Fecha de recepción: marzo 2026
Fecha de aprobación: mayo 2026

Rethinking packaging smartness: advanced design infrastructures for Made in Italy transitions

Erik Ciravegna[(*)], Sara Battistini[(**)], Lisa Filippini[(***)] y Camilla Sartor[(****)]
Università di Bologna (Italia)

Abstract: In a context where almost everything is presented as *smart*, packaging allows intelligence to be reconsidered beyond its technological dimension, shifting attention from devices to the design infrastructures that shape socio-technical change. From a Transition Design perspective, the intelligence of packaging is understood as its capacity to articulate relationships, enable responsible behaviours, and mediate values within complex socio-technical systems. Grounded in the principles of Advanced Design, this approach frames packaging smartness as a systemic, anticipatory and culturally situated form of intelligence. The FuturE-Pack project reconceptualises packaging as an active interface between brand, supply chain and user, capable of integrating environmental information, traceability, sustainability narratives and circularity criteria. The research produced two main outcomes: an interactive digital platform that organises knowledge, case studies and regulatory frameworks, and a design toolkit that translates systemic visions into applicable operational processes. These tools function as cultural and design-driven infrastructures that support organisations in navigating complexity and fostering circular innovation. Validation in the Italian fashion sector demonstrated how packaging can mediate trust, transparency and territorial collaboration, generating new ecologies of relation and action. The article positions these results within the field of Transition Design and proposes an expanded understanding of packaging "intelligence" as responsible, circular, relational and anticipatory, capable of guiding long-term change toward more sustainable futures.

Keywords: Smart packaging - Transition Design - Advanced Design - Design infrastructures - Digital platforms - Socio-technical systems - Responsible innovation - Circular economy - Sustainability - Made in Italy

[Resúmenes en castellano y en portugués en las páginas 131-132]

(*) (**) (***) (****) Ver CVs. de Erik Ciravegna, Sara Battistini, Lisa Filippini y Camilla Sartor en páginas 132-133

1. Introduction

Over the past two decades, the adjective *smart* has become pervasive across design, innovation, and policy discourses. Applied to objects, services, systems, and environments alike, it is routinely used to denote technological enhancement, digital connectivity, or data-driven performance. Although this semantic expansion has contributed to the visibility and institutional legitimacy of innovation processes, it has also resulted in a progressive flattening of meaning. *Smartness* is increasingly treated as a self-evident quality, tacitly linked to sensors, connectivity, automation, or computational capacity, with limited critical examination of its conceptual implications.

Within the domain of packaging, this flattening has had particularly significant consequences. *Smart packaging* is frequently framed as a technical upgrade of conventional packaging, defined by the integration of devices capable of monitoring conditions, storing or transmitting information, and supporting traceability across supply chains. Such framings are consolidated through standards, technical taxonomies, and sectoral classifications, which provide a necessary operational vocabulary and support industrial uptake. However, when adopted as dominant interpretative frames, they tend to reduce packaging smartness to a set of functional features, marginalising the broader social, cultural, and systemic dimensions through which packaging operates.

This reduction becomes particularly salient in the context of sustainability-oriented transitions. Packaging functions as a socio-technical artefact that mediates relationships between production systems, regulatory frameworks, brands, logistics infrastructures, and everyday practices of consumption and disposal. Design decisions embedded in packaging influence material flows, user behaviour, responsibility distribution, and the construction of value and meaning across supply chains. Framing smart packaging primarily through technological criteria narrows the analytical focus on these broader systemic dynamics.

Normative and technical framings of smart packaging play a key role in providing shared terminology, enabling standardisation, and supporting interoperability. They do not, however, address the fundamental question of what kind of intelligence is required when packaging is expected to contribute to sustainability, circularity, and long-term socio-technical change. As research on wicked problems has long shown, challenges characterised by interdependence, uncertainty, and conflicting values cannot be resolved through optimisation alone (Buchanan, 1992). When considered within sustainability transitions, smart packaging exhibits many of these characteristics.

This article proposes a rethinking of smart packaging as a form of systemic, relational, and anticipatory intelligence. Smartness emerges from how packaging is designed to operate within complex systems, rather than from the mere presence of specific devices or materials. It involves the capacity to make relationships visible, to support informed and responsible action, and to enable coordination across heterogeneous actors and temporal horizons. This understanding is consistent with broader developments in design research that foreground meaning, mediation, and responsibility alongside functional performance (Krippendorff, 2006; Manzini, 2015).

Reframing packaging smartness in this way brings ethical and temporal dimensions of design into sharper focus. Decisions made in packaging design generate effects that unfold

over time and across contexts, often extending beyond the immediate scope of designers or organisations. Anticipation refers to the capacity to consider downstream consequences and evolving conditions as part of the design process (Poli, 2019; Poli, 2010; Zamenopoulos y Alexiou, 2007). Smart packaging thus relates to supporting informed judgment in situations characterised by uncertainty and distributed responsibility.

This reframing has significant implications for the organisation of design research and innovation. Smart packaging challenges often unfold at a systemic level, where isolated solutions and project-based experimentation struggle to produce sustained change. Although pilot projects and prototypes remain valuable for exploring possibilities, their outcomes frequently remain context-specific and difficult to transfer. Knowledge tends to accumulate unevenly, evaluation criteria differ across actors, and lessons learned are seldom stabilised in ways that support collective learning. Innovation processes, therefore, tend to unfold in episodic forms, with recurring tensions across projects and limited consolidation over time.

This article addresses this gap by focusing on design infrastructures as a strategic response to the complexity of smart packaging systems. Design infrastructures are understood here as shared frameworks, tools, and environments that organise knowledge, support coordination, and enable anticipatory decision-making. Their role lies in shaping the conditions under which solutions are conceived, assessed, and adapted. By relocating intelligence from individual artefacts to the systems that govern design processes, infrastructures offer a way to align technological possibilities with sustainability-oriented transitions.

The argument developed in this article is grounded in the FuturE-Pack research project, which constitutes the empirical and projectual basis of the contribution. FuturE-Pack is a design-driven research initiative focused on rethinking smart packaging within the context of circular and sustainable Made in Italy production systems. Besides defining smart packaging in conceptual terms and proposing exemplary technological applications, the project develops and validates two complementary design infrastructures, a digital platform and a design toolkit, intended to support coordination, anticipation, and informed decision-making across smart packaging systems (Ciravegna, 2025).

FuturE-Pack was developed within the framework of *MICS-Made in Italy Circolare e Sostenibile*[1], and specifically *Spoke 1-Digital Advanced Design: Technologies, Processes, and Tools*[2], which addresses product, process, and system innovation for sustainability-oriented transitions. The project, developed by Alma Mater Studiorum-Università di Bologna, Politecnico di Torino, and Università degli Studi di Firenze, engages with production contexts characterised by distributed supply chains, strong territorial identities, and increasing regulatory and cultural pressure for transparency and circularity. The fashion sector, with its complex material flows and symbolic density, provided a particularly demanding context for validating infrastructural design approaches. The relevance of this context lies in its capacity to expose structural challenges shared by other packaging-intensive sectors. Within FuturE-Pack, the platform and the toolkit are conceived as infrastructural research outputs, designed to be used, adapted, and interpreted by different actors. Validation, therefore, takes the form of a design-led and systemic process, grounded in use and iteration and distinct from empirical testing based on predefined hypotheses. The project thus offers a concrete case through which to examine how design infrastructures can operate

as mediators within socio-technical transitions, while preserving complexity and avoiding prescriptive or solutionist approaches.

The contribution of this article is therefore twofold. Conceptually, it advances a reframing of packaging smartness that foregrounds systemic relationships, responsibility, and anticipation. Projectually, it articulates how design infrastructures can operationalise this reframing, supporting sustainability-oriented innovation beyond isolated projects. In doing so, the article positions itself within Transition Design (Irwin, Kossoff & Tonkinwise, 2022; Irwin, 2015; Kossoff, 2011) and Advanced Design (Celaschi, 2015; Celi, 2010) debates, contributing to ongoing discussions about the role of design in shaping long-term socio-technical change.

The article unfolds through a progressive articulation of this argument. It first interrogates dominant interpretations of smart packaging and outlines the need for a systemic reframing of smartness. It then examines why smart packaging challenges exceed object-level solutions and require infrastructural responses. The core of the contribution is devoted to articulating the design infrastructures developed within FuturE-Pack and to discussing their validation and implications for sustainability-oriented innovation. The concluding section reflects on the broader relevance of this approach for design research and practice, positioning smart packaging as a critical field for experimenting with design's role in socio-technical transitions.

By approaching smart packaging as a design problem embedded in complex systems, this article contributes to a more responsible and future-oriented understanding of intelligence in design. Rather than advancing definitive answers, it aims to open a space for reflecting on how design can support collective action in contexts where sustainability operates as a condition to be continually negotiated over time.

2. Rethinking packaging smartness

The notion of smart packaging has increasingly been associated with an understanding of intelligence grounded primarily in technological capability. Within dominant industrial and regulatory discourses, smartness is frequently associated with the integration of devices such as sensors, indicators, and data carriers, enabling packaging to monitor conditions, collect information, and communicate data across the supply chain. While these developments have expanded the functional scope of packaging, they have also reinforced a reductive interpretation of smartness as an intrinsic property of artefacts, measured primarily through performance and efficiency.

This interpretation reflects a broader tendency to equate intelligence with automation, connectivity, and responsiveness. Packaging becomes smart as it can detect changes, trigger alerts, or exchange information in real time. This framing privileges technological sophistication and tends to marginalise the relational, cultural, and systemic dimensions through which packaging operates. Smart packaging is often approached primarily as a technical addition, while its role as a design intervention within complex socio-technical systems remains underexplored.

This form of technological determinism becomes particularly problematic when smart packaging is framed as a lever for sustainability and circularity. The assumption that increased intelligence automatically leads to improved environmental performance overlooks the multiple mediations through which packaging influences material flows, user practices, and organisational decision-making. Smart devices may enable more precise monitoring or enhanced traceability, but their effectiveness depends on how information is interpreted, acted upon, and integrated into broader systems of production and consumption.

Reconsidering packaging smartness involves shifting the analytical focus from objects to the relationships they configure. Smartness emerges through the capacity of packaging to mediate interactions between actors, to make processes intelligible, and to support informed judgment. Packaging functions as an interface between material systems and social practices, shaping the distribution of responsibility and the construction of value across the lifecycle.

This relational view of smartness highlights design as a mediating practice. Decisions embedded in packaging affect functional performance, but also shape meanings, behaviours, and expectations. Through design, certain information is made salient, specific actors are prompted to respond, and particular conditions of action are established. Smart packaging contributes to shaping what becomes visible or invisible within socio-technical systems, influencing how action is enabled or constrained.

A systemic perspective further complicates the notion of smartness by highlighting interdependencies and trade-offs. Packaging operates within networks that include materials, logistics infrastructures, regulatory frameworks, market dynamics, and cultural norms. Introducing smart technologies into these networks can generate unintended consequences, such as increased material complexity, higher energy consumption, or new forms of exclusion. Evaluating smartness solely in terms of technological performance fails to account for these systemic effects.

From a design research standpoint, smart packaging constitutes a wicked problem, characterised by incomplete information, conflicting objectives, and solutions that reshape the problem itself. Addressing such conditions calls for approaches capable of engaging with uncertainty and ambiguity, instead of seeking their removal. Smartness concerns discernment and responsibility and cannot be adequately captured through optimisation alone.

This reframing draws attention to the temporal dimension of smart packaging. Design decisions generate effects that unfold over time and often extend beyond the immediate scope of projects or organisations. Anticipation becomes a key aspect of smartness, understood as the ability to consider future conditions, delayed consequences, and evolving constraints. Packaging intended to support sustainability, therefore, needs to facilitate reflection on long-term implications, alongside considerations of short-term efficiency.

Smart packaging can be framed as an anticipatory artefact that supports learning and reflection as conditions of use evolve. Its relevance lies less in predictive accuracy than in its capacity to enable informed and adaptive action over time. Viewed in this way, packaging smartness aligns with broader understandings of intelligence as situated, relational, and ethically grounded.

Rethinking packaging smartness requires shifting attention from the technologies embedded in packaging to how packaging participates in shaping socio-technical systems. Smartness emerges from the alignment of design intentions, technological capabilities, and systemic contexts. Recognising this shift is a necessary step for positioning smart packaging as a meaningful contributor to sustainability-oriented transitions.

3. From research to design infrastructure

In technical and scientific literature, smart packaging is commonly described as the evolution of conventional packaging through the integration of digital and intelligent technologies that enable monitoring, data exchange, and interaction across supply chains. Research addressing the convergence of digitalisation, logistics, and circular economy describes smart packaging as a set of technologically mediated solutions aimed at enhancing traceability, information transparency, operational coordination, and decision-making throughout the product lifecycle (Agrawal *et al.*, 2023; Behl *et al.*, 2023). In this framing, intelligence is associated with the capacity of packaging to function as an active informational interface, supporting data-driven processes within increasingly complex and distributed production and consumption systems.

Within this body of literature, international standards serve a terminological and consolidating role in relation to smart packaging. ISO 6608-1:2024 defines smart packaging as "a general term to describe a large category of packaging that leverages technology to provide enhanced functionality that goes beyond simply housing a product" (International Organization for Standardization [ISO], 2024). The standard refers to the integration of chemical, physical, electronic, and digital technologies enabling the monitoring of product conditions, the exchange of information across the supply chain, the mediation of user experience across the lifecycle, and the support of sustainable behaviours and circular strategies. The standard formalises a shared vocabulary and stabilises usage across technical and regulatory domains, without addressing the broader design, socio-technical, and sustainability implications that exceed functional description and compliance.

When smart packaging is examined at the level of devices and applications, the limits of this baseline definition become more apparent. The literature highlights how the technological landscape of smart packaging is characterised by a heterogeneous constellation of devices, such as indicators, sensors, and data carriers, which differ significantly in function, material composition, lifespan, and infrastructural requirements. These devices add new layers of complexity to already dense systems, reshaping how packaging operates across the supply chain. Each device category implies specific dependencies on materials, energy, data infrastructures, and interpretative competences, thereby reshaping the conditions under which packaging operates across the supply chain.

This complexity is amplified when smart packaging technologies are situated within concrete application domains. Studies on smart packaging indicate that, in food systems, smart devices intersect with issues of safety, shelf-life management, regulatory compliance, and consumer trust. In logistics contexts, they interact with traceability infrastructures, data

interoperability, and organisational coordination among multiple actors. In consumer information settings, they mediate transparency, accessibility, and user engagement, raising questions related to inclusivity, literacy, and interpretative overload. Across these domains, smart packaging technologies give rise to tensions and trade-offs that must be addressed through processes of evaluation, coordination, and decision-making at the system level.

Such tensions show that object-level solutions are insufficient to address smart packaging challenges. Research on smart packaging devices indicates that the same device may perform effectively in technical terms while generating unintended consequences at the systemic level. Increased material complexity may compromise recyclability; enhanced data collection may require infrastructures that are unevenly distributed; improved information availability may exacerbate cognitive or accessibility barriers for certain user groups. Such risks are inherent to the deployment of smart packaging technologies in sustainability-oriented contexts.

The evaluation of smart packaging extends beyond the use of performance metrics alone. The literature shows that criteria such as technical reliability, usability, and environmental implications are closely interrelated and cannot be addressed in isolation. Performance improvements achieved through smart devices may coincide with increased material complexity or higher energy demand. Similarly, enhancements in usability often rely on assumptions about user behaviour that vary significantly across contexts. Environmental benefits, in turn, may depend on system-level conditions that lie outside the scope of individual design projects. Considered collectively, these interdependencies position evaluation itself as a complex design problem, one that resists resolution through isolated assessments or standardised checklists.

This condition reveals the limits of project-based research and isolated smart solutions. While experimental projects are effective in testing devices or applications within bounded contexts, they struggle to account for the cumulative and cross-contextual effects that emerge when smart packaging technologies scale or interact. Knowledge generated in one application domain often remains difficult to translate to others, and lessons learned about trade-offs or risks are rarely formalised in ways that can inform subsequent decisions. As a result, innovation trajectories risk reproducing similar tensions across projects without building collective capacity to address them.

Design infrastructures emerge here as a necessary response to the systemic nature of these challenges. Within a sustainability framework, they represent the foundational systems and processes enabling the creation of ecologically and socially responsible built environments and products. They extend beyond physical structures to include the collaborative networks, data resources, and decision-making protocols that support sustainable design outcomes. This concept acknowledges that achieving genuine sustainability requires a comprehensive approach, integrating environmental considerations with economic viability and social equity[3].

In the FuturE-Pack research project, design infrastructures respond to device-level complexity by enabling the organisation and comparison of diverse smart packaging configurations, a means to organise, compare, and contextualise diverse smart packaging configurations across applications and criteria. They support the articulation of relationships between device typologies, application domains, and evaluation dimensions, without col-

lapsing this complexity into prescriptive models. In doing so, they enable designers and organisations to navigate trade-offs consciously, making explicit the implications of their choices across performance, usability, and environmental dimensions.
Moreover, by embedding evaluation criteria within shared frameworks that extend across projects, design infrastructures enable cumulative forms of learning. Insights concerning risks, trade-offs, and contextual dependencies can be retained, revisited, and reinterpreted over time, moving beyond the scope of individual initiatives. This cumulative capacity is essential for sustainability transitions, which rely on the progressive alignment of practices, technologies, and evaluative cultures across systems.
Smart packaging technologies generate intelligence only as far as the systems that govern their adoption can coordinate decisions, anticipate consequences, and negotiate trade-offs across domains. Design infrastructures provide the conditions under which this coordination becomes possible, reframing smart packaging from a collection of devices into a field of informed and responsible action within socio-technical systems.

4. Design infrastructures for smart packaging systems

The infrastructural perspective outlined so far finds concrete articulation in the design outcomes of the FuturE-Pack research project. The project focuses on the development of design infrastructures capable of supporting coordination, anticipation, and informed decision-making within complex smart packaging systems, instead of proposing individual solutions or exemplary applications. These infrastructures take the form of two interrelated outputs: an interactive platform and a structured design toolkit. Both function as enabling devices that shape how smart packaging is understood, evaluated, and enacted across contexts and over time.
Within FuturE-Pack, the notion of infrastructure is adopted to address a structural gap observed in smart packaging innovation. While technological capabilities and device-level experimentation continue to expand, the conditions required to integrate such developments into sustainability-oriented transitions remain underdeveloped. Knowledge is often fragmented, evaluation criteria are inconsistently applied, and decision-making processes are distributed across actors who lack shared reference frameworks. The platform and the toolkit respond to this condition by operating at a level that precedes individual projects, shaping the cognitive and organisational environment in which projects are conceived.
The FuturE-Pack platform[4] functions as a coordinating infrastructure for knowledge and interpretation. Its primary role is to organise heterogeneous forms of knowledge (conceptual, methodological, and empirical) into a navigable environment that supports sense-making within smart packaging systems. By structuring access to research outputs, mapped practices, and design-relevant insights, the platform enables users to approach smart packaging from multiple entry points without fragmenting the overall system perspective.
As an infrastructure, the platform foregrounds relationships between device typologies and application domains, design intentions and systemic implications, and performance

objectives and sustainability constraints. This relational organisation keeps complexity visible, avoiding premature categorisation or ranking. In doing so, the platform supports reflective comparison and critical judgment, enabling actors to situate their decisions within a broader field of possibilities and consequences.

The platform supports anticipatory reasoning by clarifying how smart packaging configurations relate to regulatory frameworks, supply-chain structures, and user practices. Rather than offering predictive models or prescriptive scenarios, it provides organised access to research materials that help users reflect on the potential implications of present design choices over time.

Complementing the platform, the FuturE-Pack design toolkit constitutes an operational infrastructure for action. While the platform supports interpretation and orientation, the toolkit is designed to structure decision-making within concrete design processes. Its function is to provide shared reference points that enable coordination among actors operating within distinct roles, constraints, and value systems.

The toolkit is organised around design needs identified through the analysis of smart packaging systems. This structure reflects a deliberate move away from object-centred approaches and towards a form of purpose-driven reasoning. By framing design activity in relation to needs, responsibilities, and lifecycle implications, the toolkit supports designers and organisations in considering how smart packaging decisions extend beyond the boundaries of individual projects.

As an infrastructure, the toolkit integrates evaluation directly into the design process. It brings together considerations of performance, usability, and environmental implications as interrelated dimensions that are addressed in parallel throughout design activity. This approach is particularly relevant in sustainability-oriented contexts, where interventions aimed at improving one aspect frequently produce tensions or trade-offs in others. By structuring how these relationships are examined, the toolkit offers a shared space in which such tensions can be made explicit, discussed, and negotiated within ongoing design work.

The relationship between platform and toolkit is deliberately complementary. The platform offers a broad, exploratory environment in which knowledge is organised and contextualised, while the toolkit translates this knowledge into operational guidance that can be mobilised within specific projects. Neither infrastructure is effective in isolation: the toolkit relies on the platform to situate its use within a broader knowledge landscape, while the platform gains relevance through the practices and feedback generated by the toolkit application. Together, they form a multi-layered infrastructure that connects reflection and action without collapsing one into the other.

Importantly, both the platform and the toolkit are conceived as open and evolvable. They are designed to remain adaptable, accommodating emerging devices, regulatory changes, and shifting sustainability priorities across sectors and technological contexts. This openness is intrinsic to the infrastructural role of the platform and the toolkit. Within sociotechnical transitions, their relevance depends on their ability to evolve alongside the systems they engage with, responding to changing conditions over time.

By framing the platform and the toolkit as design infrastructures, FuturE-Pack positions design as a strategic mediator within smart packaging systems. These infrastructures make

complexity operable by establishing shared conditions for coordination, anticipation, and responsibility. Smart packaging is configured as a field of collective and informed action that supports long-term sustainability transitions.

5. Validation and implications for transition design

The validation of the design infrastructures developed within FuturE-Pack does not follow conventional models of empirical testing or performance benchmarking. Their effectiveness is instead assessed in relation to how they reconfigure practices of interpretation, coordination, and decision-making within smart packaging systems. Validation is inherently design-led: it emerges from situated use, iterative refinement, and the observation of how the platform and the toolkit operate as mediating devices within complex sociotechnical settings.

Within FuturE-Pack, validation was conducted through deployment and use within a specific research and innovation context characterised by high symbolic value, fragmented supply chains, and strong sustainability pressures. The project was situated within the Made in Italy production ecosystem and developed in connection with the MICS research framework, with a particular focus on the fashion sector. This context provided a stringent testbed for infrastructural design, as it combines advanced manufacturing practices with distributed networks of small and medium enterprises, intense regulatory scrutiny, and growing demands for transparency and circularity.

Validation was conducted by observing how the platform and the toolkit were appropriated by different actors and how they influenced the framing of design problems and decisions. Designers, companies, and researchers engaged with the infrastructures as evolving environments that structured dialogue and reflection over time. Validation, therefore, concerned the extent to which these infrastructures supported informed, coordinated, and anticipatory reasoning across organisational and disciplinary boundaries.

One of the main outcomes of the validation process concerns coordination. Shared reference frameworks and articulated design needs contributed to greater alignment among actors who usually operate with different priorities and professional languages. The infrastructures provided common points of orientation that enabled comparison and dialogue, making it possible to address tensions and trade-offs explicitly. This dynamic was particularly visible in situations where smart packaging decisions intersected with material choices, regulatory constraints, and brand narratives, illustrating the mediating role of design infrastructures across heterogeneous rationalities.

Validation also highlighted the role of the platform in supporting transparency. The platform operated as a device that makes relationships between technological options, systemic implications, and sustainability objectives visible and intelligible. Transparency is understood here as the capacity to grasp complexity and to make sense of interconnected conditions. By organising knowledge through relational structures, the infrastructure allowed users to recognise the range of available choices and to understand the consequences associated with specific decisions. This form of transparency is central to sustainability-

oriented innovation, where responsibility depends on the ability to comprehend indirect and delayed effects of design decisions.

Effects were also evident in the ways design decisions were framed and discussed throughout the process. The toolkit supported reflective and anticipatory modes of action by integrating evaluation criteria directly within design activities and connecting them to broader system-level considerations. This integration prompted designers and organisations to address long-term implications together with immediate project constraints. Decision-making took the form of situated judgments informed by multiple dimensions, consistent with an understanding of intelligence grounded in discernment and responsibility within transition-oriented design thinking.

These observations describe a form of validation that is qualitative, systemic, and process-oriented. The relevance of the infrastructures emerges through their ability to sustain learning over time. As the platform and the toolkit were used repeatedly, knowledge was progressively accumulated and reinterpreted, leading to incremental changes in how smart packaging challenges were framed and addressed. This cumulative dynamic differentiates infrastructural validation from project-based evaluation and highlights the importance of continuity for sustainability transitions.

These observations point to broader implications for Transition Design. By demonstrating how design infrastructures can operate as mediators within complex systems, FuturE-Pack provides an example of how transition-oriented design can move beyond speculative visioning or abstract frameworks. The platform and the toolkit translate transition principles, such as long-term orientation, systemic awareness, and stakeholder engagement, into operational conditions that can be enacted within real-world contexts. They illustrate how Transition Design can be grounded in concrete design practices without losing its critical and anticipatory orientation.

Implications also extend to Advanced Design, particularly in relation to the role of design research outputs. Within this field, increasing attention is devoted to shaping the conditions under which innovation takes place, with artefacts and scenarios framed as components of broader and ongoing design processes. The FuturE-Pack infrastructures exemplify this orientation by operating as meta-design artefacts that organise and support design activity over time. This perspective reinforces the role of designers as curators of complexity and enablers of collective intelligence, broadening their contribution beyond the development of individual solutions.

From the perspective of sustainability-oriented innovation, the validation of the platform and the toolkit underscores the limits of technology-driven approaches. Smart packaging technologies become meaningful contributors to sustainability transitions only when embedded within systems capable of negotiating values, coordinating decisions, and addressing future consequences. Validation is inseparable from ethics: design infrastructures provide a means to cultivate such systems, aligning technological possibilities with social and environmental responsibilities.

The FuturE-Pack experience indicates that validation in design-driven research unfolds over time and through continued engagement. Because the platform and the toolkit are conceived as open and adaptable, their effectiveness depends on how they are used, revised, and critically discussed in practice. This open-ended character supports relevance

in socio-technical contexts marked by ongoing change. By treating validation as a situated and iterative practice, the project contributes to a broader understanding of responsible design action within sustainability transitions, with implications that extend beyond the specific field of smart packaging.

Conclusion

This article proposes a design-driven rethinking of smart packaging by questioning the widespread association between smartness and technological sophistication. The focus shifts from the technological features of artefacts or devices to intelligence understood as a socio-technical condition, dependent on how technologies are embedded, interpreted, and governed within systems of production, regulation, and use. Technological enhancement alone cannot be considered a sufficient or reliable pathway towards sustainability-oriented transformation.

This reframing highlights that smart packaging challenges extend beyond isolated solutions or project-based innovation. The complexity arising from device typologies, application domains, and evaluation criteria generates tensions and trade-offs that exceed the scope of object-level design. Such tensions constitute structural features of sustainability transitions, where competing values, uneven capabilities, and long-term consequences must be addressed through ongoing negotiation. Understanding smart packaging as a socio-technical problem, therefore, calls for design approaches capable of operating across multiple scales, involving diverse actors and accommodating extended temporal horizons.

The article positions design infrastructures as a critical contribution to sustainability-oriented innovation. They are understood as mediating frameworks that organise knowledge, support coordination, and enable anticipatory judgement across complex socio-technical contexts. This shift in focus relocates intelligence from individual artefacts to design processes and infrastructures. They provide shared reference systems through which complexity becomes operable. This allows designers and organisations to engage responsibly with uncertainty and systemic interdependence.

The discussion of the FuturE-Pack research project illustrates how this infrastructural logic can be operationalised within a concrete research and innovation context. The platform and the design toolkit function as complementary infrastructures that support sense-making and action while leaving outcomes open to interpretation and adaptation. Their validation, understood as design-led and systemic, has highlighted effects on coordination, transparency, and decision-making that are directly relevant to sustainability transitions. These effects point to the growing importance of design research outputs in shaping collective practices and shared evaluative cultures over time.

From a Transition Design perspective, the article contributes by translating transition-oriented principles into operational design conditions. Long-term orientation, systemic awareness, and stakeholder engagement are articulated as qualities that can be embedded in infrastructures supporting everyday design practice. This framing strengthens the

pragmatic dimension of Transition Design, demonstrating how it can inform concrete interventions while retaining its critical and ethical stance.
Within Advanced Design debates, the contribution reinforces a shift from designing objects and scenarios to designing the infrastructures that enable innovation to unfold. By framing the platform and the toolkit as meta-design artefacts, the article positions Advanced Design as a field concerned with shaping the environments in which future-oriented decisions are made. This orientation expands the role of designers from problem-solvers to facilitators of collective intelligence and mediators of complexity.
With respect to sustainability-oriented innovation, the article underscores the limits of technology-driven narratives and highlights the necessity of design-led coordination. Smart packaging becomes meaningful for sustainability only when embedded within systems that can align technological possibilities with social responsibility and environmental care. Design infrastructures provide a means to cultivate such alignment, supporting forms of innovation that are reflexive, anticipatory, and accountable over time.
By rethinking smart packaging beyond technological determinism and articulating the role of design infrastructures in socio-technical transitions, this article positions design research as a critical contributor to sustainability challenges. Its contribution lies in reframing how intelligence, responsibility, and innovation are conceived within design practice. The relevance of the proposed approach extends beyond packaging to domains in which sustainability transitions depend on the capacity to design the conditions shaping collective futures.

Acknowledgment

This study was carried out within the MICS (Made in Italy – Circular and Sustainable) Extended Partnership and received funding from the European Union Next-GenerationEU (PIANO NAZIONALE DI RIPRESA E RESILIENZA (PNRR) – MISSIONE 4 COMPONENTE 2, INVESTIMENTO 1.3 – D.D. 1551.11-10-2022, PE00000004). This manuscript reflects only the authors' views and opinions, neither the European Union nor the European Commission can be considered responsible for them.

Notes

1. https://www.mics.tech/
2. https://www.mics.tech/spokes/spoke-1/
3. https://lifestyle.sustainability-directory.com/area/design-infrastructure/
4. https://adu.unibo.it/pack/en

References

Agrawal, R., Yadav, V. S., Majumdar, A., Kumar, A., Luthra, S., & Garza-Reyes, J. A. (2023). Opportunities for disruptive digital technologies to ensure circularity in supply chains: A critical review of drivers, barriers and challenges. *Computers & Industrial Engineering, 178*, 109140. https://doi.org/10.1016/j.cie.2023.109140

Bauman, Z., & Bordoni, C. (2014). *State of crisis*. Polity Press.

Behl, A., Singh, R., Pereira, V., & Laker, B. (2023). Analysis of Industry 4.0 and circular economy enablers: A step towards resilient sustainable operations management. *Technological Forecasting and Social Change, 189*, 122363. https://doi.org/10.1016/j.techfore.2023.122363

Buchanan, R. (1992). Wicked problems in design thinking. *Design Issues, 8*(2), 5–21. https://doi.org/10.2307/1511637

Celaschi, F. (2015). Advanced Design Points of View. In M. Celi (Ed.), *Advanced Design Cultures* (pp. 3-17). Springer. https://doi.org/10.1007/978-3-319-08602- 6_1

Celi, M. (Ed.). (2010). *AdvanceDesign. Visioni, percorsi e strumenti per predisporsi all'innovazione continua*. Mc. Graw-Hill.

Ciravegna, E. (Ed.). (2025). *FuturE-Pack: Designing smart packaging for circular and sustainable Made in Italy*. Bologna University Press. https://doi.org/10.30682/9791254776711

International Organization for Standardization. (2024). *Packaging — Vocabulary — Part 1: General terms (ISO 6608-1:2024)*. International Organization for Standardization. https://www.iso.org/standard/82342.html

Irwin, T. (2015). Transition design: A proposal for a new area of design practice, study, and research. *Design and Culture, 7*(2), 229–246. https://doi.org/10.1080/17547075.2015.1051829

Irwin, T., Kossoff, G. & C. Tonkinwise (2022). Transition design: An educational framework for advancing the study and design of sustainable transitions. *Cuadernos del Centro de Estudios en Diseño y Comunicación. Ensayos*, (105), 31-72.

Jonas, H. (1984). *The imperative of responsibility: In search of an ethics for the technological age*. University of Chicago Press.

Kossoff, G. (2011). *Holism and the reconstitution of everyday life: A framework for transition to a sustainable society* [Doctoral Dissertation]. University of Dundee, Scotland.

Krippendorff, K. (2006). *The semantic turn: A new foundation for design*. CRC Press.

Manzini, E. (2015). *Design, when everybody designs: An introduction to design for social innovation*. MIT Press.

Poli, R. (2010). The many aspects of anticipation. *Foresight, 12*(3), 7–17. https://doi.org/10.1108/14636681011049839

Poli, R. (Ed.). (2019). *Handbook of anticipation: Theoretical and applied aspects of the use of future in decision making*. Springer.

Tronto, J. C. (1993). *Moral boundaries: A political argument for an ethic of care*. Routledge.

Zamenopoulos, T., & Alexiou, K. (2007). Towards an anticipatory view of design. *Design Studies*, *28*(4), 411–436. https://doi.org/10.1016/j.destud.2007.04.001

Resumen: En un contexto en el que casi todo se presenta como *smart*, el packaging permite reconsiderar la inteligencia más allá de su dimensión tecnológica, desplazando la atención desde los dispositivos hacia las infraestructuras de diseño que configuran el cambio sociotécnico. Desde una perspectiva de Diseño para la Transición, la inteligencia del packaging se entiende como su capacidad para articular relaciones, habilitar comportamientos responsables y mediar valores dentro de sistemas sociotécnicos complejos. Basado en los principios del Diseño Avanzado, este enfoque concibe la inteligencia del packaging como una forma de inteligencia sistémica, anticipatoria y culturalmente situada. El proyecto FuturE-Pack reconceptualiza el packaging como una interfaz activa entre marca, cadena de suministro y usuario, capaz de integrar información ambiental, trazabilidad, narrativas de sostenibilidad y criterios de circularidad. La investigación produjo dos resultados principales: una plataforma digital interactiva que organiza conocimientos, estudios de caso y marcos normativos, y un toolkit de diseño que traduce visiones sistémicas en procesos operativos aplicables. Estas herramientas funcionan como infraestructuras culturales y orientadas al diseño que apoyan a las organizaciones en la gestión de la complejidad y en el impulso de la innovación circular. La validación en el sector de la moda italiana mostró cómo el packaging puede mediar confianza, transparencia y colaboración territorial, generando nuevas ecologías de relación y acción. El artículo sitúa estos resultados dentro del campo del Diseño para la Transición y propone una comprensión ampliada de la "inteligencia" del packaging como responsable, circular, relacional y anticipatoria, capaz de orientar transformaciones de largo plazo hacia futuros más sostenibles.

Palabras clave: Packaging inteligente - Diseño para la Transición - Diseño Avanzado - Infraestructuras de diseño - Plataformas digitales - Sistemas sociotécnicos - Innovación responsable - Economía circular – Sostenibilidad - Made in Italy

Resumo: Em um contexto no qual quase tudo é apresentado como *smart*, a embalagem permite reconsiderar a inteligência para além de sua dimensão tecnológica, deslocando a atenção dos dispositivos para as infraestruturas de design que moldam as mudanças sociotécnicas. A partir de uma perspectiva de *Transition Design*, a inteligência da embalagem é compreendida como sua capacidade de articular relações, possibilitar comportamentos responsáveis e mediar valores dentro de sistemas sociotécnicos complexos. Fundamentada nos princípios do *Advanced Design*, essa abordagem enquadra a inteligência da embalagem como uma forma sistêmica, antecipatória e culturalmente situada de inteligência.
O projeto FuturE-Pack reconceitualiza a embalagem como uma interface ativa entre marca, cadeia de suprimentos e usuário, capaz de integrar informações ambientais, rastreabilidade, narrativas de sustentabilidade e critérios de circularidade. A pesquisa produziu dois resultados principais: uma plataforma digital interativa que organiza conhecimentos, estudos de caso e marcos regulatórios, e um *design toolkit* que traduz visões sistêmicas em processos operacionais aplicáveis. Essas ferramentas funcionam como infraestruturas culturais e orientadas pelo design, que apoiam organizações na navegação da complexidade e no fomento à inovação circular.

A validação no setor da moda italiana demonstrou como a embalagem pode mediar confiança, transparência e colaboração territorial, gerando novas ecologias de relação e ação. O artigo posiciona esses resultados no campo do *Transition Design* e propõe uma compreensão ampliada da "inteligência" da embalagem como responsável, circular, relacional e antecipatória, capaz de orientar mudanças de longo prazo rumo a futuros mais sustentáveis.

Palavras-chave: Smart packaging - Transition Design - Advanced Design - Infraestruturas de design - Plataformas digitais - Sistemas sociotécnicos - Inovação responsável - Economia circular - Sustentabilidade - Made in Italy

---

(*) **Erik Ciravegna** holds a PhD in Design and a master's degree in Industrial Design from Politecnico di Milano. Since 2023, he has been a Researcher and Lecturer at the Department of Architecture, Alma Mater Studiorum – Università di Bologna, and a member of the Advanced Design Unit (ADU). He previously taught and conducted research at the Pontificia Universidad Católica de Chile, Universidad de Chile and Politecnico di Milano. His research and teaching focus on communication design, with expertise in packaging, branding and product identity systems. He studies the systemic role of packaging as a material and cultural artefact and its ethical implications as a mass medium shaping social practices. He leads the FuturE-Pack project within the Made in Italy Circolare e Sostenibile (MICS) programme (PNRR–PE11), guiding research on smart and sustainable packaging innovation.

(**) **Sara Battistini** is a Research Fellow at the Department of Architecture, Alma Mater Studiorum – Università di Bologna, and a member of the Advanced Design Unit (ADU). She works within the Made in Italy Circolare e Sostenibile (MICS) programme (PNRR–PE11). With a background in Industrial Design from Università degli Studi di Firenze and a master's degree in Advanced Product Design from Università di Bologna, she has expertise in packaging, visual communication and digital media. Her research focuses on the development of digital tools and guidelines for smart and sustainable packaging, with particular attention to UX/UI design and advanced technological solutions to support designers and companies.

(***) **Lisa Filippini** is a Research Fellow at the Department of Architecture, Alma Mater Studiorum – Università di Bologna, and a member of the Advanced Design Unit (ADU). She holds a bachelor's degree in Product Design from Università degli Studi di Perugia and a master's degree in Advanced Product Design from Università di Bologna. Her academic background combines design practice with methodological and systemic perspectives, forming the basis of her current research. She works on the development of tools and methods for sustainable and strategic packaging design, with attention to environmental responsibility, technological progress and systemic awareness. Her research interests include design methodologies, sustainability assessment and forward-looking approaches that foster innovation across value chains.

(****) **Camilla Sartor** is a Research Fellow at the Department of Architecture, Alma Mater Studiorum–Università di Bologna, and a member of the Advanced Design Unit (ADU). She holds a master's degree in Advanced Service Design with a dissertation on reactivating local communities through design, combining methodological research and applied experimentation. She works on UX/UI design and the development of tools that enhance transparency, accessibility and systemic innovation along supply chains. Her research interests include service design, communication strategies, sustainable innovation and interaction design, exploring how design can act as a cultural and technological enabler, fostering collaboration and responsible transitions across socio-technical and environmental contexts.