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SMART PACKAGING FOR FASHION E-COMMERCE: EXPERIMENTATION IN THE MADE IN ITALY ECOSYSTEM

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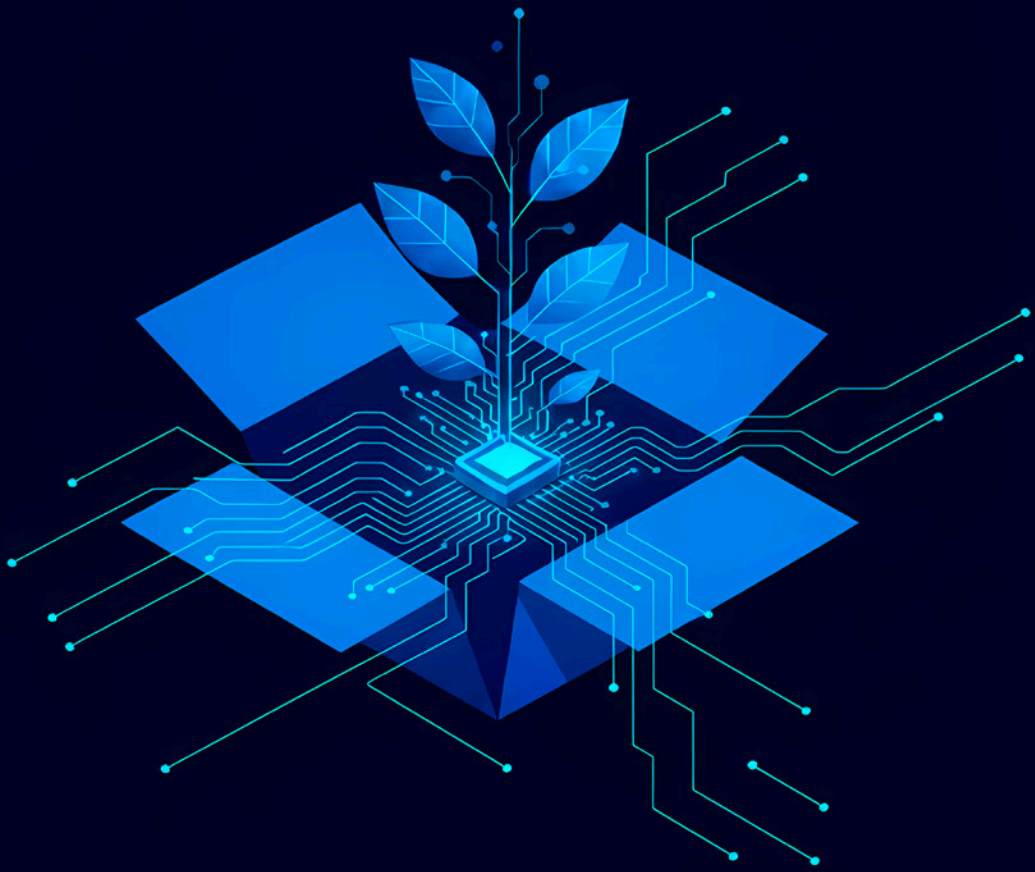
FuturE-Pack

Designing Smart Packaging for Circular and Sustainable Made in Italy

edited by Erik Ciravegna



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Summary

6. SMART PACKAGING FOR FASHION E-COMMERCE: EXPERIMENTATION IN THE MADE IN ITALY ECOSYSTEM

Ludovica Rosato, Caterina Antonia Dattilo, Mariapaola Puglielli, Camilla Carrara

Abstract: This chapter presents a field experiment on smart packaging for fashion e-commerce within the Made in Italy context, addressing systemic pressures for transparency, circularity, and data-informed decision-making. Building on a supply-chain mapping of the sector, we ran a design laboratory with three local partners: ZEROBARRACENTO (brand and use case), Movopack (reusable physical packaging), and Astrakode (blockchain-enabled digital infrastructure). The experimentation unfolded across four phases: requirements analysis, co-definition of the brief, design and development, and testing and validation, culminating in a reusable packaging solution linked via QR code to a digital interface aligned with the forthcoming Digital Product Passport. Life Cycle Assessment (LCA), conducted to compare candidate options, provided objective evidence on environmental performance, challenging intuitive assumptions and underscoring the value of measurement in design choices. While the process confirmed the strategic role of packaging as a communicative and traceability device, it also highlighted constraints typical of SMEs (economic/organisational resources), regulatory and standardisation uncertainties, and open questions regarding the effectiveness of communicating sustainability data to consumers. The findings yield a pre-framework of actionable guidance that informs the subsequent chapter's operational guidelines for smart packaging in fashion e-commerce.

Keywords: circular fashion, blockchain traceability, reusable packaging, design experimentation, Made in Italy ecosystem.

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6.1. Transformations of the Made in Italy ecosystem

Made in Italy is a nationally and internationally recognised production model combining artisanal know-how, local manufacturing traditions, and cultural symbolism. It is commonly associated with high-quality products in fashion, furniture, and food sectors, where aesthetic sensibility and material excellence converge. At its core, the label reflects a geographic origin and a set of values rooted in territorial identity, manual skill, and creative innovation. Historically, this model has been supported by Italy's industrial districts, geographically concentrated networks of small and medium-sized enterprises (SMEs) with strong social and economic interconnections. These districts, emerging prominently in the 1970s, represented a distinctive response to the dominant Fordist model of mass production (Bellandi & De Propris, 2015; Becattini, 1991). Their success was based on flexible specialisation, collaborative competition, and the integration of localised supply chains. This structure enabled firms to remain agile and responsive while maintaining strong ties to cultural and regional heritage.

However, despite its cultural prestige and commercial appeal, the Made in Italy system has shown growing signs of structural vulnerability. Its reliance on micro-enterprises and its limited capacity for digital and organisational adaptation have become increasingly problematic in the face of global disruptions. The 2008 financial crisis marked a first rupture, revealing the economic fragility of many SMEs heavily dependent on export markets. More recently, the COVID-19 pandemic further highlighted systemic deficiencies in supply chain coordination, digital readiness, and overall resilience (Grosso et al., 2021). These shocks have exposed deeper tensions between tradition and transformation. While the artisanal foundation of Made in Italy remains a core strength, the current global context demands greater agility, innovation, and transparency. Italian SMEs (still the backbone of national production) often lack the scale or resources to fully engage with international markets or adopt sustainable and circular practices (Rabellotti et al., 2009; Salvioni et al., 2021). Moreover, persistent infrastructure, digital literacy, and governance gaps continue to hinder the sector's evolution towards more integrated and future-ready systems (Matarazzo et al., 2025).

Simultaneously, the globalisation of production has complicated the very notion of origin. Legal definitions, such as the EU's rule allowing products to be labelled "Made in Italy" if their final substantial transformation occurs domestically, fail to reflect the fragmented reality of international supply chains. This has introduced loopholes whereby goods manufactured largely abroad may still bear the label, creating dissonance between brand promise and production practice (Garcia-Torres et al., 2022). Such ambiguities open the door to reputational risks, particularly in sectors where provenance and authenticity are critical in value perception. Fashion suffers from widespread misuse of national labelling, which erodes consumer trust and undermines the efforts of authentic producers (Simeone et al., 2022). Attempts to introduce stricter certification systems, such as the 100% Made in Italy label or targeted legislation in textiles and leather, have been slowed by fragmented governance and regulatory misalignment at the EU level.

Compounding this is the decline of the original industrial district model itself. Many traditional clusters have experienced reduced cohesion, offshoring of key activities, and a general weakening of inter-firm cooperation (Corò & Grandinetti, 2023). Although some territories have sought to reposition themselves through specialisation or global partnerships (Chiarvesio et al., 2010), others risk losing competitiveness and identity (Bellandi & De Propris, 2015). Given these developments, the Made in Italy label can no longer function as a static brand marker. It must evolve into a more adaptive, transparent system, capable of demonstrating compliance with environmental standards, ensuring traceability, and communicating value through verifiable data (Bettiol et al., 2022). This shift is both strategic and existential: what is at stake is the continued relevance of a cultural and economic model grounded in territorial intelligence and material integrity.

At the same time, the transformations under way reveal broader cultural tensions. The balance between artisanal knowledge and technological innovation, between local identity and global competitiveness, is increasingly fragile. These contradictions bring to light the need for new governance mechanisms, greater digital maturity, and more robust connections between SMEs and institutional frameworks. Above all, they highlight

that Made in Italy can no longer rely exclusively on its symbolic value but must demonstrate tangible commitments to sustainability, ethics, and transparency. Among the different sectors, the fashion industry emerges as the most emblematic arena of these tensions. It combines creativity and craftsmanship with highly complex, globally distributed supply chains, making it both a strength of the Made in Italy model and a critical test bed for its transformation.

6.2. Systemic challenges in the fashion supply chain

The fashion industry, long a flagship of the Made in Italy reputation, is now facing profound systemic pressures. While historically celebrated for its craftsmanship, creative leadership, and design excellence, the sector has also become closely associated with environmentally and socially unsustainable practices. Within the Made in Italy manufacturing landscape, the Italian textile industry represents the third-largest manufacturing sector, comprising approximately 13,000 companies that cover nearly all stages of the production chain. However, its economic relevance and structural breadth now face the urgent need for a profound rethinking due to the environmental and social impacts of its production-consumption system. The supply chain consumes significant resources and energy in the production of garments and textiles, contributes to high levels of greenhouse gas emissions, and generates considerable volumes of waste (European Environment Agency, 2022). The choice of materials, design and manufacturing methods, modes of consumption and use, as well as production and disposal technologies, are among the main drivers of these impacts (Ellen MacArthur Foundation, 2021).

Today, the fashion value chain is marked by critical impacts at every stage, from fibre production to end-of-life disposal, raising urgent ecological and ethical concerns.

- At the fibre level, environmental costs begin to accumulate. Synthetic textiles are derived from fossil resources, contributing to carbon emissions and resource depletion. Even renewable, plant-based alternatives often entail high

water consumption and dependency on pesticides, raising issues of land degradation and biodiversity loss. Adding to this complexity is the widespread use of mixed-material textiles (combinations of natural, synthetic, and semi-synthetic fibres), which are difficult to recycle using current technologies (Roy et al., 2024).

- The design phase further accelerates unsustainable patterns. Fast fashion business models prioritise rapid turnover, with new collections released weekly to meet shifting consumer tastes (Jayot, 2020). This push for novelty leads to an overproduction of low-quality garments, which are often discarded after minimal use. The emphasis on speed compromises durability and craftsmanship, contributing to mounting textile waste and the devaluation of materials.
- Manufacturing practices reflect similar inefficiencies. The standard cut-and-sew method generates significant volumes of offcuts and pre-consumer waste, most of which is not recovered or repurposed. Compounding this issue is the industry's widespread outsourcing model. Brands frequently operate without owning production facilities, relying on supply chains based in regions where labour and environmental standards are far less stringent. This "fabless" structure enables companies to sidestep direct responsibility for working conditions and sustainability performance across the production chain (Jayot, 2020).
- Post-purchase, environmental burdens continue. Washing synthetic fabrics releases microplastics into aquatic ecosystems, while materials like polyester, despite their physical resilience, pose long-term pollution threats due to their resistance to decomposition. Garments are now estimated to be worn only 7 to 10 times before being discarded (Ellen MacArthur Foundation, 2021), reinforcing waste cycles and accelerating the depletion of fossil and renewable resources.
- Although the distribution phase (comprising transportation, storage, packaging, and retail) is generally associated with a lower environmental impact compared to other life cycle stages, it remains a relevant factor. Designers can contribute to impact reduction by making conscious decisions, such as prioritising local suppliers or selecting

low-emission transportation options. In this context, packaging plays a key role: designing lighter, compact, reusable, or easily recyclable packaging can reduce both transportation volume and overall distribution impact (Vezzoli et al., 2022). More importantly, packaging can act as a connector and vehicle for information across all stages of the supply chain, traversing them transversally and aggregating data from all involved stakeholders.

In response, European regulators are introducing measures designed to steer the sector toward greater accountability. The Ecodesign for Sustainable Products Regulation (ESPR), a key initiative under the European Green Deal (see Chapter 3), aims to establish mandatory sustainability requirements across product categories, including textiles. These standards encompass repairability, recyclability, and product longevity (European Commission, 2022). A central mechanism of this strategy is the Digital Product Passport, which is intended to enable traceability across the product life cycle and provide consumers with accessible, verifiable data (European Parliament, 2024). For manufacturers, however, aligning with such initiatives demands more than compliance. It substantially transforms business practices, supply chain governance, and product development strategies. Transparency and traceability are no longer optional values but emerging imperatives. The Italian fashion industry is facing an urgent need for change. As a key symbol of national production identity and quality, it must now reconfigure its operational logic to meet the standards of an ethically and environmentally conscious market. This shift requires not only the validation of origin and material composition but also the assurance of fair labour practices and responsible sourcing. As regulatory frameworks evolve, so must the infrastructures that support them, opening new opportunities for design innovation, data integration, and the adoption of circular economy actions.

In response to the systemic pressures affecting the Italian fashion industry and the growing demand for transparency, accountability, and circularity, the research developed a comprehensive mapping of the fashion supply chain. The analysis examined the complex ecosystem of stakeholders and their interconnections, with particular attention to the integration of

e-commerce channels and the transversal role of packaging as a site for innovation, experimentation, and sustainable transformation. It also considered the diversity of fashion products, their specific characteristics, and functional requirements to gain a clearer understanding of the supply chain's complexities. The resulting representation highlighted the intersections between production flows and the actors involved in both the front end of the user experience and the back end of business relationships, structuring the process into three main segments: from production to sale, from sale to consumption, and from consumption to post-consumption, as mapped within the FuturE-Pack research project. This classification allowed for the precise identification of the phase most suitable for further investigation during the experimental phase.

The research also mapped and analysed the various players within the fashion sector (raw material suppliers, manufacturers, distributors, retailers, and consumers), highlighting their roles and interrelationships. It explored the specific challenges and opportunities associated with e-commerce, particularly in relation to logistics, inventory management, and customer service. On this basis, a design experimentation phase was then launched to test smart packaging solutions within the context of fashion e-commerce and assess their feasibility through collaboration among local stakeholders operating at different stages of the supply chain.

6.3. Experimentation in fashion e-commerce

The experimental activity was structured as a design laboratory aimed at investigating tools and processes for the development of smart packaging solutions tailored to the Made in Italy fashion e-commerce context. The objective was to test their effectiveness through a co-design simulation involving three types of local stakeholders, representative of the main components of the supply chain. ZEROBARRACENTO[1] acted as the commissioning brand, responsible for employing the packaging to deliver its product; Movopack[2] provided the reusable physical packaging; and Astrakode[3] was in charge of developing the blockchain-based digital infrastructure suited to transmit

information to the end user. The experimentation was coordinated and managed by a research group from the University of Bologna, simulating the functions and tools of the FuturE-Pack platform (see Chapter 7).

The experimental process was articulated in four main phases.

- The first phase concerned the analysis and definition of requirements related to the selected textile product, its production supply chain, and packaging needs, outlining the initial technical specifications and constraints for the experimentation.
- The second phase involved the definition of design requirements in close collaboration with the project partners, aimed at developing a shared design brief.
- The third phase focused on the design and development of packaging solutions and digital devices, selecting those best suited to address the project's objectives.
- Finally, the fourth phase consisted of the testing and validation of the proposed solutions, carried out through iterative prototyping and the evaluation of their impacts across the supply chain.

The first phase focused on product requirements analysis and definition and started by analysing the Italian fashion brand chosen for the experimentation. ZEROBARRACENTO is a company strongly aligned with the values of sustainability and circularity, criteria considered fundamental to ensure consistency with the objectives of the project. It is an innovative Italian outerwear brand founded by Camilla Carrara, and it stands out for its commitment to zero-waste design and a pioneering approach to circular fashion. All garments are Made in Italy and designed with gender and age inclusivity in mind. The brand renounces seasonal trends, offering timeless designs with minimal, clean lines inspired by Italian art and architecture. Its core values include using high-quality recycled and certified materials, full supply chain traceability, and rigorous sustainability practices. ZEROBARRACENTO's zero-waste pattern-making enables the use of fabric in its entirety, typically saving 15% of material wasted in conventional production. For these reasons, the brand was an ideal partner, fully consistent with the objectives of our

experimentation. Through direct discussion with the company, we identified the specific product to be addressed in the packaging development and selected the Luciana coat (fig. 1). This garment exemplifies brand philosophy: a genderless piece made with recycled ingredients, developed with zero-waste patterns, free of buttons and zippers, making disassembly and recycling easy at its end-of-life. For this product, specific requirements, needs, and constraints were collected to inform the design of a smart packaging solution suitable for its protection and delivery. The brand's packaging must reflect its values both physically and in communication, with careful attention to zero-waste messaging. ZEROBARRACENTO's need for packaging goes beyond protection, serving as a tangible communicator of its circular ethos, traceability, and transparency, reinforcing the emotional and values-driven connection with conscious consumers. The packaging should convey an understated luxury and minimalist elegance, while ensuring optimal protection of the items, delivering a uniquely refined user experience.

1. The Luciana coat, selected for the experimentation. Courtesy of ZEROBARRACENTO.

To support the methodological process of synthesising and organising the information gathered during the research, a series of analysis cards was developed: each card was designed to collect and structure data relevant to different design dimensions.

- The *Brand Card* captures the brand's core values and is essential for guiding the definition of the packaging's communicative elements.
- The *Product Card* outlines the characteristics of the garment, including aspects related to user interaction and maintenance, the circular innovation embedded in the product, its material composition and dimensions, which are critical for determining technical and structural packaging constraints, as well as the circular practices applied during production.
- The *Material Card* details the specificities of the materials used, including supplier information, provenance, traceability, and certifications, all of which are crucial to ensuring sustainability and circularity.
- The *Supply Chain Chart* maps the structure of the production and distribution network, identifying key stakeholders, distribution and sales methods, and the profiles of end users.
- Finally, the *Packaging Card* analyses the currently used packaging in terms of materials, components, and objectives, both functional and communicative, to assess its alignment with the new design goals.

The analysis led to the definition of a set of design requirements, formulated by considering the specific needs and impacts of each actor involved in the supply chain. In this framework, all stakeholders affected by, or responsible for, the packaging are regarded as relevant design actors. These include the brand owner, the product, the supply chain, the end user, society, the territory, and the environment.

6.4. Design criteria and development of smart packaging solutions

The systematisation of the information collected led to the development of a summary framework, which, combined with the results of the interviews with the brand and the analysis of unmet needs related to the current packaging, made it possible to identify four key areas for design intervention. The first concerned the strengthening of the communication of brand identity through packaging, achieved both by means of graphic and layout choices capable of coherently conveying the brand's values and image, and by designing packaging that expresses symbolic meaning, e.g., by using sustainable and circular materials. At present, the packaging consists of a standard DHL Flyer XL commercial envelope, with no reference to the brand. The only communicative elements employed are a card summarising the brand's values and providing a link to the website, together with a ZEROBARRACENTO logo sticker used to seal the tissue paper wrapping the coat.

The second is related to promoting the standardisation and adaptability of the packaging to accommodate a variety of products, while ensuring both functional performance and consistency with the brand identity. The third focused on guaranteeing the packaging's resistance to environmental factors such as humidity, rain, dust, extreme temperatures, and odours. This requirement is particularly significant for a luxury Made in Italy product, which requires high-quality standards not only for the garment itself but also for its protection and presentation during transport.

Finally, the fourth addressed the enhancement of communication regarding environmental impacts along the supply chain, highlighting the processes, suppliers, and actors involved. At present, ZEROBARRACENTO makes available on its website a mapping of the supply chain and its suppliers through a prototype Digital Product Passport (DPP) integrated into each product page. However, this information is not always easily accessible or understandable to users, and it remains unclear whether it significantly influences purchasing decisions. The experimentation, therefore, aimed to explore ways of integrating such information directly into the packaging, transforming it into an effective vehicle for product-specific data and reinforcing the

emotional and value-based connection between the customer and the product.

For this purpose, Astrakode was involved, a tech company specialised in the development of blockchain-based solutions. Blockchain technology can play a strategic role in supporting sustainable practices, particularly in relation to resource efficiency, product reuse, and recycling processes. It ensures traceability, data security, and optimised management of digital documentation, thereby promoting transparency throughout the entire supply chain. Furthermore, it enhances material visibility, combats counterfeiting, supports more informed consumer choices, and facilitates connections between primary and secondary markets. In this way, it contributes to a more sustainable and circular economic model.

The design of smart packaging solutions stemmed from insights previously identified in research on packaging for fashion e-commerce. Within the framework of a sustainable and circular transition, two main strategic directions were explored: the development of single-use packaging made from circular and sustainable materials, and the adoption of reusable packaging based on take-back systems or user ownership models fit to ensure extended use cycles. Both approaches align with circular economy principles.

Accordingly, two design solutions were developed: the single-use "Zero-Waste Box" and the reusable packaging in collaboration with Movopack.

The "Zero-Waste Box" concept (fig. 2) aims to maximise material efficiency, reduce packaging volume, and improve product fit. It consists of two primary elements made of FSC-certified cardboard: a die-cut, custom-shaped inner layer designed to support and protect the garment, and a larger outer sheet folded perpendicularly to wrap and secure the item during transportation. The entire system is glue- and plastic-free, thanks to a perforated tear-strip closure that ensures sealing and facilitates unboxing. In line with circular design principles, the project includes a plantable paper sleeve, transforming a typically secondary element into a regenerative and narrative component that communicates ZEROBARRACENTO's brand values. This sleeve serves multiple functions: a tamper-evident seal, a branding surface, and an informative support featuring printed instructions and a QR code, whose content will be detailed later.

2. Concept of the Zero-Waste Box packaging solution. Design by Andriano Pentassuglia, developed within the FuturE-Pack project.

Despite its conceptual coherence with the brand's values, this solution was not prototyped, as it would have required the brand to establish a partnership for the development of a custom, non-standard, and non-commercial packaging solution, which proved less viable from an economic standpoint.

Instead, a collaboration was initiated with Movopack, a company providing a solution that reflects the brand's principles of sustainability and circularity, while also supporting effective brand communication through an accessible and implementable service. Movopack designs packaging-as-a-service systems for e-commerce, significantly reducing the environmental impact associated with single-use packaging. Its packaging is made from recycled and recyclable materials, including recycled polypropylene (PP), R-PET, and polyester, and is designed to be reused up to 20 times. These materials ensure durability, lightness, and water resistance, making the packaging suitable for a variety of products while meeting the protection requirements defined.

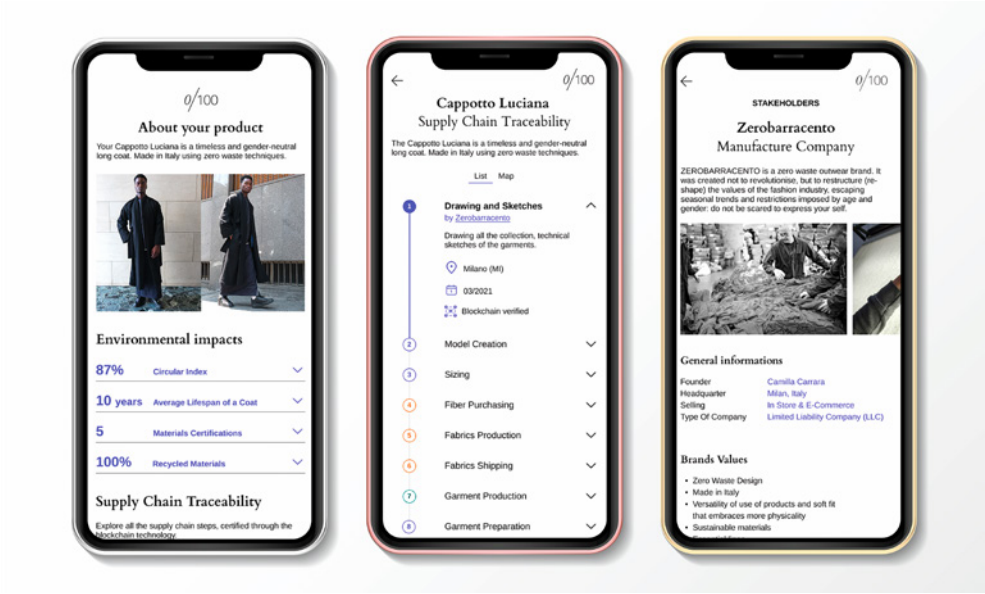
After use, customers can easily return the packaging by folding it and dropping it into any mailbox using a prepaid return label and a QR code that locates the nearest drop-off point. Moreover, Movopack allows for high levels of customisation, turning the packaging into a visual communication tool for the

3–6. Prototype of the reusable packaging for ZEROBARRACENTO produced by Movopack. Graphics by L. Rosato, developed within the FuturE-Pack project.

brand. Already active in the luxury sector, Movopack identified, based on the dimensions of the Luciana coat, the MOVO Classic L packaging made from recycled polypropylene, a solution that adapts to smaller volumes as well, thus offering flexibility and space optimisation (figs. 3–6).

Following the physical design of the packaging, attention shifted to the definition of the supply chain data to be conveyed via the QR code, identified as the most appropriate tool to bridge the physical and digital dimensions and to provide product-related supply chain information in a transparent and verifiable manner. The objective was to communicate to the user the complete production journey of the purchased garment, leveraging blockchain technologies to certify each step.

In selecting and structuring the data to be conveyed through the smart packaging, reference was made to the Digital Product Passport (DPP) for textile products currently under development (European Parliament, Directorate General for Parliamentary Research Services, 2024), in order to align the solution with the operational model expected to be imple-



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

mented by 2027. By comparing the data requirements outlined in the forthcoming DPP with the information already provided by ZEROBARRACENTO, it was possible to define a dataset to be integrated into the smart packaging.

The digital interface includes detailed information on both the product and packaging supply chains, with the goal of making the environmental impacts of each phase visible and comprehensible. This encompasses data on each supplier, including contact information, website, and production location; information on the materials used, including their composition, processing steps, and certifications, presented in an accessible and informative language; and details on transportation methods and distances, intended to highlight the environmental burden of logistics. It also provides information on the packaging process, its location, and the product's circular and sustainable properties, together with data on the packaging itself and its life cycle. Finally, it contains usage and care instructions for the garment, including notes related to fit.

In collaboration with Astrakode, a digital interface was designed to collect, manage, and visualise this data (fig. 7), accessible to the end user via a QR code printed directly on the packaging. This system supports enhanced traceability and supply

chain transparency, enabling clear and reliable communication of the product's sustainable and circular attributes.

Since the packaging is reusable while the data refers to individual products, ZEROBARRACENTO will apply a product-specific label containing the QR code at the time of packaging. This label will be placed in a dedicated area on the Movopack packaging and can be removed and retained by the customer, preserving access to the information even after the packaging is returned.

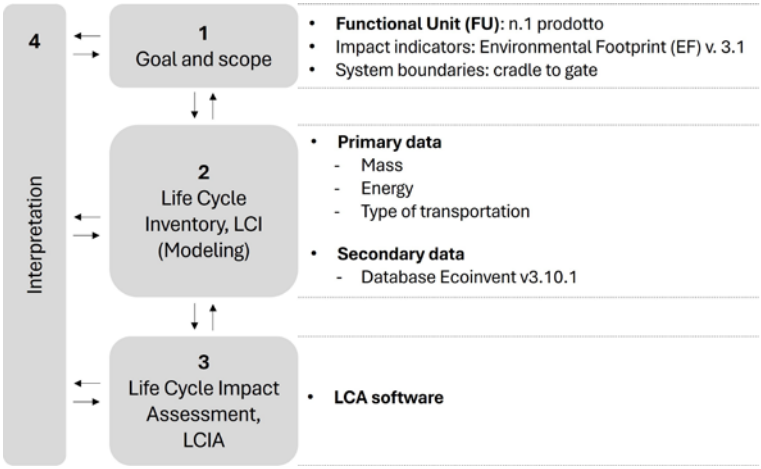
The selected solution proved to be particularly well-aligned with ZEROBARRACENTO's aspirations, both in terms of environmental performance and communicative effectiveness. The smart packaging system developed represents a solid, scalable design proposal consistent with the brand's goals of sustainability, circularity, and transparency. It emerges as a strategic tool suited to combine technical, narrative, and relational dimensions in a coherent user experience.

6.5. Testing and validation through Life Cycle Assessment

This section provides an analysis of packaging solutions for the Luciana coat, using the Life Cycle Assessment (LCA) methodology (see Chapter 4) to evaluate and compare their environmental impacts. The LCA methodology is governed by the ISO 14040:2006 (International Organization for Standardization [ISO], 2006a) and ISO 14044:2006 (ISO, 2006b) standards, and is composed of four fundamental phases summarised in Figure 8.

The logical structure shows that the phases of the process are interdependent; therefore, none can be considered complete until the entire process is finished. Additionally, this methodology can be applied iteratively, based on the availability of data and resources, as well as the type of product being analysed. This environmental analysis aims to assess the impact of existing packaging solutions, specifically the *DHL Flyer XL* and *cardboard box*, while comparing them to an alternative product made from recycled polypropylene, namely Movopack.

All the topics required by the *goal and scope* stage (i.e., functional unit; system boundaries; "cut-off" criteria; impact categories) are preparatory to the process modelling. The focus of this analysis is the "production of packaging for the Lucia-



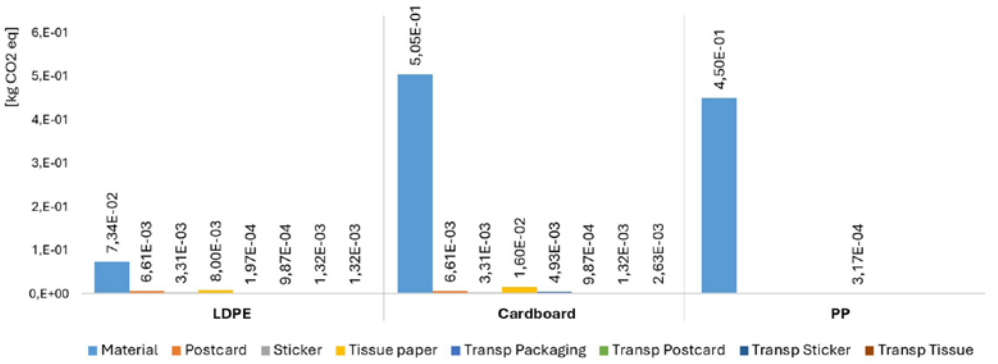
8. Structure of the Life Cycle Assessment methodology. Adapted from ISO 14040:2006 and ISO 14044:2006, elaboration by C. A. Dattilo within the FuturE-Pack project.

na coat," which serves as the functional unit (FU). The system boundaries are defined to encompass "cradle-to-gate" processes, considering both mass and energy. Regarding transportation considerations, we have considered the distances between the material supplier and the packaging production company. Impact categories are derived from the "Environmental Footprint v.3.1" methodology (European Commission, Joint Research Centre, 2022), with a particular emphasis on climate change, measured in CO2 equivalents.

Regarding the LCA phase, the data used in this analysis are mainly direct, meaning they are provided by companies. However, we have also supplemented this information with secondary data from specific commercial databases, such as Ecoinvent® (Ecoinvent Association, 2022), as well as sources from scientific literature. This approach has enabled us to develop detailed models using specialised software for environmental analysis.

Upon concluding the first two steps, the approach moves to the environmental impact assessment (LCA), focusing on the climate change results, as reported in the following Figure 9.

The LCA unveils crucial perspectives on the environmental impacts of various packaging materials. It reveals that cardboard packaging, often the go-to choice for many, shows the highest environmental footprint, questioning its widespread use. In contrast, LDPE shows comparatively lower impacts, confirming its potential as a more sustainable option. As we delve



9. Climate change impact results comparing current and new packaging solutions. Elaboration by C. A. Dattilo within the FuturE-Pack project.

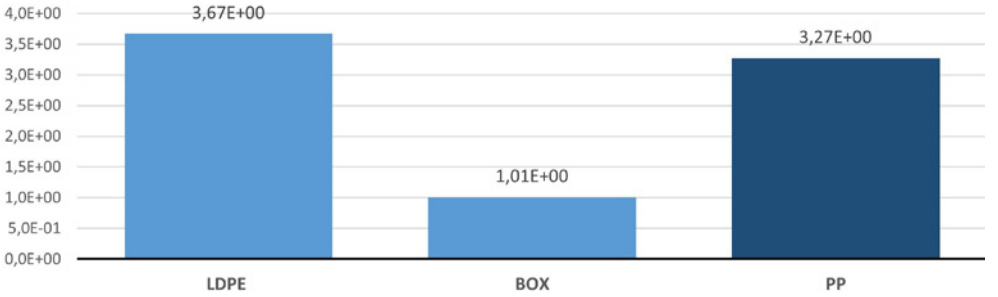
deeper into the data presented in Figure 10, a remarkable visual emerges: the bar representing material type is considerably higher than those of other elements in the analysis.

This stark difference suggests the adoption of the "cut-off" method, allowing us to zero in on the diverse array of packaging materials available. When we shift our focus to a standardised mass of 1 kg, the findings take on a new dimension, indicating potential areas for improvement.

In this scenario (fig. 10), cardboard unexpectedly comes to the forefront as a more favourable choice than plastic, showing a preference margin of 72%. Following closely is PP, which carves out its own niche as a promising alternative. While LDPE retains its status as the most sustainable material overall, its position in this comparison indicates opportunities to reconsider packaging choices.

This analysis provides useful insights for comparing packaging solutions and highlights opportunities for improvement in the transition toward more sustainable practices.

10. Impact assessment results normalised to 1 kg of packaging material. Elaborated by C. A. Dattilo within the FuturE-Pack project.



6.6. Insights from the experimentation

The experimentation carried out has made it possible to critically observe both the potential and the limitations of a design-driven approach to smart packaging for e-commerce within the Made in Italy fashion sector. The process demonstrated the capacity of packaging to evolve from a logistical tool into a medium of communication and traceability, capable of integrating technical, narrative, and relational dimensions. The adoption of digital technologies enabled the collection and transmission of complex information along the supply chain, ensuring transparency and reinforcing the bond of trust between brand and consumer. At the same time, collaboration with specialised partners highlighted the importance of building territorial design ecosystems combining manufacturing, technological, and design expertise, thereby offering scalable solutions consistent with the principles of sustainability and circularity. A particularly significant element was the testing and validation phase, which, through the application of Life Cycle Assessment (LCA) methodology, made it possible to objectively compare the different packaging solutions. The analysis highlighted not only the advantages of reusable options but also the need to challenge simplified perceptions of sustainability.

Nonetheless, the process also revealed several critical issues. First, the experimentation had to contend with the economic and organisational constraints typical of small enterprises, which often lack the resources required to develop customised packaging solutions or to integrate advanced digital systems. Moreover, the need emerged for greater attention to regulatory and standardisation aspects: the absence of stable reference frameworks risks slowing the adoption of innovative tools and generating uncertainty among businesses. From a communicative perspective, the question of effectiveness also remains open: although packaging can serve as a vehicle for environmental data and traceability, it is still unclear to what extent such information is genuinely understood and valued by consumers in their purchasing decisions.

The experimentation confirmed the validity of the methodological approach and the relevance of packaging as a strategic lever for circular transition, while also underlining the necessi-

ty of more accessible operational tools, shared guidelines, and greater involvement of all actors across the supply chain. Among the key factors that emerged are the centrality of analysing the specific requirements of both product and supply chain; the need to envisage iterative design processes that allow for progressive prototyping and validation of solutions; and the value of establishing partnerships with external actors capable of contributing complementary technological and logistical expertise.

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Notes

[1] https://zerobarracento.com
[2] https://movopack.com
[3] https://www.astrakode.tech/it/

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