Advanced and Systemic Design Approaches to Smart Packaging for the Made in Italy Fashion Transition.

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Abstract
This paper presents an Advanced and Systemic Design approach to smart packaging as a lever for a circular transition, applied to the Made in Italy fashion system. The study investigates how this approach can guide the sector's transition by integrating digital technologies and redefining packaging as a strategic interface for circularity. To address contemporary challenges, such as environmental degradation, regulatory shifts, and digital transformation, this work aims to reframe packaging from a technical object to a multidimensional artefact that supports knowledge exchange, encourages collaboration across sectors, and helps stakeholders make informed decisions. By combining Systemic and Advanced Design approaches, the study investigates how smart packaging can align technological innovation with ethical responsibility, promoting transparency, traceability, and value regeneration. The research includes an experimental project involving a group of universities and companies from the fashion, packaging, and information technology sectors. Using a co-design methodology, the project developed a smart, reusable packaging prototype incorporating blockchain infrastructure. This solution responds to both logistical and communication needs while anticipating and aligning with upcoming European sustainability policies such as the Digital Product Passport. This paper shows how theoretical insights can relate to applied innovation to highlight the significant role of design in steering systemic transitions. Smart packaging, therefore, can be seen as a catalyst for distributed innovation, serving as a bridge between physical systems, digital tools, and cultural values across the fashion supply chain

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CONTEMPORARY CHALLENGES IN THE FASHION SUPPLY CHAIN AND MADE IN ITALY

SYSTEMIC ISSUES IN THE FASHION SUPPLY CHAIN

The fashion sector stands out as one of the most critical when addressing a circular transition due to its long and fragmented value chains.
Each phase of the value chain, from production to distribution up to current consumption patterns, negatively impacts the use of natural resources, particularly water, soil, and energy, thereby contributing substantially to climate change (European Environment Agency, 2022).
During the fibre production phase, synthetic materials rely on non-renewable resources such as petroleum, while the most widespread bio-based alternatives, though renewable, require copious quantities of water and the use of environmentally harmful pesticides. Textiles are often composed of mixed fibres: natural, artificial, and synthetic; this makes recycling processes particularly challenging with currently available and economically viable technologies.
At the design level, the adoption of fast and responsive models, such as those used in fast fashion, enables companies to introduce new garments on a weekly basis. This fosters a constant desire for expressive novelty among consumers (Jayot, 2020), contributing to the rapid obsolescence of clothing items and their transformation into waste within a short time frame. The need for speed in production often results in lower garment quality, with products made from less durable and more fragile materials.
From a manufacturing perspective, cut-and-sew production methods generate a significant amount of pre-consumer waste that is rarely recovered. However, the criticalities of the system are not limited to environmental aspects but also extend to the social dimension. The fabless model, characteristic of fast fashion and based on the absence of proprietary manufacturing facilities, allows companies to outsource production, thereby circumventing direct social and environmental responsibilities related to manufacturing (Jayot, 2020), which are instead transferred to partners operating in countries with less stringent regulations than those in Europe.
The use phase also entails considerable impacts: domestic laundering of garments, especially those made from synthetic fibres, contributes to the release of microplastics into the oceans; materials such as polyester, although durable, take centuries to degrade in the environment. According to recent estimates, garments in the current fast fashion model are worn on average only 7 to 10 times before being discarded (Ellen MacArthur Foundation, 2021), further intensifying the exploitation of both fossil-based and renewable resources for products with extremely short lifespans.
In response to these challenges, European institutions are progressively introducing regulatory instruments to guide the sector towards more sustainable and circular models. Among the most relevant initiatives is the Ecodesign for Sustainable Products Regulation (ESPR), a key component of the European Green Deal. The ESPR (European Commission, 2022) aims to establish mandatory ecodesign requirements for a broad range of products, including textiles, by promoting criteria such as durability, reparability, recyclability, and the incorporation of recycled content. These measures, supported by tools like the Digital Product Passport, are intended to enable traceability across the entire value chain and enhance transparency for consumers, thereby encouraging more responsible purchasing behaviours.

Such regulations represent an effort to steer businesses towards a systemic transition, where sustainability becomes not an option but a structural requirement for fashion products. Each phase of the fashion system, outlined here for illustrative purposes, generates harmful inputs and outputs, from intensive resource consumption to ecosystem impacts. This complexity must be addressed not only at the systemic level but also clearly and transparently communicated to end users, enabling them to make more informed and responsible choices.
Of particular interest in this scenario is the Italian context, which plays a crucial role in the global fashion discourse, particularly through the Made in Italy ecosystem. The following section examines the challenges faced by this ecosystem, which are closely linked to those affecting the broader fashion sector discussed above. This framing completes the scenario in which design-driven approaches can strategically leverage packaging as a tool for systemic change, translating global pressures into locally grounded actions that align with ongoing European regulatory transitions, particularly in areas such as traceability, data transparency, and eco-design requirements.

TRANSFORMATIONS FACING THE MADE IN ITALY ECOSYSTEM

In recent years, the transformation of the Made in Italy ecosystem has increasingly intersected with European regulatory pressures towards traceability, digitalisation, and sustainability.
The Made in Italy phenomenon emerged as a powerful industrial and cultural identity in the 1970s, coinciding with Italy's Industrial Districts' (IDs) affirmation as a competitive alternative to the Fordist model (Bellandi & De Propris, 2015; Sforzi, 2015). These districts, rooted in territorial and artisanal know-how, fuelled a production system based on small and medium-sized enterprises (SMEs), flexible specialisation, and strong social embeddedness (Becattini, 1991; Piore & Sabel, 1984). This localised structure ensured close control over production phases, enabling high traceability of materials and processes and strengthening consumer trust in the quality and authenticity associated with the Made in Italy label.
However, over the last two decades, it has undergone profound transformations. The 2008 global financial crisis marked the beginning of a restructuring phase characterised by the redefinition of the IDs' boundaries, which was also correlated with the entrance of new emerging countries on the market, thereby exacerbating the lengthening of supply chains due to competitiveness logic. Moreover, the COVID-19 pandemic further worsened structural imbalances, revealing weaknesses in digital preparedness, supply chain coordination, and resilience to global shocks (Grosso et al., 2021).
Nowadays, Made in Italy operates within an increasingly complex and demanding environment shaped by global competition (Giuliani & Rabellotti, 2017), technological transitions, and environmental challenges. SMEs still represent the backbone of Italian production. However, their small size, once a strength, now limits their capacity for innovation and engagement in digital and sustainable transformations (Rabellotti et al., 2009; Salvioni et al., 2021). Many firms remain excluded from the opportunities offered by digitalisation and circular economy models due to gaps in infrastructure, skills, and governance (Matarazzo et al., 2025).
In parallel, globalisation has transformed the very notion of production origin. The fragmentation of global value chains and the relocation of production

phases across multiple countries have introduced ambiguities in the legal and economic definition of 'Made in Italy.' While the label is perceived globally as a guarantee of quality, design, and national production, in practice, its use is regulated by the EU's non-preferential origin criteria, particularly Article 60 of the Union Customs Code that allows goods to carry the Made in Italy label if their 'last substantial transformation' occurs in Italy. However, this can apply even when most of the value chain is located abroad. The lack of clarity on what constitutes a 'substantial transformation' has created legal grey areas, enabling producers to exploit the brand's market appeal without adhering to its traditional values (Garcia-Torres et al., 2022).

This regulatory ambiguity has contributed to the proliferation of counterfeiting and deceptive practices that undermine the authenticity of Italian products. Misusing the Made in Italy label damages the reputation of genuine producers and weakens consumer trust, particularly in sectors such as fashion, where product origin is closely tied to brand identity and perceived value (Simeone et al., 2022).

Legislative attempts to strengthen origin and "Made in Italy" labelling—such as Decree-Law 135/2009 (Italy, 2009a), subsequently converted into Law 166/2009 (Italy, 2009b), and Law 55/2010 (Italy, 2010), also known as the Reguzzoni–Versace–Calearo Law for textile and leather products—have struggled to achieve full implementation due to regulatory misalignment at the European level.

The competitiveness of Italian firms increasingly depends on their ability to ensure product traceability, comply with environmental standards, and communicate authenticity through transparent and verifiable data (Bettiol et al., 2022). Thus, the hybridisation between traditional manufacturing excellence and emerging technological and regulatory frameworks is becoming essential.

In this context, Made in Italy is no longer a static label but an evolving ecosystem that must reconcile its heritage with the demands of a global, digital, and circular economy. This transition requires rethinking production processes and the interfaces between products, users, and systems. The challenge is to preserve the intangible values, creativity, craftsmanship, and territorial culture while adopting new tools for sustainability, transparency, and systemic innovation.

In this transition, the need for reliable, verifiable, and interoperable information along the value chain becomes central. Emerging requirements for traceability and data transparency, accelerated by the forthcoming Digital Product Passport, underscore the need to redesign interfaces between products, users, and systems. Within this framework, the integration of Systemic, Advanced, and Transition design provides the methodological foundation for addressing these complex scenarios, in which packaging acquires renewed strategic relevance. Through these methodological lenses, its potential to be a carrier of material and digital information that can support new models of authenticity, sustainability, and circularity leverages it as a catalyst for systemic change, while connecting global pressures to actionable, locally grounded interventions.

THE ROLE OF DESIGN IN THE CIRCULAR TRANSITIONS

SYSTEMIC DESIGN: MAPPING INTERDEPENDENCIES TO SUPPORT CIRCULAR STRATEGIES

In this discourse about a circular transition of a complex ecosystem, such as the Made in Italy fashion system, examining the broader context when designing interventions becomes crucial. Systemic Design (SD) provides a methodological foundation for understanding and managing complex systems, such as supply chains, territories, and socio-ecological networks, while fostering circular business models.
The Systemic Design (SD) methodology of the Politecnico di Torino is rooted in foundational principles that align with the tenets of the CE (Barbero, 2017). Systemic Design provides a framework to translate the foundational ideas of the Circular Economy into operational strategies. By examining the relations among processes, actors, and territorial resources, it highlights how material, energy, and information flows can be reorganised to support cycles of value regeneration (Bistagnino, 2011). This systemic perspective underpins key CE principles, such as designing out waste, by showing how outputs from one process can serve as inputs for another. At the territorial scale, SD's attention to locally available resources and context-specific configurations reinforces CE's emphasis on strengthening local economies. Moreover, its focus on diversity and adaptive capacity aligns with the CE's understanding of resilient systems. Taken together, SD offers a methodological basis that renders the CE's conceptual principles applicable in practice, supporting a more effective transition towards sustainability. In practice, SD employs maps and visualisations to render the intricate interdependencies within socio-ecological and industrial systems perceptible (Battistoni et al., 2019). This process is instrumental in transforming abstract CE goals into concrete, actionable objectives. Visual tools, including complexity maps, have the capacity to simultaneously chart systemic loops, material and energy flows, stakeholder relationships, and territorial characteristics. By capturing these multilayered connections, complexity maps reveal critical intervention points where circular actions, such as waste elimination, resource regeneration, and local empowerment, can gradually be achieved.

ADVANCED DESIGN FOR CIRCULAR TRANSITIONS: THE FIGURE OF THE TRANSITIONAL INDUSTRIAL DESIGNER

In addition to going beyond the product dimension and embracing the context in which products are made, to guide a transition, it is also essential to think ahead and predict future scenarios and their impacts. Based on the research activities developed at Alma Mater Studiorum - Università di Bologna, a new profile of designer is emerging, capable of addressing the complexities of contemporary production chains in a systemic and anticipatory manner. The so-called 'Transitional Industrial Designer' (TID) (Zannoni et al., 2024) integrates knowledge from Advanced Design (AD) (Celi, 2015) and Transition Design (TD) (Kossoff et al., 2015), leveraging anticipatory practices (Celaschi & Celi, 2015; Celaschi et al., 2019) to guide the transformation of social, economic, environmental, and productive contexts through a holistic approach that considers all elements, both material and immaterial, as interconnected components of an integrated ecosystem.

AD equips designers with the ability to think in anticipatory terms and to respond to the rapid changes of contemporary contexts, fostering continuous innovation (Celi, 2015). This is achieved by enhancing the designer's capacity to mediate between different bodies of knowledge (Celaschi, 2008b) and to operate systemically in the definition of products and processes. TD, originating from the fields of service design and design for social innovation (Irwin, 2015), seeks to address complex, deep-rooted, and long-term problems through a systemic and transformative design perspective (Irwin, 2018).
The integration of these two approaches enables action at social, strategic, and conceptual levels (Irwin, 2015) while maintaining a systemic vision that allows for intervention across multiple scales, from the micro level (aesthetic, material, chemical) to the macro level (processual, relational, holistic, and symbiotic) (Zannoni et al., 2024). The TID considers the entire value chain, critically and proactively evaluating the future impacts of every design decision and mediating among stakeholders with the aim of generating sustainable and circular solutions.
Given these competencies, the TID approach has proven particularly suitable to enable transversal intervention across the entire supply chain. It is a multi-agent and multidisciplinary process requiring the engagement of diverse actors and the integration of multiple knowledge domains, coordinated across all phases of the production system.

DESIGN TO ENABLE CIRCULAR TRANSITIONS

The integration of Systemic, Advanced, and Transition Design enables the rethinking of packaging not just as a container but as a dynamic interface that mediates knowledge, coordinates multi-actor interactions, and drives circular transitions across the Made in Italy supply chain. This integration has been examined within the framework of Spoke 1[1] of the MICS research programme. Coordinated by Alma Mater Studiorum - Università di Bologna and involving 13 partners from the MICS Extended Partnership, Spoke 1 focuses on mapping and developing a portfolio of digitally enhanced solutions, including technologies, methodologies, and tools, to support, augment, and validate design and decision-making processes, while embedding circularity across the entire life cycle of products and machines. Its overarching goal is to empower industrial designers to operate across the value chain by integrating digital solutions that mediate among diverse stakeholders and anticipate future impacts, thereby enabling sustainable innovation and facilitating circular transitions.
This approach combines tangible elements, such as advanced manufacturing processes, innovative materials, and systems for assessing environmental, social, and economic impacts, with intangible and human-centred dimensions, including gender equity, ethical values, civic engagement, and psycho-social well-being. Within this framework, sustainability is understood as the convergence of technological advancement and socio-humanistic values. Design, therefore, functions both as a mediator of knowledge and as a catalyst for collaborative, multi-stakeholder processes. Digitalisation serves as a unifying thread throughout the research, facilitating the management of information flows and the anticipation of the effects of design decisions.

[1] https://www.mics.tech/spokes/spoke-1/

Digital tools are not merely operational supports but function as active agents of interaction and knowledge exchange.
Among the initiatives developed within Spoke 1, several focus on the role of design in mediating inter-organisational relationships within and across supply chains, contributing to the emergence of industrial symbiosis (Lange et al, 2017). One particularly significant example is the project "FuturE-Pack. Digital Advanced Design for the Enhancement of Packaging as a 'Broadcaster' in the Made in Italy Supply Chain"[2] led by Alma Mater Studiorum - Università di Bologna in collaboration with Politecnico di Torino and Università degli Studi di Firenze. The project explores the application of smart technologies to enhance packaging as a strategic communication interface within the Made in Italy ecosystem. The study focuses on the e-commerce sector of the fashion system as a first application case, with the intention of extending it to other strategic sectors of Italian manufacturing.
The research investigates how packaging can function as a dynamic medium for recording, translating, and transmitting product-related information throughout the entire life cycle. Conceived as a true broadcaster, packaging supports more informed, transparent, and sustainable decision making across production and consumption networks.
In this way, Design reframes packaging from a purely technical object into a powerful device capable of mediating knowledge, structuring systemic interactions, and enabling informed choices throughout the product life cycle. Packaging emerges as a strategic interface that facilitates communication, promotes cross-sector collaboration, and activates sustainable value creation along the supply chain. Moreover, it becomes a driver of innovation and a bridge between technological and human-centred domains, reinforcing the pivotal role of Design in supporting circular transitions within complex production ecosystems.

SMART PACKAGING FOR CIRCULAR TRANSITIONS IN THE FASHION SUPPLY CHAIN

PACKAGING AS A PLATFORM FOR INNOVATION: TECHNOLOGICAL OPPORTUNITIES AND ETHICAL COMMITMENTS

Packaging is arguably one of the most pervasive objects of everyday life: it is the result of industrial production processes, yet also an expression of contemporary culture. Over time, packaging has become a complex artefact with significantly expanded functions (Bucchetti, 1999, 2005; Ciravegna, 2010, 2017). Primarily, it is an object of use that protects, preserves, and facilitates the transportation of contents after production. In consumption contexts, it enables users to physically interact with both content and container, for dispensing, handling, processing, and so on. However, packaging is also a communication device (Bucchetti & Ciravegna, 2009), allowing products to stand out on shelves, attract consumer attention, convey brand values, provide essential information (e.g., expiry dates, ingredients), and offer guidance on use and disposal.
Beyond functioning as a container and communication medium, packaging may be understood metaphorically as a 'bridge': it connects subjects and

[2] https://www.mics.tech/projects/1-1-future-pack-digital-advanced-design-for-the-enhancement-of-packaging-as-a-broadcaster-in-the-made-in-italy-supply-chain/

contexts that are temporally and geographically distant (Chiarenza & Formati, 2022), linking production with consumption and facilitating relationships, both rational and emotional, between brand narratives and target audiences. It also serves as an informational interface through which end users can make informed choices (Bucchetti, 2007) regarding product use, accessibility, and end-of-life management.

Given this multifaceted nature, packaging design requires interdisciplinary expertise and the coordination of various stakeholders. It should therefore be viewed as the outcome of an integrated set of choices made by a plurality of actors, each playing a specific, direct or indirect, role in its definition. These actors, and the network of relationships they establish in designing, producing, and managing packaging throughout its life cycle, constitute the so-called 'packaging system' (Bucchetti & Ciravegna, 2009; Ciravegna, 2010, 2017; Giardina & Celaschi, 2020; Giardina, 2024; Mauri, 1996).

Compared with other sectors, the packaging supply chain is particularly fragmented across time and space. The design process is shaped through successive, incremental interventions occurring at different stages, in diverse ways, and for distinct purposes. In this context, design assumes a crucial directorial and mediating role (Celaschi, 2008a, 2008b), synthesising multiple inputs to produce packaging solutions that reconcile the diverse needs of all involved actors and the various functions of the artefact, bridging its communicative and instrumental dimensions.

Innovation in packaging, therefore, extends beyond technological enhancements of the container itself (Lydekaityte & Tambo, 2020), such as smart or high-performance packaging systems, and becomes central to a creative process aimed at solutions that meet product requirements, address supply chain needs, reflect user expectations, and respond to broader responsibilities towards society and the environment. Packaging can thus be interpreted in a dual perspective: physically as an object, and metaphorically as a platform for innovation, through which material constraints, market dynamics, emerging technologies, social demands, sustainability imperatives, and circular logics converge. This approach leverages collaborative activities among multiple actors (Zamenopoulos & Alexiou, 2018) to drive transformation within the contexts in which it operates and to outline desirable futures through an anticipatory perspective.

In light of this, it is necessary to critically re-evaluate the role of packaging in response to contemporary social and environmental crises. Rather than regarding it as a disposable by-product or mere source of pollution, packaging should be recognised as a necessary artefact with essential social, logistical, and communicative functions, which are rendered even more visible during emergency contexts such as pandemics or humanitarian crises (Ciravegna, 2020). This perspective calls for the adoption of an 'ethics of responsibility' (Jonas, 1979; Weber, 1919), attentive to the entire life cycle of packaging and the shared accountability of all actors in the packaging system, from producers to end-users. Within this framework, design becomes a form of mediation between technical performance and ethical awareness, where innovation is driven not solely by efficiency or user experience, but by a broader purpose aimed at generating positive impacts on both people and the planet (Spence & Rushing, 2009).

The integration of emerging technologies, and smart technologies in particular, offers new potential for transforming packaging from a passive container into an active, intelligent interface. Smart packaging systems, enabled through digital sensors, RFID tags, QR codes, and IoT connectivity,

enhance both the functional and communicative dimensions of packaging (International Organization for Standardization, 2024), contributing to broader objectives such as traceability, transparency, and user engagement. Within this framework, packaging supports circular transitions by enabling the monitoring of material flows, facilitating reuse and recycling practices, and providing critical information on origin, composition, and end-of-life scenarios. These technological advances strengthen sustainability on both environmental and social fronts. Environmentally, they promote more efficient resource management and waste reduction through data-driven decision making. Socially, they support more responsible and informed consumption practices, empower users to contribute to sustainability objectives, and open new channels for inclusion, accessibility, and ethical accountability across the supply chain. In this light, smart packaging emerges as a key enabler in the convergence between digital transformation and systemic ecological transition.

The intersection between packaging innovation and smart technologies provides a key entry point for addressing the challenges of traceability, sustainability, and user engagement discussed above.

SMART TECHNOLOGIES FOR CIRCULARITY AND SUSTAINABILITY

A considerable increase in the adoption of smart technologies has been observed within the industry, particularly in the domains of food and pharmaceuticals. The implementation of such technologies has been particularly salient in addressing concerns related to traceability, counterfeiting, reduction of waste, and consumer engagement. In this regard, smart technologies are emerging as strategic enablers for the fashion industry's transition towards more sustainable and circular supply chains. Technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), blockchain, and big data analytics enable companies to improve efficiency, transparency, and sustainability by optimising resource usage, minimising waste, and extending product life cycles (Massari et al., 2023; Neri et al., 2025; Schilling & Seuring, 2024).

Blockchain, in particular, introduces a critical layer of transparency and accountability across supply chains. It enables both companies and consumers to verify that materials are ethically sourced. It also ensures they are reused or recycled wherever possible, ensuring compliance with environmental standards (Samuels & Pelser, 2025). Moreover, it enhances inventory management, prevents fraud, and supports social equity by verifying product origins, benefiting small producers and promoting fair wages (Massari et al., 2023; Piron et al., 2024; Wang et al., 2023).

Beyond traceability, digital technologies advance circularity through enhanced resource optimisation. AI and big data analytics automate processes, enhance demand forecasting, streamline inventory management, and limit overproduction, thereby reducing waste and energy consumption (Kristoffersen et al., 2020; Samuels & Pelser, 2025; Yiyan & Zakaria, 2023). These capabilities also improve decision making and help identify new opportunities for recycling and material repurposing (Mahajan et al., 2023; Kristoffersen et al., 2020).

IoT enables real-time monitoring of resource flows, allowing businesses to detect inefficiencies and take corrective action. By collecting and analysing live data, IoT facilitates resource optimisation, waste prevention, and the

extension of product life cycles (Rusch et al., 2023). It also improves energy efficiency and supports circular strategies by enabling reverse logistics and tracking material flows, essential for identifying synergies in industrial symbiosis (Kristoffersen et al., 2020; Wang et al., 2023).
Digital platforms and cloud-based tools enhance collaboration across supply chain actors. They facilitate shared logistics, redistribution of unsold inventory, and reduced reliance on virgin raw materials. These technologies also underpin circular business models, such as product-as-a-service and leasing, which decouple consumption from resource extraction while maintaining customer value (Rejeb et al., 2022; Winkelmann et al., 2024).
The impact of these technologies spans economic, environmental, and social dimensions. Economically, they drive operational efficiency, lower transaction and logistics costs, and open new revenue streams through circular services (Samuels & Pelser, 2025; Wang et al., 2023). Environmentally, they optimize both input (resource use) and output (waste generation), while enabling practices such as reverse logistics, product life extension, remanufacturing, and industrial symbiosis (Harikannan & Vinodh, 2025; Kristoffersen et al., 2020; Rejeb et al., 2022). Socially, digitalisation enhances transparency, strengthens accountability, improves working conditions, and supports ethical labour and sourcing practices (Rani et al., 2024; Schilling & Seuring, 2024).
By combining traceability, resource efficiency, and consumer empowerment, digital technologies not only facilitate compliance with EU sustainability initiatives such as the Digital Product Passport and Extended Producer Responsibility but also accelerate the systemic transformation towards a more circular and resilient textile economy (Hörner Bussolo et al., 2024).

CASE STUDY: A CIRCULAR SMART PACKAGING SOLUTION FOR A MADE IN ITALY FASHION BRAND

Drawing on the previously discussed integration of design, digital technologies, and circular strategies, this case study examines how these elements were applied to the development of smart packaging for the fashion e-commerce sector. This experimental project simulated a co-design scenario involving three main actors: a fashion brand, a packaging manufacturer, and a technology partner responsible for the digital infrastructure.
ZEROBARRACENTO was chosen for its strong alignment with sustainability and circularity, assumed as core criteria for the project's coherence. The brand adopts zero-waste manufacturing techniques that eliminate pre-consumer textile waste through optimised cutting patterns. It uses only certified materials from responsible suppliers, who produce fabrics from regenerated textile waste via environmentally and socially conscious processes. Garments are designed to reduce multi-materiality, favouring compatible selvedge over non-recyclable components like buttons or zips, to facilitate recyclability using existing technologies. Their fluid, inclusive fit supports extended use across diverse body types and users.
Through a series of interviews and collaborative meetings with the brand, the product selected for experimentation was identified, and a set of needs, values, constraints, and production-related requirements was collected. As part of the methodological framework, a series of cards was developed to systematise five key domains: the brand's values; the product characteristics, including circular innovations and technical constraints; material specifications focused on sustainability and traceability; the production and

distribution chain; and the current packaging solution, assessed in terms of both use and communication functions.
The resulting analysis led to the creation of a list of design requirements, which guided the development of smart packaging guidelines dedicated to ZEROBARRA-CENTO's Luciana overcoat. These requirements were based on the needs of various actors across the value chain, each contributing, either directly or indirectly, to the product's physical and symbolic construction. The actors considered, both directly and in a broader systemic sense, include the product itself, the brand owner, supply chain operators, the end users, society, the territory, and the environment.
A synthesis framework was developed, cross-referencing interview insights and unmet needs from the existing packaging, leading to the identification of four primary areas for intervention:

1. Communication on the environmental impacts of the supply chain.
2. Valorisation of brand identity through the package, not only graphically, but also symbolically, via all its elements (such as morphology, materials, and superficial treatments).
3. Standardisation and adaptability of packaging to accommodate diverse products.
4. Durability and protection against environmental factors such as humidity, rain, dust, temperatures, and odours.

Packaging manufacturer Movopack was chosen for its focus on circular solutions and the "packaging-as-a-service" model it uses in e-commerce, which significantly reduces waste compared to single-use solutions. Its packaging is made from recycled polypropylene (PP), R-PET, and polyester; it is durable, lightweight, waterproof, and reusable up to twenty times. After use, it can be folded and returned via any mailbox using a prepaid label and QR code, sanitised, and recirculated. Movopack's highly customisable formats also function as branding and communication tools. For the Luciana overcoat, one of the largest items in ZEROBARRACENTO's collection, Movopack

Fig. 1
Prototype of the reusable packaging for ZEROBARRACENTO produced by Movopack. Graphics by L. Rosato, developed within the FuturE-Pack project.

provided a format capable of holding the garment while remaining compressible for smaller volumes; as shown in **Fig. 1**, the opening and closing system allows for adaptability.

Astrakode, a software firm specialising in blockchain solutions, has been chosen as a technology partner to enable smart features and ensure the traceability, data security, and transparency required for circular practices and the fight against counterfeiting. The packaging will include a data carrier (e.g., QR code) linking to ZEROBARRACENTO's website, where blockchain-certified supply chain information will be accessible.
The dataset was selected in accordance with the upcoming EU Digital Product Passport (DPP) for textiles, allowing for early adoption of its transparency standards. By comparing DPP requirements with the brand's existing data, it was possible to define a relevant dataset to be integrated.
Together with Astrakode, a digital interface is being designed to collect, manage, and display data, as exemplified in **Fig. 2**. The system will feature, on the one hand, an internal management interface for suppliers to upload and validate data, some of which may be automatically or externally certified; on the other hand, a user-facing interface for consumers, accessible by scanning the QR code. This will ensure greater transparency and traceability throughout the supply chain; furthermore, the circular and sustainable characteristics of the product will be communicated in a clearer and more verifiable manner.

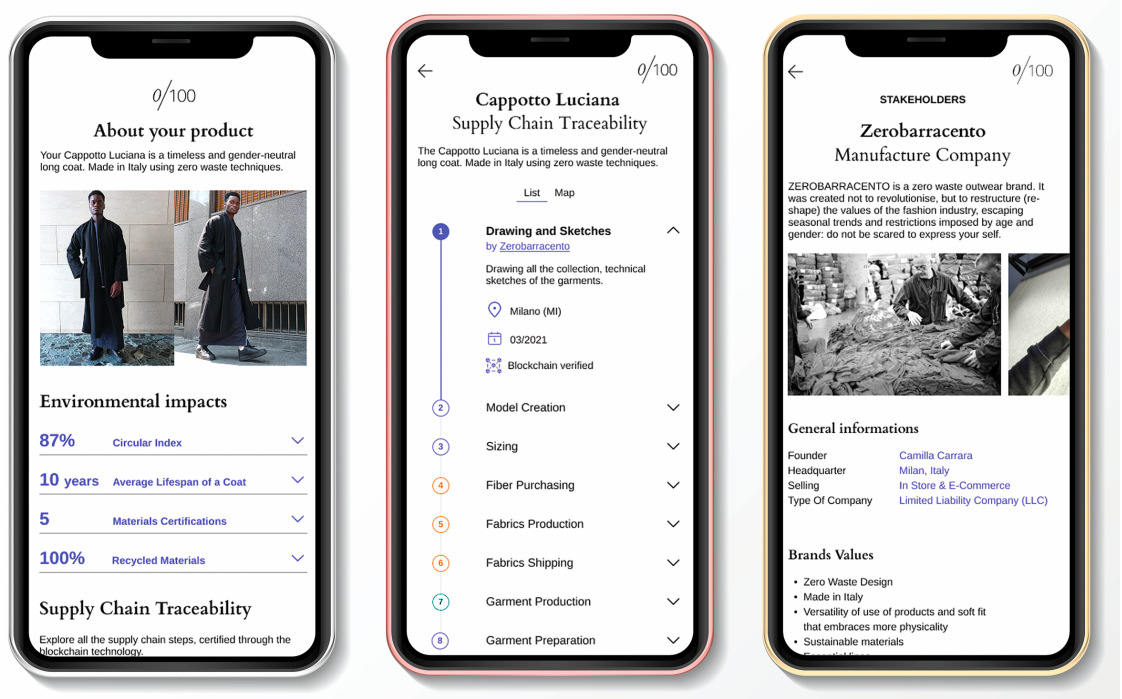

Fig. 2
Prototype of the blockchain-enabled interface developed in collaboration with Astrakode on ZEROBARRACENTO data. Graphics by C. Sartor, developed within the FuturE-Pack project.

The experimental project shows that smart packaging, developed through collaboration among different sectors, can foster innovation across the fashion value chain: using digital tools with advanced features that improve communication and make it more accessible not only helps to improve logistical efficiency and make it easier to track and share data, but also allows brands to connect with consumers more engagingly and effectively. Consequently, it may enable consumers to make more informed and thoughtful purchasing decisions. From this viewpoint, smart packaging serves as an ecological and digital bridge, integrating and connecting individuals,

systems, and data within a circular ecosystem, embodying the role of design as a tool for transformation in the fashion industry.
To realign the case study with the conceptual framework outlined in the previous sections, the following elements are specified.
In the case study, the packaging was treated as a genuine interface, going beyond its traditional function as a container. The project considered packaging as a device capable of conveying ZEROBARRACENTO's values (from waste reduction to the selection of responsible materials) through a coherent combination of form, materials, and informational content. At the same time, the packaging assumed a mediating role among the actors in the supply chain, facilitating the exchange of information and the sharing of responsibilities throughout the product's life cycle. From this perspective, packaging becomes an enabler of informed decision making for both the company and the end user, supporting more responsible consumption and production practices.
Finally, within the project, blockchain was not adopted merely as an enabling technology but as a direct response to the systemic pressures that emerged during the analytical phases. Its use was linked to the European requirements of the ESPR and the Digital Product Passport, which call for traceability, transparency of supply-chain data, and verifiability of information across the entire life cycle of the product. Moreover, blockchain helps counteract counterfeiting practices affecting Made in Italy products by ensuring that data related to origin, processes, and materials are securely recorded and cannot be altered. In this sense, the technology becomes a structural element for strengthening the authenticity and accountability of the supply chain.

CONCLUSIONS: ADVANCING DESIGN FRAMEWORKS FOR CIRCULAR SMART PACKAGING

This article explored the evolving role of design in advancing circular transitions within the Made in Italy fashion system, showing how the convergence of digital innovation, sustainability, and cultural identity can be pursued through packaging. By framing packaging not only as a technical device but as a platform for both material and symbolic innovation, this research contributes to design approaches that respond to the structural challenges currently affecting the fashion industry.
The study has highlighted the potential of systemic design to map interdependencies and activate circular strategies across supply chains, supporting place-based interventions and collaboration between sectors. Alongside this, the integration of advanced and transition design perspectives has enabled the formulation of the figure of the Transitional Industrial Designer, someone capable of working across temporal, disciplinary, and organisational boundaries. Such a figure helps companies make sense of complex information and think through how design choices might influence broader social or material systems, especially when it comes to how products are made, shared, or consumed.
The study examined how smart technologies, such as blockchain, IoT systems, and digital platforms, might support greater traceability and transparency of product data, particularly in response to changing environmental policies and regulatory expectations. Within the packaging sector, these tools were considered as practical solutions for improving how information is communicated, both among supply chain actors and between

brands and consumers, making it easier to understand where products come from and how they move through the system.
The case study was an opportunity to test these theoretical assumptions in practice. It brought together a reusable packaging concept, a blockchain-based tracking system, and a co-design process shaped by conversations and mapping exercises with the key people involved. Rather than presenting a finished solution, the project focused on building something that made sense for the brand, both in terms of its technical requirements and how it communicates. Although still early-stage, the outcome reflected the direction of upcoming policies like the EU Digital Product Passport and gave a glimpse of how design can tie together practical tools, values, and regulation.
One of the key takeaways from this study is a more grounded view of what design can do in the context of circular innovation. In the case of smart packaging, this means working with materials that reflect the product's full life cycle, integrating digital features where appropriate, and making sure that responsibility is shared among the different people and organisations involved in the supply chain.
Despite the potential highlighted, however, the research presents several limitations that require further investigation. The structural complexity of fashion and Made in Italy supply chains makes the uniform adoption of digital and circular solutions challenging, particularly in contexts characterised by production fragmentation and heterogeneous levels of digitalisation. The integration of technologies such as blockchain and traceability systems requires skills and infrastructures that are not always available, especially for SMEs that constitute the foundation of the Italian production system. Furthermore, alignment with a European regulatory framework that is still evolving, as in the case of the ESPR and the Digital Product Passport, introduces elements of uncertainty that may slow the implementation of innovative tools and processes. There also remain open issues related to the management, validation, and updating of data along the value chain, which entail organisational burdens and the need for more mature collaborative models.
In conclusion, circular smart packaging should be recognised not just as a context for technical testing but as a strategic context in which design can mediate ecological, technological, and socio-cultural transitions. It is precisely through this convergence, where physical systems meet digital infrastructures and human values, that design can play a decisive role in advancing the transformation of the fashion sector and the broader Made in Italy ecosystem towards more circular and sustainable futures.

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