

WASTE ECOLOGIES.

CIRCULAR PATHWAYS RESHAPING ITALIAN FASHION MANUFACTURING

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Abstract

The ecological transition is compelling the Made in Italy fashion and manufacturing ecosystem to confront the material and organizational implications of circularity. Pre- and post-consumer waste streams—long overlooked or treated as residual—are becoming strategic sites for innovation, revealing both structural vulnerabilities and untapped opportunities within Italy's specialized industrial districts. This article traces how emerging European regulations, evolving infrastructural capacities, and regenerative design approaches are reshaping traditional production models, challenging established value chains while enabling new forms of material responsibility. By integrating a multi-scalar perspective on waste generation and recovery, the study highlights the systemic reconfiguration underway and argues that the future competitiveness of Made in Italy depends on its ability to transform waste into a driver of ecological and industrial renewal.

Keywords: *Waste Ecologies, Circular Fashion Manufacturing, Made in Italy, Design for Circular Transition, Territorialized Production Systems*

INTRODUCTION: WASTE AS A STRATEGIC LENS FOR CIRCULAR TRANSITION

The ecological transition is compelling the Italian fashion manufacturing system to undergo a profound transformation that simultaneously affects materials, processes, infrastructures, and organizational models. The adoption of the EU Strategy for Sustainable and Circular Textiles and the introduction of Extended Producer Responsibility (EPR) (European Commission, 2022; Köhler et al., 2021) mark a structural shift in European policies, steering the sector toward production models required to address the systemic complexity of waste in relation to material flows (Obregón & Danies, 2024) and treatment

infrastructures (Sandin & Peters, 2018; Kirchherr et al., 2017). At the same time, growing consumer awareness (Niinimäki, 2020; Henninger et al., 2016) and the increasing pressure exerted by new traceability mechanisms fosters the need to rethink fashion products in their entirety, from design and development to end-of-life (EEA, 2025; Mishra et al., 2021; Fletcher, 2013).

This contribution is situated as part of the RHITA – Reshaping Made in Italy through Circular Models and Conscious Innovation project, contributing in particular to the activities of Milestone 3 (M3) – Redesigning Fashion for Made in Italy. This milestone aims to reframe the cultural and productive landscapes of Italian fashion across the four regions involved in the project (Campania,

Lombardia, Veneto, Toscana) through an integrated reading of manufacturing systems, human capital, and material competences, in relation to the challenges posed by ecological and digital transitions. Building on territorial investigations developed in earlier phases, M3 compares and interprets local production configurations in order to identify transformation trajectories capable of reshaping manufacturing models, inter-actor relations, and the design and operational practices that sustain the Made in Italy fashion system. In this framework, the article addresses how these models are changing—and how they should further evolve—to respond to sustainability and circularity imperatives, with specific attention to the redesign of production systems and the material ecologies that structure their functioning.

In the Italian case, these transformations acquire a specific relevance as they are embedded in a historically territorialized production system (Becattini, 1991; 1998), characterized by strong manufacturing specialization, dense networks of interdependent firms, and a high concentration of material competences (Bellandi et al., 2021; Mazzoni, 2020). As discussed in the following section, this configuration represents both a strategic asset and a source of vulnerability in the transition toward circular models, making the role of infrastructures, forms of industrial coordination, and governance arrangements especially visible and consequential.

Within these premises, the article adopts waste as a key interpretative lens for understanding the transformations currently reshaping Italian fashion manufacturing. Waste makes visible the interdependencies between production quality, material complexity, and infrastructural capacity, bringing to the surface tensions and misalignments that remain largely obscured in analyses focused exclusively on products, processes, or technologies, yet are central to the redesign of production systems from a circular perspective (Tufarelli et al., 2025).

Pre-consumer waste—generated during cutting, assembly, finishing, and quality control phases—highlights the operational relations that structure territorial manufacturing systems, while post-consumer waste streams expose the limits of collection and sorting infrastructures, increasingly strained by the heterogeneity of materials entering the global market. The imminent introduction of EPR for textiles further amplifies these criticalities,

positioning waste as a strategic node through which shifting responsibilities, competences, and roles along the entire product life cycle can be examined. On this basis, the article adopts the perspective of waste ecologies to interpret the ongoing reconfiguration of Italian fashion manufacturing. Looking at the system through the lens of waste means conceiving it as a point of condensation of complex socio-material relations, in which design decisions, production arrangements, infrastructural capacities, and regulatory frameworks coexist, mutually shape one another, and evolve over time. In this sense, choosing ecologies entails shifting attention from isolated objects to the dynamic and situated processes through which circularity takes form within specific territorial contexts.

PRODUCTIVE ECOLOGIES OF MADE IN ITALY FASHION: INDUSTRIAL STRUCTURE AND EMERGING TENSIONS

Made in Italy fashion manufacturing has historically been grounded in a strongly territorialized production structure, characterized by specialized industrial districts, dense subcontracting networks, and a pronounced division of labor by production phases. This configuration has long been interpreted as one of the main sources of competitiveness of the Italian system, as it has enabled high levels of manufacturing quality, production flexibility, and responsiveness to market demands (Becattini, 1998; Belussi & Sedita, 2010). Today, however, the ecological and circular transition places under pressure precisely those arrangements that have historically sustained this model, calling for a critical re-reading of its industrial architectures. Italian fashion districts can be understood as complex productive ecosystems in which geographical proximity facilitates the circulation of tacit knowledge, technical specialization, and informal forms of cooperation among firms (Becattini, 1991; Bellandi et al., 2021). In these contexts, product quality cannot be attributed to a single actor, but rather emerges from the interaction of multiple subjects and manufacturing phases distributed along the production system. While this articulation constitutes a strength in terms of material excellence, it simultaneously produces a fragmentation of responsibilities that obscures the relationships between design decisions, production processes, and downstream

material consequences (Bressanelli et al., 2022). Over time, and particularly within the luxury and premium fashion segments, this district-based structure has increasingly been overlaid by the presence of industrial holdings and integrated groups coordinating brands, suppliers, and subcontractors through vertically oriented governance logics (Djelic & Ainamo, 1999; Tokatli, 2014). These actors play a central role in defining quality standards, production timelines, and compliance requirements, introducing control and coordination mechanisms that coexist—often in tension—with the autonomy of small and micro-enterprises operating within districts (Canello et al., 2025). The result is a hybrid configuration (Giuliani & Rabellotti, 2017; Conti & Franzo, 2020), in which informal coordination based on trust and proximity coexists with centralized decision-making architectures and industrial planning imperatives.

This hybridization has profound implications for the implementation of the circular transition. On the one hand, productive specialization and territorial proximity enable material experimentation and the recovery of pre-consumer waste, particularly in districts with a long-standing tradition of fiber regeneration like Prato (Bressanelli et al., 2022; Tufarelli, 2022). On the other hand, the growing distance between design, commissioning, and manufacturing execution tends to generate misalignments that are reflected in material complexity, assembly systems, and difficulties in managing waste at end-of-life (Tufarelli et al., 2025; Niinimäki et al., 2020). From this perspective, the industrial structure of Made in Italy appears highly effective in terms of product quality, yet less equipped to address the systemic implications of circularity across the entire product life cycle.

A further tension concerns the relationship between production and consumption. Italian manufacturing continues to generate materials and products characterized by high quality standards, while post-consumer waste streams re-entering collection and sorting systems increasingly reflect the heterogeneous composition of the global market, dominated by synthetic fibers, complex blends, and low-durability products (Sandin & Peters, 2018; Henry et al., 2019). This qualitative discontinuity introduces a structural short-circuit: the industrial competences and infrastructures are only partially aligned with the complexity of the

materials that must now be managed. Taken together, these elements outline an industrial structure traversed by deep tensions between specialization and fragmentation, proximity and centralization. Within this framework, the ecological transition is understood as a process of systemic reconfiguration involving roles, responsibilities, and relationships across the entire productive ecosystem (Geels & Schot, 2007; Köhler et al., 2022). Indeed, the tensions embedded in Italian fashion manufacturing remain difficult to grasp when analyzed exclusively through conventional categories such as supply chain, process, or technology.

It is precisely at the point where these configurations generate residues, excesses, and material blockages that the contradictions of the system become most visible. Waste thus emerges as a privileged analytical site in which design decisions, organizational arrangements, infrastructural capacities, and regulatory frameworks condense. On this basis, the following section introduces waste ecologies as an analytical lens capable of rendering intelligible the ongoing reconfigurations of Italian fashion manufacturing, shifting attention from isolated objects to the socio-material relations that structure their existence.

TOWARD WASTE ECOLOGIES: THEORETICAL FRAMEWORK

The growing attention to circularity in the fashion sector has generated an extensive body of study aimed at making visible the causes and consequences underlying the urgency of the ecological transition (Mishra et al., 2021; Abate et al., 2023; Odabasi et al., 2023). Within this debate, an increasing strand of the literature questions the interpretation of waste—both from production and consumption—as a problem to be contained or optimized, as well as its residual positioning to the processes and relations that generate it (Binotto & Payne, 2017). Studies on circular transition of fashion show instead that waste does not emerge in isolation, but constitutes the outcome of endemic conditions that permeate the entire system, reflecting deep structural dynamics (Kirchherr et al., 2023; Fletcher & Tham, 2019).

Waste materializes within distributed configurations operating simultaneously at the micro level—through design decisions, production practices, and consumption habits; at the meso level—across subcontracting networks, industrial

districts, and inter-firm coordination mechanisms; and at the macro level—through European policies, extended producer responsibility schemes, and national industrial strategies (Tufarelli et al., 2025). The perspective of *waste ecologies* adopted in this contribution is grounded in a body of studies that has, over the last two decades, challenged anthropocentric and instrumental conceptions of matter, emphasizing instead the active, relational, and processual nature of material systems. Within new materialist and posthumanist debates, matter is understood as a dynamic participant in socio-technical and ecological processes (Bennett, 2010; Coole & Frost, 2010). From this standpoint, waste emerges as a material configuration endowed with a specific form of agency, capable of shaping practices, infrastructures, and decision-making processes through its persistence, mobility, and resistance to containment (Bennett, 2020). Waste materials—fibres, blends, residues, micro-components—exert constraints and affordances that actively condition what forms of circularity can be enacted and stabilized within specific contexts. This relational understanding of material agency resonates with Ingold’s conception of materials as processes rather than objects. Ingold (2012) argues that materials should be understood through their ongoing trajectories of transformation, circulation, and entanglement. Applied to fashion manufacturing, this implies reading waste not as the terminal stage of a linear lifecycle, but as a moment within a broader material metabolism in which fibres, chemicals, infrastructures, and practices continuously interact and evolve. Complementing this view, actor-network theory further supports an ecological reading of waste by conceptualizing production systems as assemblages of heterogeneous actors—human and non-human—whose relations co-produce material outcomes (Latour, 2005). Within such assemblages, waste operates as a mediator rather than an exclusive outcome: it connects design decisions, manufacturing practices, regulatory dispositifs, and infrastructural capacities, making visible the points where these relations align or fracture. This interpretation resonates with recent fashion studies scholars that also attribute agency to materials within socio-technical processes. Payne and Smelik (2024), for instance, show how textile fibers participate in planetary material flows that shape ecologies, practices, and infrastructures (Hetherington, 2004; Hawkins, 2006; Gregson &

Crang, 2010). In continuity with new materialism and posthumanist approaches (Bennett, 2010; 2020), waste is therefore conceptualized not as inert residue, but as an active node within broader socio-material metabolisms, encompassing dispersed microfibers, contamination, recycling infrastructures, and regeneration processes. In the fashion sector, waste production exposes organizational rigidities, material incompatibilities, and infrastructural limits, while many circular innovations—such as fiber-to-fiber recycling or design for disassembly—remain confined to niche contexts in the absence of favorable systemic conditions for their stabilization and diffusion. Even apparently marginal elements, including sewing threads, micro-components, or adhesives that prevent disassembly, emerge as critical disablers of circularity, testing the coherence between design decisions, infrastructures, and regenerative capacities (D’Itria & Trejo Machin, 2024).

This multi-level reading exposes the limits of the linear approach that has historically segmented the fashion system into discrete phases—make, take, waste—producing a disconnection bias that obscures continuity, responsibility, and interdependence across the product life cycle (Whitty, 2021; Voulvoulis et al., 2022). These limits become particularly evident in territorially embedded production systems, where supply chain fragmentation, regulatory misalignment, and infrastructural inadequacies—especially in relation to advanced recycling—further complicate the implementation of integrated circular models (Bocken et al., 2016; Ritzen & Sandström, 2017). From this perspective, waste makes visible the conditions under which circularity becomes practicable—or, conversely, where it comes to a halt—opening up the investigation of situated ecologies of waste that illuminate both the limits and the possibilities for reshaping the fashion system within the circular transition. Rather than abstracting waste from its contexts, the notion of waste ecologies foregrounds how material properties, territorial infrastructures, and organizational arrangements co-evolve, shaping the concrete conditions under which circularity becomes practicable—or remains structurally blocked—in fashion manufacturing systems. In this contribution, waste ecologies are thus defined as situated socio-material configurations in which waste is generated, negotiated, transformed,

and valorized through the interaction of design decisions, manufacturing arrangements, infrastructural capacities, regulatory frameworks, and material properties. They are not typologies of waste, but relational fields that reveal the conditions under which circularity becomes practicable, conditionally enabled, or structurally blocked within territorially embedded production systems.

WASTE ECOLOGIES SHAPING FASHION MANUFACTURING

This paper introduces waste ecologies as an analytical lens to investigate the circular processes progressively reshaping Italian fashion manufacturing. Waste ecologies are understood as socio-material configurations through which waste is generated, classified, transformed, and rendered—or not rendered—valuable within specific productive and territorial contexts. This section develops waste ecologies as a conceptual device grounded in empirical observation of Italian fashion manufacturing systems. They emerge as analytical configurations derived from the qualitative interpretation of empirical materials collected within the RHITA project, including semi-structured interviews with manufacturers, brands, waste management providers, and territorial actors, as well as the analysis of policy documents and technical reports. Within the empirical framework of this study, waste is approached as an analytical entry point through which to examine the co-evolution of materials, practices, infrastructures, organizational arrangements, and regulatory frameworks. Tracing waste across production, selection, and treatment contexts enables the identification of sites where circular transition is negotiated, constrained, or interrupted.

From this perspective, waste functions as a methodological device that renders visible tensions within manufacturing systems: situations in which infrastructural capacities prove insufficient, material compositions are misaligned with available technologies, regulatory frameworks encounter operational limits, or, conversely, context-specific opportunities for circular innovation emerge. Rather than treating circularity as an intrinsic property of materials or systems, the analysis conceptualizes it as a relational and situated condition, contingent upon the often-precarious alignment between design decisions, production capacities, and territorial arrangements.

On this basis, the following subsection operationalizes the concept by identifying recurrent waste ecologies within Italian fashion manufacturing. These configurations should not be read as fixed typologies, but as analytical arrangements that illuminate different conditions of possibility for circularity. They indicate where circularity is already practicable, where it is conditionally enabled through organizational coordination, where it is structurally obstructed, and where design can intervene as a critical lever of transition. Taken together, these waste ecologies shift analytical attention from isolated materials to the relations that render them regenerable or not; from universal solutions to situated and territorialized trajectories; and from waste management to the systemic reconfiguration of fashion manufacturing as a whole.

PRE-CONSUMER INDUSTRIAL WASTE ECOLOGIES

These ecologies represent the most structured and historically consolidated configuration within Italian fashion manufacturing, especially relevant for natural fibers, such as cotton, silk and wool, whose pre-consumer residues retain strong regenerative potential and may also generate limited economic returns. Pre-consumer waste emerges within controlled and highly specialized production processes, where the relative material purity and traceability, together with territorial proximity between waste generation and treatment, enable forms of recovery and reintegration. In this context, waste regenerability is directly shaped by process design: quality standards and technical specifications significantly influence both the quantity and the quality of residues. This ecology is therefore generally enabling circularity, provided that material architectures and operational logics remain aligned with available infrastructural capacities.

CONSORTIAL AND DISTRICT-BASED RECYCLING ECOLOGIES

In these configurations, waste is reorganized through collective mediating devices—such as consortia, district-based platforms, and specialized operators—that connect production and regeneration. Circularity here emerges from territorial and institutional coordination, supported by shared standards, semi-institutional governance, and localized infrastructures. These ecologies make explicit that circular transition cannot be reduced

to technological solutions alone, but depends on fragile socio-technical alignments between materials, volumes, and processing capacities. As a result, they are conditionally enabling and particularly vulnerable to increasing material complexity and flow discontinuities.

POST-CONSUMER AND SORTING ECOLOGIES

Post-consumer ecologies represent the most structurally problematic configuration within Italian fashion manufacturing. They are characterized by high material heterogeneity, limited traceability, and a pronounced spatial and organizational separation between sites of production and sites of consumption. This disconnection exposes a deep asymmetry between the material quality embedded in Italian manufacturing processes and the composition of post-consumer flows entering collection and sorting systems. These flows are increasingly dominated by synthetic blends, low-durability garments, complex finishes, and multi-material assemblies that resist separation and compromise material purity. As a result, post-consumer waste systematically exceeds the technological and organizational capacities of existing collection, sorting, and recycling infrastructures, which remain largely calibrated to more homogeneous and predictable material streams.

In this configuration, circularity is not merely difficult to implement but structurally undermined: the misalignment between upstream design logics, globalized consumption patterns, and downstream infrastructural capacities produces waste streams that are largely incompatible with regenerative pathways. Post-consumer ecologies thus reveal the limits of the current circular regime, showing how circular ambitions collapse when material complexity, scale, and infrastructural readiness fail to converge.

BRAND-LED AND ORGANIZATIONAL WASTE ECOLOGIES

Particularly relevant in the mid-to-high-end and luxury segments, these ecologies are defined less by the material visibility of waste than by governance arrangements imposed by commissioning brands. Waste management is structured through internal protocols, traceability systems, residue selection criteria, and stable supplier relationships that reflect upstream decisions regarding aesthetics, performance standards, and quality requirements

established by brands.

In these configurations, waste does not directly inform design choices; rather, it materializes as an organizational and material consequence of decisions taken earlier in the process. A critical issue concerns the asymmetric distribution of responsibility: while brands retain control over design decisions, material selections, and quality standards, manufacturing SMEs are often required to absorb the operational and environmental implications of these choices. Subcontractors are thus compelled to accommodate highly impactful design requests, even when these increase waste volumes or undermine their regenerative potential. As a result, these ecologies are selectively enabling: they may support circular practices within tightly controlled and brand-governed perimeters, yet they remain difficult to scale systemically due to the misalignment between decision-making power and responsibility for waste management.

CRITICAL MISALIGNMENT ECOLOGIES

Transversal to all other configurations, these ecologies take shape where design decisions remain disconnected from manufacturing constraints and end-of-life infrastructures. Complex assemblies, disabling micro-components, incompatible finishes, and composite material choices embody design priorities that are often articulated without considering their downstream implications. The absence of stable feedback loops between designers, manufacturers, and recyclers further amplifies these disconnections, allowing misalignments to persist across the production system.

In such configurations, waste represents the material manifestation of unresolved tensions between aesthetic, functional, and symbolic ambitions on the one hand, and infrastructural, technological, and regenerative capacities on the other. It is precisely within these ecologies that the limits of current design practices become most evident, revealing how circular transition is hindered when design operates in isolation from its systemic consequences.

WHAT IS BEING RESHAPED, AND WHY IT MATTERS

The analysis of waste ecologies shows that the circular transition currently underway in Italian fashion manufacturing cannot be interpreted as a simple reconfiguration of material flows or as a technical adjustment to new regulatory requirements. What is being reshaped is a deeper

and more articulated set of relations that concerns the very boundaries of the production system, the value hierarchies that structure it, and the forms of responsibility that regulate its functioning. Waste Ecologies reveal how circularity in Italian fashion manufacturing is not a uniform process, but a differentiated and situated one, shaped by specific material, organizational, and territorial conditions. By following waste across these configurations, the analysis makes visible the concrete trajectories through which the manufacturing system is being reshaped, as well as the structural constraints that continue to limit systemic transition.

RESHAPING BOUNDARIES: FROM LINEAR SUPPLY CHAINS TO EXTENDED WASTE-BASED ECOLOGIES

First, waste ecologies make evident an ongoing redefinition of the boundaries of the Made in Italy fashion manufacturing system. Traditionally, Italian manufacturing has been conceptualized as a sequence of highly specialized production phases, centered on product quality and territorial proximity among actors. Focusing on waste unsettles this representation, revealing a more extended and porous system that includes collection and treatment infrastructures, logistics platforms, waste service providers, regeneration actors, and environmental governance devices previously considered external or ancillary. In this sense, circular transition redefines who belongs to the system and which activities become strategic. Waste ecologies show that the manufacturing system does not end with production or sale, but continues across the territories where waste is sorted, accumulated, valorized, or blocked. For Made in Italy, this entails a significant shift: competitiveness no longer depends exclusively on the ability to produce quality, but on the capacity to govern an expanded system of material and infrastructural relations.

RESHAPING VALUE HIERARCHIES: FROM RESIDUE TO STRATEGIC MATERIAL

The analysis highlights a transformation of the value hierarchies that structure the fashion system. Within waste ecologies, waste assumes an ambivalent role: on the one hand, it signals inefficiencies, material incompatibilities, and infrastructural limits; on the other, it becomes a strategic resource around which skills, investments, and design practices are reorganized. This ambivalence challenges the historical association

between value and the finished product, shifting attention toward processes, intermediate materials, and industrial residues.

This transformation is particularly significant in the Italian context, where production has historically been oriented toward material quality, while post-consumer flows increasingly reflect the logic of the global fast fashion market. Waste ecologies make this structural discontinuity visible: Italy produces high-quality, potentially regenerable pre-consumer waste, yet must contend with heterogeneous, contaminated, and difficult-to-treat post-consumer waste streams. In this scenario, waste becomes a site of negotiation between divergent value models, revealing a central tension for the future of Made in Italy.

Design plays a key role in redefining these hierarchies by translating material constraints into design criteria and making the systemic implications of choices related to composition, assembly, and finishing visible. Through this lens, value is no longer attributed exclusively to the object itself, but to its compatibility with broader productive and regenerative ecologies.

RESHAPING RESPONSIBILITIES: FROM INDIVIDUAL TO DISTRIBUTED GOVERNANCE

A third level of reconfiguration concerns responsibility relations along the supply chain. The introduction of EPR and the strengthening of the European regulatory framework formally shift attention toward the entire product life cycle. However, the analysis of waste ecologies shows that responsibility does not automatically redistribute evenly, but is negotiated within specific socio-material configurations marked by power asymmetries, differentiated operational capacities, and infrastructural constraints.

Following waste makes it possible to observe how responsibility is translated into everyday practices: who selects residues, who invests in traceability, who absorbs the costs of material inefficiency, and who benefits from valorization opportunities. In this process, new intermediary roles emerge—such as textile waste service providers and regeneration actors—that do not merely manage flows, but actively contribute to redefining the conditions of possibility for circularity.

For Made in Italy, this implies a reconfiguration of responsibility not only as a regulatory obligation, but as a distributed and territorially situated competence. Waste ecologies show that the capacity

to respond to the ecological transition depends on the ability to construct shared responsibilities, supported by adequate infrastructures and coherent design practices.

Taken together, these processes indicate that what is being reshaped is not simply the fashion supply chain, but the way Made in Italy conceives itself: no longer as a linear, product-oriented chain, but as a productive ecology grounded in relations, materials, and territories. Waste ecologies make visible that the circular transition cannot be addressed as an incremental adjustment, but as a systemic transformation that affects productive identities, organizational arrangements, and value regimes.

From this perspective, it is through the capacity to recognize, govern, and design its own waste ecologies that Italian fashion manufacturing can transform circularity into a strategic lever for resilience and competitiveness. The contribution of this article lies precisely in showing how waste ecologies enable a situated and materially informed reading of the reshaping processes currently underway, and in identifying the conditions under which such transformations can consolidate over time.

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