
- "Textile Libraries"
- "Material Selection methods FOR Fashion designers"
- "Material Selection Tools FOR fashion Designers."

The obtained results have been analysed and selected according to the following exclusion criteria: too narrow case studies (e.g., focusing on a specific material as "wool") have been excluded from the analysis in order to select examples with a broad impact; methodologies that were too engineering oriented or not relevant at fashion product level (according to authors background knowledge on the topic, see Mazzitelli et al., 2024 and Papile and Del Curto, 2021) have been excluded in order to obtain a methodological overview coherent with the fashion design practice.

The second methodological step focused on collecting and categorising principal ecodesign tactics, guidelines and strategies for fashion design, according to a homogeneous definition of these terms (Italia et al., 2023; Vezzoli et al., 2022). These elements were also linked to diverse certifications and international standards to identify the material-level information that fashion designers must manage to comply with the regulatory framework.

Linking ecodesign strategies to regulations facilitates the categorisation and practical evaluation of design guidelines and material-related information. This linkage is fundamental for highlighting actionable intervention points in developing a material selection tool for fashion designers that holistically collects all the essential information.

Finally, the synthesised information was integrated into the design of a mock-up tool. This tool aligns with the established material selection process, employs terminology familiar to the fashion industry, and implicitly supports the management of diverse fibre and textile information during the design phase. This mock-up tool has been designed with Adobe XD, a vector design software developed by Adobe for creating interactive prototypes, wireframes, and user interfaces (UI/UX), which can be particularly useful for digital mock-ups in the context of ecodesign and textile material selection.

Given the limited standardisation of material selection processes within fashion design, this study adopts an exploratory approach aimed at mapping and systematising existing tools, methodologies, and practices. Rather than testing predefined hypotheses, the research investigates the current state of the art to inform the conceptual development of a preliminary material selection mock-up tool tailored to fashion design practice.

3 Results

3.1 State-of-the-art analysis: material libraries, material selection methodologies and material selection tools for fashion designers

Material libraries, both physical and digital, have become increasingly essential resources for fashion designers seeking innovation, sustainability, and efficiency in their workflows. These repositories enable designers to explore novel fibres, finishes, and materials across disciplinary boundaries, offering both aesthetic inspiration and comprehensive technical data. Digital libraries further facilitate integration with 3D design tools, supporting virtual prototyping and rapid experimentation, while reducing the need for costly physical samples.

Table 2 presents a curated repository of selected material libraries explicitly targeting fashion designers, mapping the state of the art of existing resources and tools available to the sector, derived from web-based research. The analysis highlights the principal functions and workflow advantages of each library.

Cases such as Material ConneXion stand out as a comprehensive global database of innovative materials, covering sectors beyond textiles. Its extensive categorisation and physical samples make it a critical resource for interdisciplinary material exploration in almost all design-driven activities.

The TextielLab Library (Netherlands) and the Textile Museum of Prato (Italy) exemplify how textile heritage archives support contemporary innovation. Both provide direct access to historic and technical textile resources from woven patterns to manufacturing techniques. That enables designers to reinterpret craftsmanship through a modern lens. These archives serve as active laboratories of material culture, offering tactile, visual, and contextual data that connect tradition to digital experimentation. Equally significant is the Fondazione Fashion Research Italy (Bologna), whose vast collection of over 30,000 textile designs forms a crucial bridge between Italy's industrial textile heritage and contemporary creative industries. The digital accessibility of such archives democratises access to inspiration and supports material-driven design education. The Fabricant Material Library exemplifies the shift toward fully digital fashion, allowing designers to test and render materials in virtual environments, thereby supporting sustainable design by reducing the reliance on physical prototypes.

In summary, material and textile libraries, whether physical, digital, or hybrid, serve as strategic infrastructures for innovation in

TABLE 2 A selection of material and textile libraries for fashion designers.

Category	Example (real)	Type (digital and/or physical)	Function for fashion designer	Key workflow advantage	Application context	Cost/ accessibility
Digital Sourcing Library	SwatchOn	D/P	Global sourcing platform offering digital fabric twins and physical swatches at low MOQ.	Democratises access to fabrics and reduces sampling time.	Digital fashion and sourcing platform.	Free browse; pay for physical samples.
Innovative Library	Material ConneXion	P/D	Global database of innovative materials across multiple sectors.	Expands material vocabulary and supports product innovation.	Industry reference for material innovation.	Subscription/ institutional access.
Digital Textile Library	The Fabricant Material Library	Digital	Digital materials for 3D fashion and metaverse applications.	Enables the creation of photorealistic digital collections without the need for physical materials.	Digital fashion and virtual design.	Professional license/ collaboration-based access.
Innovative Library	Materioteca (Politecnico di Milano)	P/D	Academic archive of new and sustainable materials.	Supports experimental inspiration and future materials research.	Italian academic context.	Free for students and researchers.
Sustainable Library	Materia MX	P/D	Platform and space for regenerated, bio-based, and low-impact materials.	Supports the adoption of sustainable material alternatives.	Latin American focus.	Free access upon request.
Historical Archive	FIT Material Archive	P/D	Historical collection of textiles and materials for fashion study.	Provides a reference for the reinterpretation of historical and vintage materials.	Academic and research context.	Free for students and researchers.
Creative/Digital Library	Adobe Substance 3D	Digital	Creation of digital materials (textures, fabrics, finishes).	Reduces physical sampling and accelerates visualisation.	Adobe product ecosystem.	Adobe license/trial.
Textile Library/ Archive	TextielLab Library (Netherlands)	P/D	Extensive textile reference library with books, sample books, archives, fabrics, and yarns.	Enriches the designer's background knowledge and inspiration through deep material and technique reference.	Europe's most extensive textile libraries.	Physical + online; access may require a visit/appointment.
Textile Library/ Archive	Textile Library (Textilmuseum St. Gallen) (Switzerland)	P/D	Open-access textile library with sample books, fashion sketches, photographs, and historic fabrics.	Supports tactile and inspirational use; adds depth to brand heritage references.	Museum-based textile library.	Free for younger users (students); small fee for general membership.

(Continued)

TABLE 2 (Continued)

Category	Example (real)	Type (digital and/or physical)	Function for fashion designer	Key workflow advantage	Application context	Cost/ accessibility
Textile Library/ Archive	Fondazione Fashion Research Italy (Archive Bologna)	P/D	Online and physical fashion archive of textile designs, 30,000 handmade designs on paper/fabric (19th–21st century).	Key source for pattern and historical textile design inspiration, linking traditional manufacturing to contemporary fashion.	Italian archive dedicated to the "Made in Italy" textile heritage.	Consultation is available free of charge by appointment for professionals and students.
Textile Library/ Archive	Textile Museum of Prato Library and Sample Archive (Italy)	P/D	Collection of books (4,000 volumes) and textile sample books, fashion plates (18th–20th century).	Valuable mix of sample books and literature; supports material sourcing with historical context and local textile industry insight.	Regional textile museum in Italy with global relevance.	Free to consult (by appointment) in the museum.

fashion design. They operate not merely as archives but as active systems of knowledge, connecting aesthetics, technology, and sustainability. Their integration into design workflows enhances not only creativity but also the ethical and environmental consciousness of the next generation of designers.

Material selection methodologies offer fashion designers a structured framework for evaluating fabrics and components across multiple criteria, including performance, sustainability, cost, and aesthetic quality. These approaches encompass multi-criteria decision-making (MCDM) techniques and weighted scoring methods, as well as environmental and social life cycle assessments (LCA and S-LCA). These methods ensure that material choices align with both creative objectives and ethical, environmental, or social imperatives.

In Table 3, a collection of material selection methodologies that can overlap with fashion designers' activity has been provided.

Methods such as Multi-Attribute Criteria Decision Making (MCDM) offer a transparent and rational framework for evaluating multiple materials against predefined priorities, effectively balancing technical performance with aesthetic and sustainability criteria. While life cycle assessment (LCA) and social life cycle assessment (S-LCA) approaches are increasingly applied in fashion design to quantify environmental and social impacts, they provide objective data to support ethical sourcing and reduce the ecological footprint of collections. Although emotional and aesthetic considerations undoubtedly constitute fundamental elements of the fashion design material selection process, a comprehensive, holistic methodology integrating these dimensions remains notably absent. Yet necessary in this domain.

The material selection process is typically structured in sequential steps (Ashby and Johnson, 2013) and guides designers in identifying and selecting the most suitable materials for specific artefacts. This process is feasible by establishing design criteria that demand specific material properties, and it proceeds in parallel with the creative conceptualisation and technical definition of the artefact.

This central activity in the creative process determines the final products' impact at several levels: at the environmental level, it determines, e.g., emissions necessary to extract, manufacture, maintain and circle or dismission the product itself (Niinimäki et al., 2020; Allwood et al., 2006); at social level may determine the investment in fair trade-certified companies and fair labour supply chains (Niinimäki et al., 2020; Shen, 2020); at economic level can determine a substantial percentage of the artefact's final price (Allwood et al., 2006; Shen, 2020). In addition, also at the cultural level materials can play a significant role: it is sufficient to look at history to understand how metals and polymers permeated the whole societal culture and progress (Dresselhaus, 1991); to the extent that there is a whole branch of research dedicated to materials-products design and consumer behaviour (and sustainable behaviour), underlining the significant cultural influences of materials in everyday life (Csaba and Bengtsson, 2015; Joy et al., 2012).

Fashion design is a discipline profoundly related to cultural expression, but it is also deeply entangled with the sustainable transition. In this discipline, the material is a means not only to define a physical product but to carry cultural meanings (Barnard, 2013; Csaba and Bengtsson, 2015) (the word fashion itself, e.g., is commonly used also to describe specific cultural dissemination or a way of doing things). From a sociological perspective, the relationship between clothing and culture presents a fascinating and contradictory phenomenon, intersecting with the sociology of consumption, production, and material culture (Entwistle, 2000; Woodward, 2007). Material culture and fashion studies offer insights into the role of clothing and materials in shaping cultural identities, social dynamics, and historical contexts (looking at the phenomenon of sub and counter cultures offers an immediate understanding of this topic). These fields emphasise the significance of fashion as both an aesthetic and symbolic practice, as well as a mode of consumption and production influenced by global economic, social, and technological forces (Joy et al., 2012; Fletcher, 2014).

Being materials and their characteristics at the core of fashion products, it becomes immediately clear that the material selection process plays a key role in this discipline, highlighting the necessity of understanding how specific textiles are selected to respond to physical, cultural and economic drivers of production. Fashion designers often

TABLE 3 A selection of material selection methodologies for fashion designers.

Method	Example	Type (digital/ physical/ analytic)	Function for fashion designer	Key workflow advantage	Source/ application context
Multi-attribute criteria	Weighted scoring method (MCDM)	Analytic	Evaluate materials by weighted criteria (aesthetic, cost, impact).	Objective decision among multiple options.	(Academic research)
Environmental analysis	LCA (life cycle assessment)	Analytic/digital	Evaluate environmental impacts across the material life cycle.	Objective comparison: CO_2, water, energy.	(General research)
Social analysis	S-LCA (social life cycle assessment)	Analytic/digital	Identify social risks in the supply chain.	Ethical sourcing decisions.	(Fashion/social impact research)
Sensory/tactile analysis	Kawabata system/FAST	Physical/analytic	Measure tactile properties (softness, drape).	Align tactile feel with performance.	(Textile labs/brand R&D)
Aesthetic/emotional selection	Moodboard/emotional design matrix	Creative/visual	Connect materials to aesthetics and brand values.	Visual coherence with brand identity.	(Design studio/concept stage)
Circular selection	CircularMAT toolkit	Digital/analytic	Guide material selection for durability and circularity.	Integrate circularity from the concept phase.	(Sustainable fashion/ academia)

follow a quite structured sequence of steps to select materials for their designs (Ashby and Johnson, 2013; Hasling, 2014):

1. Define the Design Concept, i.e., to understand the desired look, functionality, and purpose of the garment;
2. Evaluate Fabric Properties, i.e., to consider the fabric's weight, stretch, durability, texture, and colour;
3. Source Fabric Samples, i.e., to test fabric samples for their response to stitching, movement, and wear;
4. Prototype and Evaluate, i.e., to create prototypes using selected materials and evaluate their fit, drape, and performance;
5. Finalise the selection, i.e., once the Material meets aesthetic and functional requirements, finalise the selection.

In fact, some attempts are being made to respond to both the needs of fashion design theory and practice, aiming to address the gap between creative activity and systemic information management. In Table 4, a collection of fashion design-oriented material selection tools is presented. Material selection tools can be defined as digital and physical platforms that enable designers to analyse, compare, and simulate fabrics and other materials efficiently. These tools range from software that digitises material properties for 3D garment simulation to traceability platforms and sustainability indices. By integrating data-driven insights into the design process, these tools enhance decision-making, reduce prototyping costs, and improve design accuracy.

Browzwear Fabrics, Analyser, VStitcher, and CLO 3D Fabric Kit are exemplary tools in 3D garment simulation, enabling designers to model fabric behaviour realistically. This reduces the need for physical sampling while maintaining fidelity in draping and fit evaluation. However, comprehension of material properties that generate specific fabric behaviour is not immediately supported. Repositories such as Textile Exchange, PFMM and Higg MSI are primarily designed for corporate sustainability assessments. Higg MSI (Material Sustainability Index) provides an analytical basis for selecting environmentally responsible materials, offering quantitative comparison metrics that can influence sourcing and design decisions at an early stage. However, its usability for fashion designers is not a declared objective, making the tool very useful but at a systemic level. The platform DAMō instead integrates material selection, certification, and physical sample management in a single platform, representing a novel approach to combining sustainability, sourcing, and digital workflow. The missing link is between material properties and their impact on design activities from the perspective of eco-design practice. Adobe Substance 3D Sampler and Vectary for Fashion demonstrate the growing importance of visual and virtual experimentation, enabling rapid exploration of textures and patterns in digital fashion pipelines; however, a proper material selection process is lacking.

Therefore, from the state-of-the-art analysis, it emerges that there is a necessity for a comprehensive and holistic tool that can support and stimulate fashion designers' reflections on the impact of materials, as well as the implementation of ecodesign and sustainable practices in their daily activities.

3.2 Interpolating material selection for fashion design with ecodesign strategies and regulations

When interpolating these selection steps with sustainable transition objectives, the procedure becomes pretty challenging.

The environmental impacts of every product category are determined by all the inputs (i.e., extraction of resources) and all the outputs (i.e., emissions to soil, water, and air), both directly and indirectly associated with the product system (Vezzoli et al., 2022). To measure these categories, a quantified element must be defined to measure the performance of any product typology, named "functional unit" of the product system itself. The functional unit provides the baseline to compare and proportionate data in the product systems: according to

TABLE 4 A selection of material selection tools for Fashion Designers.

Tool/ platform	Example (real)	Type (D/P/A)	Function for fashion designer	Key workflow advantage	Source/ application context	Cost/ accessibility
Digital fabric analyser	Browzwear fabric analyser + VStitcher	P/D	Digitises fabric properties for 3D simulation.	Realistic 3D drape; optimised selection and fitting.	(Fashion tech reference)	Professional software license.
3D fabric tool	CLO Fabric Kit + CLO 3D	P/D	Import physical fabric parameters into virtual models.	Reduces physical prototypes, accelerates sample approval.	(Fashion-tech workflow)	Monthly license.
Sustainable material tool	Higg MSI (material sustainability index)	Digital	Evaluate the environmental impacts of fibres and materials.	Transparent comparison for sustainable choices.	(Sustainable apparel coalition)	Free to access; advanced features require Higg Platform Pro subscription.
Sustainability standards assessment tool	Preferred Fibre and Materials Matrix (PFMM) – textile exchange	Digital	Interactive assessment tool for sustainability standards, branded fibres and improvement programs.	Enables brands to compare and evaluate fibre and material programs according to holistic impact criteria (Climate, Nature, People, Animals, Governance).	Tool developed by textile exchange for industry sourcing and standards evaluation.	Open-source access; free for industry users.
Traceability tool	TextileGenesis/ retraced	Digital	Trace material origin via blockchain.	Strengthens transparency and ethical storytelling.	(Fashion transparency index)	Custom license for brands/suppliers.
Innovative material library (digital)	Material ConneXion Database Online	Digital	Technical data and images of innovative materials.	Inspiration + high-performance material data.	(Fashion/research sector)	Subscription/ institutional access often via university libraries.
Digital asset/ material optimisation	DAMō	D/P	Certified material catalogue, custom search, and physical sample shipping.	Integrated workflow: sustainability + sourcing + prototyping.	DAMō site	Free tier available; pricing starts at €99/month.
3D/visual material library	Vectary for fashion	Digital	Create/import/test/ share materials in a 3D environment.	Quick visualisation + shared material libraries.	(Fashion/3D/AR workflow) platform is general 3D design tool.	Free trial/variable pricing.
Digital texture and pattern tool	Adobe substance 3D sampler	Digital	Generate textures/ fabrics from photos or data.	Rapid visual testing; accelerated design decisions.	(Adobe product)	Adobe license/trial available.

(Vezzoli et al., 2022), the functional unit for the clothing system can be defined as 'the use of a garment for one year'.

Once the functional unit is defined, the clothing system life cycle phases must be taken into account. In the fashion domain, these phases are typically (a) pre-production, (b) production, (c) distribution, (d) use, (e) disposal (Figure 1).

The pre-production phase encompasses all impacts related to the extraction of raw materials and their processing into textiles and yarns for use in various clothing products. The production phase refers to all garment manufacturing activities, including the "make-up" process (Khan and Islam, 2015; Moazzem et al., 2018; Vezzoli et al., 2022) and, in some cases, ironing; its environmental impact is generally much lower than that of pre-production, yet still significant over the product's life cycle. The distribution phase covers the environmental impacts of transportation (from factory to user), packaging, and all retail and storage activities. The use phase encompasses impacts from wearing clothes and from clothing care, including washing, drying, and ironing, as well as repair or upgrading. The impacts of washing are particularly relevant due to the consumption of energy, detergents, and water. The disposal phase encompasses the impacts of end-of-life activities, particularly landfilling, incineration, and recycling. The central role of materials in regulations is evident; however, anticipating reflections on material use can allow designers to preview the effects on the whole product's life cycle.

Figure 2 provides a comprehensive mapping of ecodesign strategies, tactics, and their corresponding European policy and regulatory frameworks. Each row translates a specific design guideline into its associated policy value, highlighting where concrete regulatory drivers

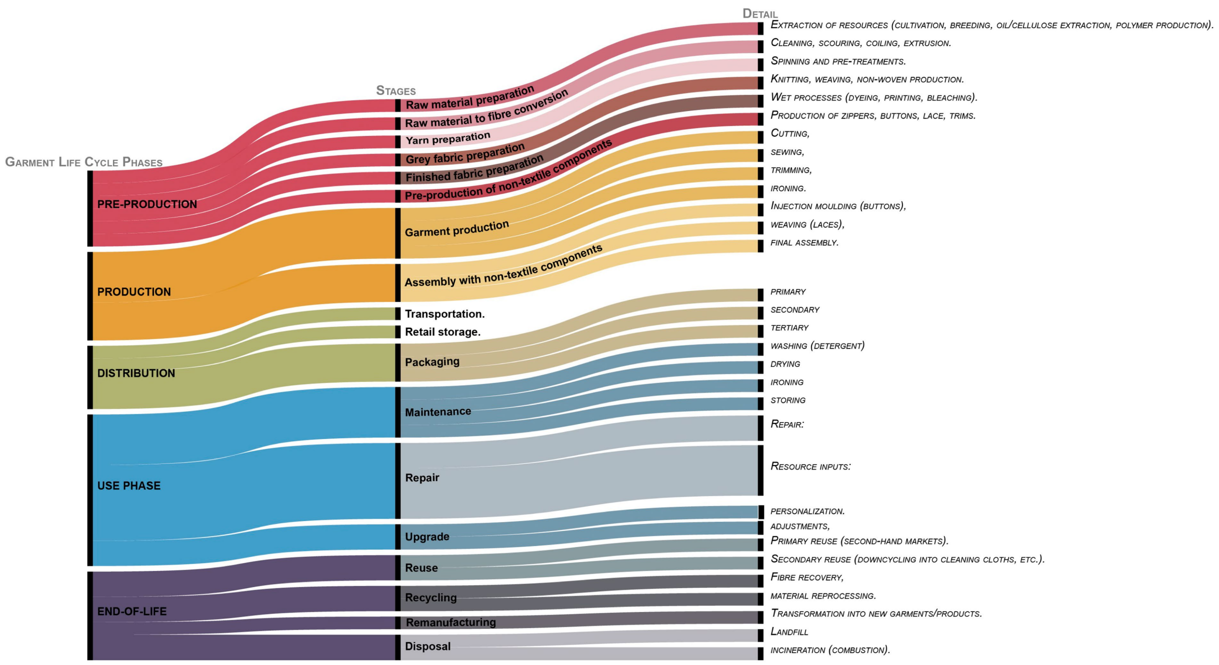

FIGURE 1
The clothing system's life-cycle boundaries and key stages in the apparel life cycle. Author elaboration from Tomaney (2015) and Vezzoli et al. (2022).

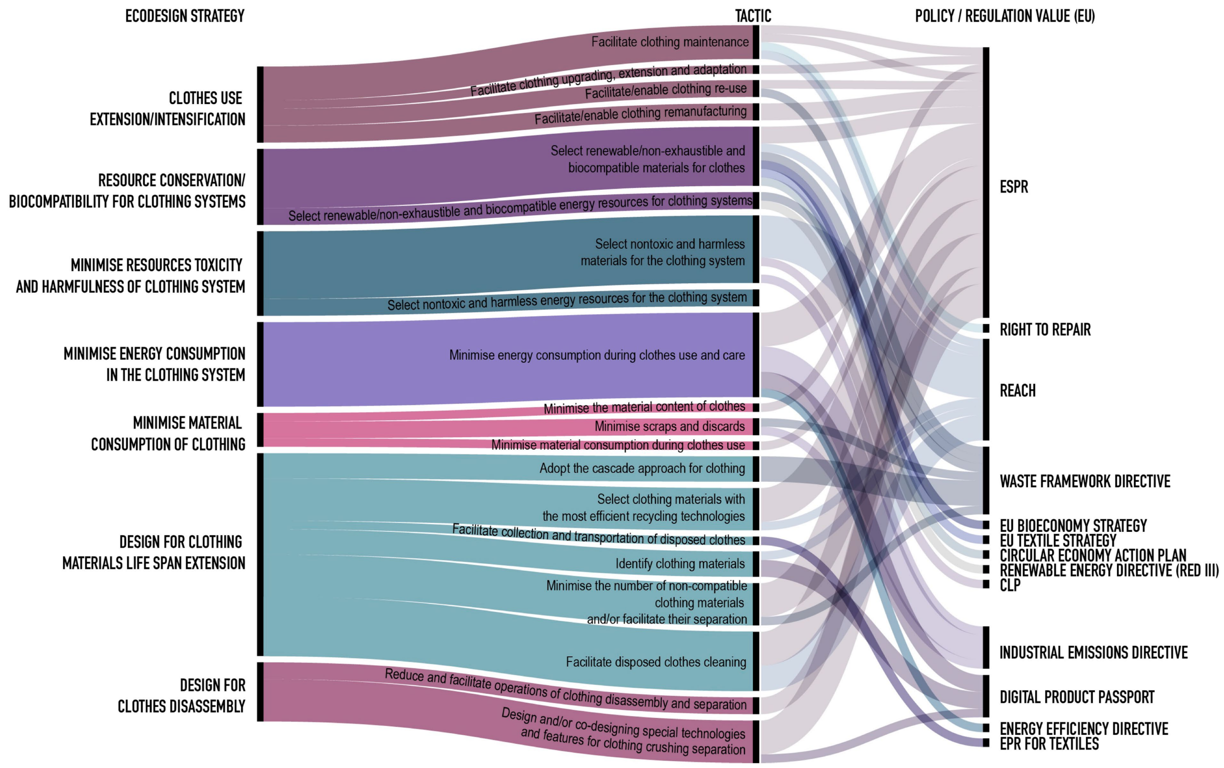

FIGURE 2
Comprehensive collection of material and design-related guidelines and tactics according to regulations and policy supporting the ecodesign approach for fashion application. Another version of the image is also provided in the Supplementary Materials document.

exist (e.g., the Ecodesign for Sustainable Products Regulation (ESPR), the REACH Regulation, the Waste Framework Directive, and the forthcoming Extended Producer Responsibility (EPR) scheme for textiles) and where policy guidance remains indirect or absent. By assigning policy references at the level of individual design actions, the table enables a fine-grained analysis of regulatory alignment across the product life cycle, from the initial design phase and material selection through to the use phase, until end-of-life disassembly and recycling.

This approach supports the identification of regulatory gaps, clarifies the degree of policy support for different ecodesign practices, and provides a structured basis for assessing how current and emerging EU regulations operationalise circular economy principles within the textile and clothing sector.

Detailed operational guidelines can be linked to the referring tactics (Vezzoli et al., 2022), producing a broad range of sustainability objectives, including the extension and intensification of clothing use, resource conservation and biocompatibility, the minimisation of material and energy consumption, the reduction of toxicity and harmfulness, and the extension of material life spans through recycling and disassembly-oriented design, involving in the reflection both design and material related choices. A complete collection of the detailed guidelines is provided in the Supplementary material document. The collection of all guidelines, with a focus on design or material, is reported in Tables 6, 7.

By bridging ecodesign regulations with strategies, tactics, and guidelines, fashion designers can consistently and holistically select textile materials for their work. However, for the sake of everyday practice usability, an operative tool must be designed to consider, at a glance, the technical, regulatory, sustainability, and aesthetic features of textile materials for fashion design applications. Hence, a mock-up tool has been designed as a preliminary attempt to realise a comprehensive database for textile material selection that can holistically consider, in a very usable way, all the complex information surrounding textiles.

3.3 Design of the mock-up tool

The results emerging from the integration of data establish the foundational framework for the development of a mock-up tool dedicated to textile material selection. Building on the clothing system life-cycle boundaries as defined by Vezzoli et al. (2022) and previous research by Mazzitelli et al. (2024), material-related information can be systematically categorised into the following stages: pre-production (raw material acquisition and refining), production (manufacturing, assembly, and finishing), distribution (packaging, transportation, and storage), use (wearing and care practices such as washing and ironing), and end-of-life (disposal or recycling). The analysis reveals that environmental impacts are not uniformly distributed across these stages, with the most significant impacts concentrated in the pre-production and production phases, as well as during the use phase.

Environmental information on products is typically communicated through numerical indicators, reflecting the technical and quantitative nature of environmental assessment methods such as Life Cycle Assessment (LCA) (ISO, 2006a; ISO, 2006b). However, several studies have demonstrated that detailed numerical results can be challenging to interpret and apply during the early stages of design, when critical decisions about materials and product architecture are made (Bovea and Pérez-Belis, 2012; Hallstedt et al., 2010). To facilitate the integration of life-cycle considerations at the design and textile selection stage, it is essential to explore approaches for communicating environmental information in a more accessible, at-a-glance format. Visual, qualitative, or semi-quantitative representations (e.g., heuristics, simplified indicators, or categorical labels) have been shown to support designers' cognitive processes more effectively and enhance the integration of environmental criteria into early-stage decision-making (Daalhuizen et al., 2015; Lofthouse, 2006). These approaches aim to complement, rather than replace, numerical data by translating complex life-cycle information into actionable insights suitable for early-stage design contexts.

Consequently, a hypothetical material datasheet within a material selection tool should encompass the following elements:

- Information on fibre nature, origin, and related certifications;
- Details on textile composition, physical properties (e.g., weight), hand description, and suggested use (with a focus on specific characteristics provided by the producer);
- Geographical information regarding fibre and/or textile production sites;
- Environmental impacts associated with textile production (cradle-to-gate, e.g., water use, ecotoxicity);
- Guidance on textile maintenance during the use phase (e.g., washing, ironing, physical durability);
- Information on textile end-of-life impacts (e.g., recyclability, biodegradability).

Based on this framework, Figure 3 presents a mock-up material datasheet for a digital selection tool, designed to support informed decision-making in fashion design.

By leveraging the specific set of properties associated with each Material, a corresponding selection of ecodesign guidelines (derived from the framework outlined in Tables 6, 7) can be assigned to each material record. For instance, if a material exhibits a high potential for microplastics release, the associated ecodesign recommendation may involve prioritising its application in garments that require infrequent washing. Similarly, if a material datasheet indicates that end-of-life options are limited to energy recovery, the relevant ecodesign guideline may emphasise design for remanufacturing or life-extension strategies aimed at delaying disposal. Accordingly, the tool should provide a clear and direct link between each material record and a tailored set of "Suggested Ecodesign Strategies," dynamically generated based on the material's specific property profile.

Additionally, moodboarding activity is widely recognised as a core practice within fashion and product design workflows, supporting early-stage ideation, aesthetic exploration, and the articulation of conceptual narratives through visual and material references (Eckert and Stacey, 2000; McKelvey and Munslow, 2012). Recent research in sustainable and digital design tools suggests that integrating material information directly into early ideation environments can enhance designers' ability to consider environmental criteria alongside aesthetic qualities (Lofthouse, 2006; Daalhuizen et al., 2015). Therefore, enabling the direct import of material data and material alternatives into a digital moodboarding environment has the potential to improve tool usability significantly, allowing designers to seamlessly align creative exploration with sustainability-informed material selection during the initial phases of the design process (Figure 4).

Once several material entries are collected, information filtering can be employed through a set of filters, as hypothesised in Figure 5, which are set on fibre nature, fibre origin, geographical production site, and certifications.

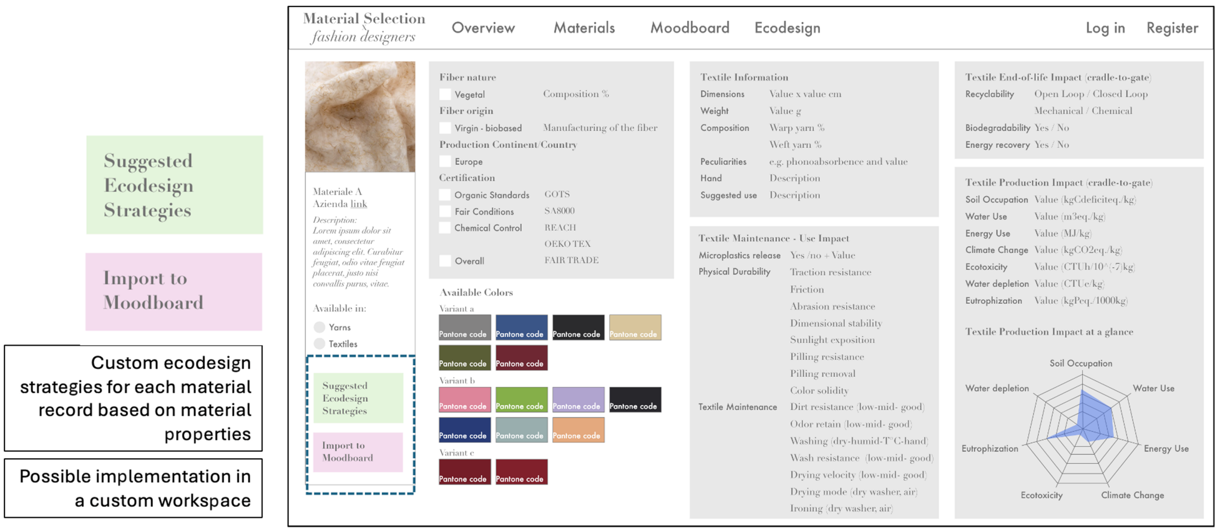

FIGURE 3
Material datasheet for fashion design material selection.

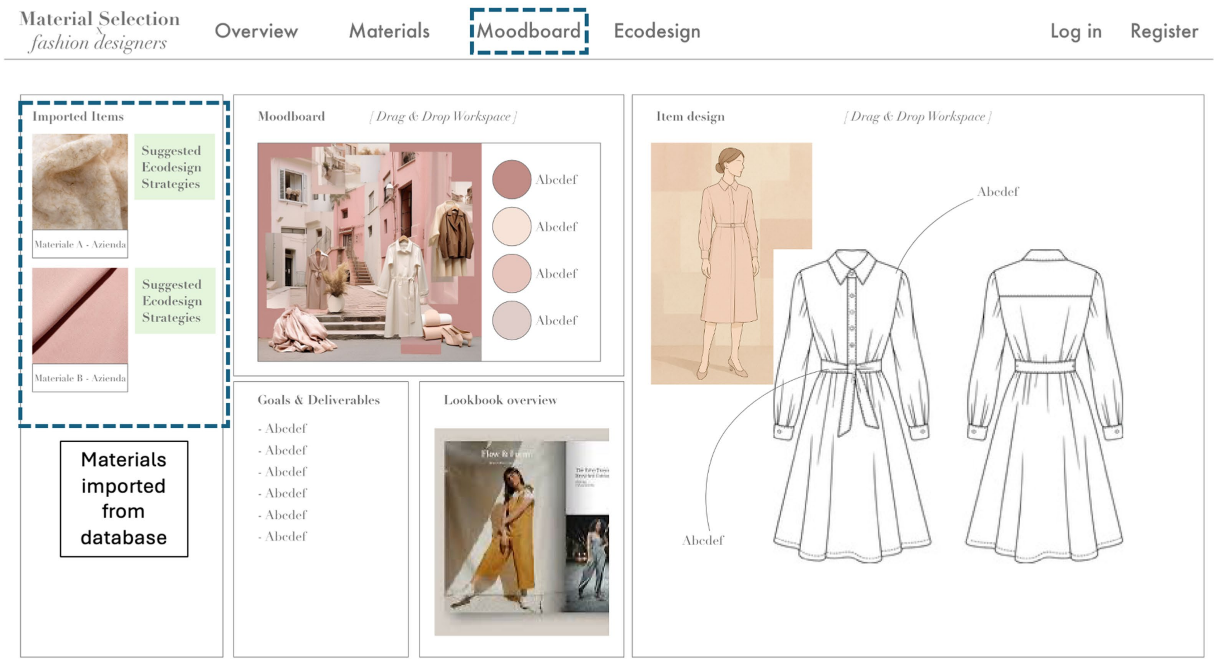

FIGURE 4
Material datasheet import into a moodboarding space.

Finally, Figure 6 presents a storyboard illustrating the potential use of the mock-up tool, encompassing the homepage, overview page, materials database/collection page, material datasheet, ecodesign guidelines overview, and moodboard page.

4 Discussion

The methodological and instrumental proposal presented in the article provides a solid foundation for advancing sustainability in the fashion industry. The integration of regulatory frameworks with practical design strategies demonstrates a comprehensive understanding of both the challenges and opportunities associated with sustainable fashion. However, the real-world effectiveness of this approach will ultimately depend on its implementation and validation in industrial contexts. A critical aspect concerns the consumers engagement, as emotional durability and circularity are shaped not only by material choices but also by user behaviour. While the article acknowledges the importance of systemic durability, which encompasses emotional, symbolic, and cultural dimensions, further research

TABLE 6 Design guidelines linked to textile materials to consider when selecting textiles.

Design focus	Guideline/Description	Related material property
Design to increase crease resistance	Prefer twisted yarns for better fabric recovery and woven structures such as basket and twill, where yarns move more freely, thus absorbing stress more easily.	Medium-low crease resistance
Design to increase stain resistance	Prefer natural fibres and/or circular cross-sections and fabrics with low surface hairiness. Fabrics with tight weaves or closed knits tend to be less easily dirty but are more challenging to clean.	Medium-low stain resistance
Low-impact textile structures	Prefer knitted textile structures to reduce energy consumption during production and pre-consumer waste.	High textile production impact
Functional textile structures	Ravelling: prefer plain weaves and interlock knits; avoid satin weaves and French-terry knits. Elasticity: prefer rib knits to avoid elastane. Cover and warmth: prefer tighter weaves and closed knits. Drape: structures with free-moving, low-twist yarns provide a softer drape.	Medium-low abrasion resistance
Design to increase abrasion and pilling resistance	Avoid textile structures in which yarns and fibres have high mobility and avoid fancy or bulky yarns, as they are more prone to abrasion.	Medium-low pilling resistance
Design to extend product lifespan	Apply functional surface treatments to improve durability without compromising end-of-life processing.	Low stain resistance, low colour fastness, low UV resistance
Functional variation of thicknesses	To avoid excessive material use or premature wrinkling, reinforce only the areas most subject to wear by layering materials.	High textile production impact
Design for connection strength	Use strong connections between different parts of the garment and accessories to ensure durability.	Critical end-of-life management
Multifunctional design	Transformable and versatile garments suitable for various contexts reduce the number of purchases and promote emotional durability.	Strong durability properties
Monomaterial product	Use a single material for the entire product.	Critical end-of-life management
Design with end-of-life in mind	Anticipate the possible end-of-life of the product during its design phase and facilitate this process.	Critical end-of-life management
Design for easily disassemblable components	Use reversible connections between parts (e.g., avoid high-tension stitching and rivets).	Critical end-of-life management
Modular design	Use materials with different end-of-life options in separate and easily disassemblable modules.	Critical end-of-life management
Minimisation of parts/ components	Simplify the product structure by reducing the number of parts and accessories to minimise material usage.	Critical end-of-life management, high textile production impact
Laser cutting of synthetic fabric patterns	Laser cutting thermally seals the edges of patterns, reducing microfiber release and fraying.	Fraying tendency, microplastic release
Textile and yarn structures to reduce microfiber release	Prefer twisted yarns and woven structures (instead of knitted ones) since they exhibit higher abrasion resistance, leading to fewer broken microfibers on the fabric surface.	Medium-low pilling resistance
3D printing technology	Use 3D printing for accessories to enhance personalisation and emotional durability.	
Aesthetic-functional patterned design	Prefer decorative patterns that can "mask" minor stains, postponing washing or disposal.	Low stain resistance, low colour fastness, low UV resistance
Elimination of unnecessary treatments	Prefer natural fibre colouration and replace polluting functional treatments with fibre blends.	
Use of functional textile structures	Utilise knitted or woven structures to enhance material performance and/or minimise the need for blends.	Critical end-of-life management

is required to further investigate the connection between material selection and consumer engagement.

The technical and complex nature of certain information relevant to material selection may limit its accessibility to practitioners without specialised training in industrial design or materials engineering. This highlights the need for broader dissemination through more accessible formats to promote wider adoption across the industry. The proposed digital tool, while innovative, remains at the mock-up stage and requires further development and empirical testing to validate its applicability and real-world impact. Overall,

TABLE 7 Material selection guidelines linked to textile materials to consider in textile selection.

Material selection focus	Guideline/description	Related material properties
Selection of efficiently recyclable materials	Select materials whose recycling technology results in the highest material recovery. Given the difficulties of fibre-to-fibre recycling, it is necessary to establish agreements with specialised recycling companies to ensure product recovery at the end of life.	Disposable end-of-life treatment
Selection of certified materials and suppliers	Prefer materials and suppliers certified by third parties for their environmental impact and adherence to ethical standards.	No, few certifications available
Selection of renewable materials	Prefer renewable raw materials (and rapidly renewable ones) to avoid the depletion of fossil resources.	Non-renewable material origin
Selection of recycled materials	Prefer recycled raw materials to minimise virgin material extraction and promote circularity.	High percentage of virgin material origin
Selection of materials efficient in water consumption	Prefer raw materials that minimise water consumption during fibre cultivation or production.	High textile production impact
Selection of less energy-intensive materials	Prefer raw materials that minimise energy use during the production phase.	High textile production impact
Selection of materials that do not release microplastics	Prefer raw materials that do not contribute to microplastic pollution during the production and use phases.	Microplastics release
Selection of alternative materials to the most commonly used ones	Prefer alternative fibres to reduce global environmental stress caused by high market demand.	Virgin material origin
Select materials with high dirt resistance	Prefer fabrics that naturally exhibit high dirt resistance to minimise the need for frequent washing. For materials that easily accumulate pollutants, choose easily washable textile structures.	Dirt resistance medium-low
Selection of materials with high colour fastness	Prefer fabrics with good colour fastness to avoid premature disposal of garments.	Poor colour fastness
Selection of materials with high durability	Prefer materials with high abrasion and pilling resistance. When pilling occurs, prefer natural materials that are easier to remove and have more resistant textile structures.	Pilling resistance medium-low
Select materials with high crease resistance	Prefer fabrics that naturally have high crease resistance to minimise the need for frequent ironing at high temperatures. For materials that wrinkle easily, select textile structures that can absorb stress more effectively.	Medium-low crease resistance
Selection of materials with high odour resistance	Prefer fabrics that naturally resist odours, avoiding frequent high-temperature washing that contributes to the garment's environmental impact and reduces physical lifespan.	Medium-low odour resistance
Selection of fast-drying materials	Prefer fabrics that naturally dry quickly to avoid using tumble dryers, which are energy-intensive and increase environmental impact during use.	Low drying velocity
Selection of easy-to-maintain materials	Prefer materials that do not require specialised maintenance skills and can be easily maintained by users. Handwashing or complex maintenance could discourage proper care and reduce material durability.	Check washing options
Selection of materials with minimal human toxicity	Prefer raw materials whose production minimises risks of human toxicity.	High textile production impact
Selection of materials with minimal climate impact	Prefer raw materials whose production minimises contributions to climate change.	High textile production impact

the article makes a significant contribution to the field by providing a structured methodology for sustainable material selection; however further research and practical validation are necessary to fully realise its potential and address the multifaceted challenges of sustainable fashion.

In conclusion, this article underscores the pivotal role of material selection in fashion design, particularly in relation with sustainability and circularity. Through a comprehensive analysis of European and international regulations, environmental certifications, and existing methodologies, the study proposes a structured approach to guide designers toward more informed and sustainable material choices. The introduction of a digital tool mock-up represents an innovative step towards integrating technical, regulatory, and sustainability-related information into the design process, thereby facilitating the transition towards circular and sustainable fashion practices. The proposed methodology not only supports the physical durability of garments but also addresses emotional and systemic durability, which are essential for extending product lifespans and reducing environmental impacts.

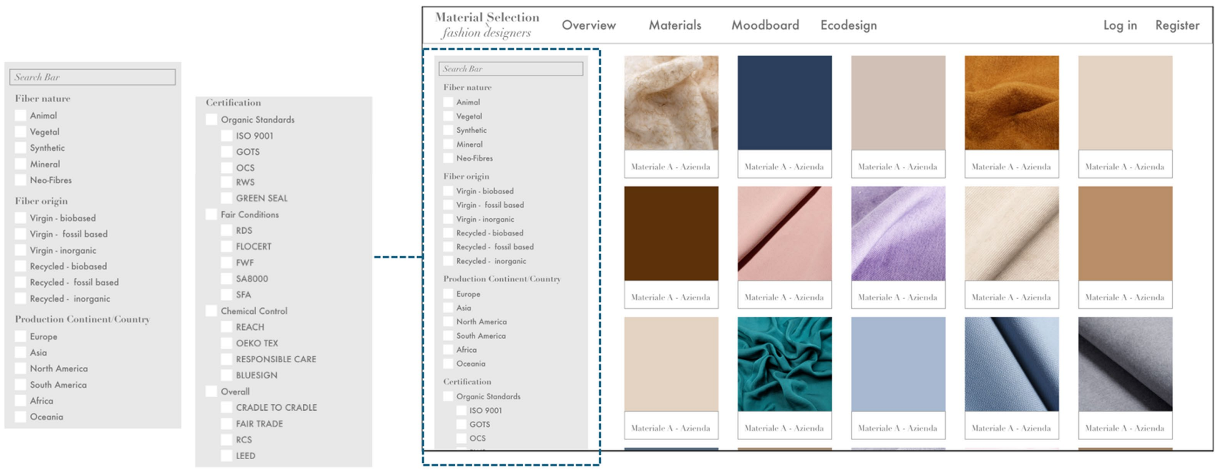

FIGURE 5
Material scouting through filter research hypothesis.

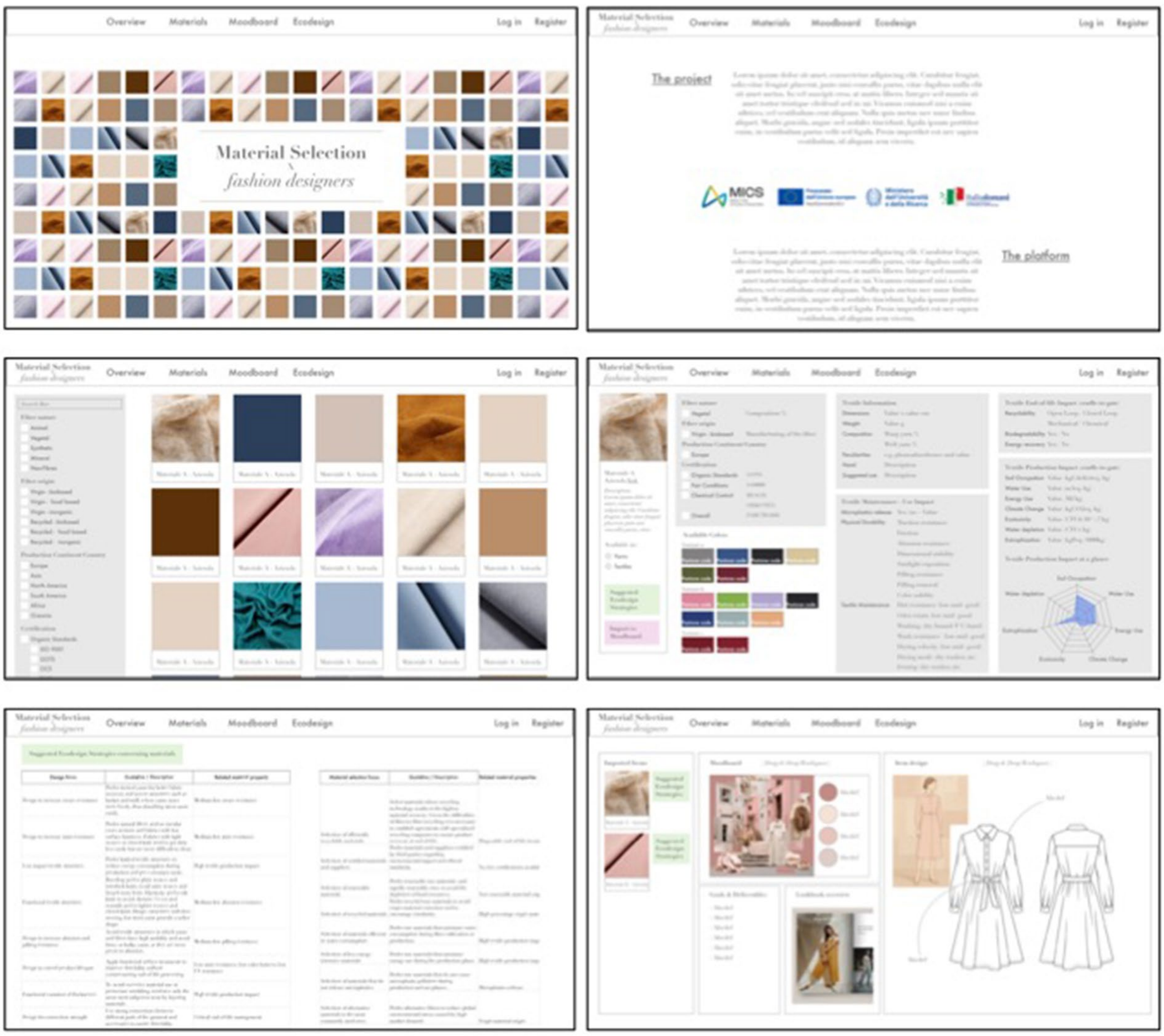

FIGURE 6
Storyboard of the tool. From frame up left: Homepage, overview page, materials database/collection page, material datasheet, ecodesign guidelines overview, moodboard page.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

FP: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Visualization, Writing – original draft, Writing – review & editing. BD: Formal analysis, Project administration, Supervision, Writing – review & editing.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frsus.2026.1773542/full#supplementary-material

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