

FuturE-Pack

Designing Smart Packaging for
Circular and Sustainable Made in Italy

edited by Erik Ciravegna



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7. DIGITAL ADVANCED TOOLS FOR SMART AND SUSTAINABLE PACKAGING DESIGN

Erik Ciravegna, Sara Battistini, Lisa Filippini, Camilla Sartor, Michele Zannoni

Abstract: Digital tools are increasingly transforming packaging into a strategic enabler of smart and sustainable innovation. Within the FuturE-Pack project, these tools are investigated as instruments to integrate advanced and systemic design approaches with digital technologies, providing designers and companies with concrete resources to address environmental and socio-technical challenges. The chapter introduces the conceptual and operational framework of the FuturE-Pack interactive digital platform, which organises theoretical contents, case studies, design methods, and guidelines into an accessible infrastructure that fosters collaborative learning and experimentation. By supporting traceability, interoperability, and knowledge sharing, digital tools expand packaging functions beyond protection and communication, enabling transparency, responsibility, and inclusivity across the value chain. At the same time, they raise critical questions regarding accessibility, costs, and data management that need to be addressed through purpose-driven design. Through selected scenarios and practical applications, the chapter illustrates how digital advanced tools can bridge research and practice, reinforce connections between industry and academia, and position packaging as a cultural and strategic medium for advancing circularity, sustainability, and innovation.

Keywords: digital tools, interactive platform, collaborative design, circular innovation, systemic approach.

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7.1. From systemic challenges to smart and sustainable packaging

The contemporary scenario is defined by overlapping environmental, social, and economic crises that increasingly reveal the vulnerability and complexity of global systems. Climate change, resource depletion, digital transformation, and geopolitical instabilities converge into a condition of uncertainty that affects both industries and everyday life. In this context, packaging becomes emblematic: it embodies many of the contradictions of contemporary production and consumption, while also offering opportunities to activate change. Packaging is no longer a neutral artefact but a strategic lever for systemic challenges and experimenting with new models of circularity and sustainability. Advanced Design provides the methodological foundation for this transformation. It is an anticipatory, multidimensional approach that frames design as mediation, connecting disciplines, actors, and perspectives. It translates complexity into actionable knowledge, promotes collaboration, and anticipates possible futures to support responsible innovation. By combining systemic thinking with operational tools, Advanced Design enables designers and organisations to intervene not only at the level of individual products but within extended socio-technical systems, aligning ecological objectives with industrial strategies and cultural values.

The project presented in this chapter has been developed within this framework. It is conceived as a research and innovation initiative that translates theoretical principles into an operational infrastructure, bridging the gap between visions of sustainability and the concrete needs of enterprises. Its goal is to strengthen the role of packaging as a smart and sustainable device capable of acting as a broadcaster of information, ensuring transparency, and fostering responsible interactions along supply chains.

The research underpinning this initiative has been articulated along two main lines. The first consists of extensive mapping and analysis of state-of-the-art solutions. More than two hundred case studies of digital applications and packaging practices were collected, categorised, and systematised into a database. This work resulted in a taxonomy of technologies applicable to

packaging design, ranging from data carriers such as QR codes and RFID tags to sensors, indicators, and integrated digital systems. In parallel, methods for assessing environmental, social, and economic impacts were identified and organised, laying the foundations for a holistic Life Cycle Sustainability Assessment approach.

The second line of activity focuses on experimentation with industrial partners. Proofs of concept are being developed in sectors such as fashion, combining packaging design with digital technologies like blockchain, sensors, and traceability systems. These experiments simulate the dynamics of real supply chains, allowing the validation of technological solutions and the evaluation of their impacts on logistics, brand communication, and consumer experience. Collaboration with companies ensures that the solutions tested respond to actual operational constraints and market requirements, reinforcing the co-design dimension of the project.

The insights gained from mapping and experimentation converge into the design of an *interactive digital system* that integrates a theoretical framework, a case studies archive, a design toolkit, and various educational resources. Rather than a static repository, the FuturE-Pack digital platform is conceived as a dynamic system that evolves with new knowledge and practices. It supports companies and designers in configuring tailored design paths, evaluating trade-offs, and developing smart and sustainable packaging solutions aligned with systemic objectives.

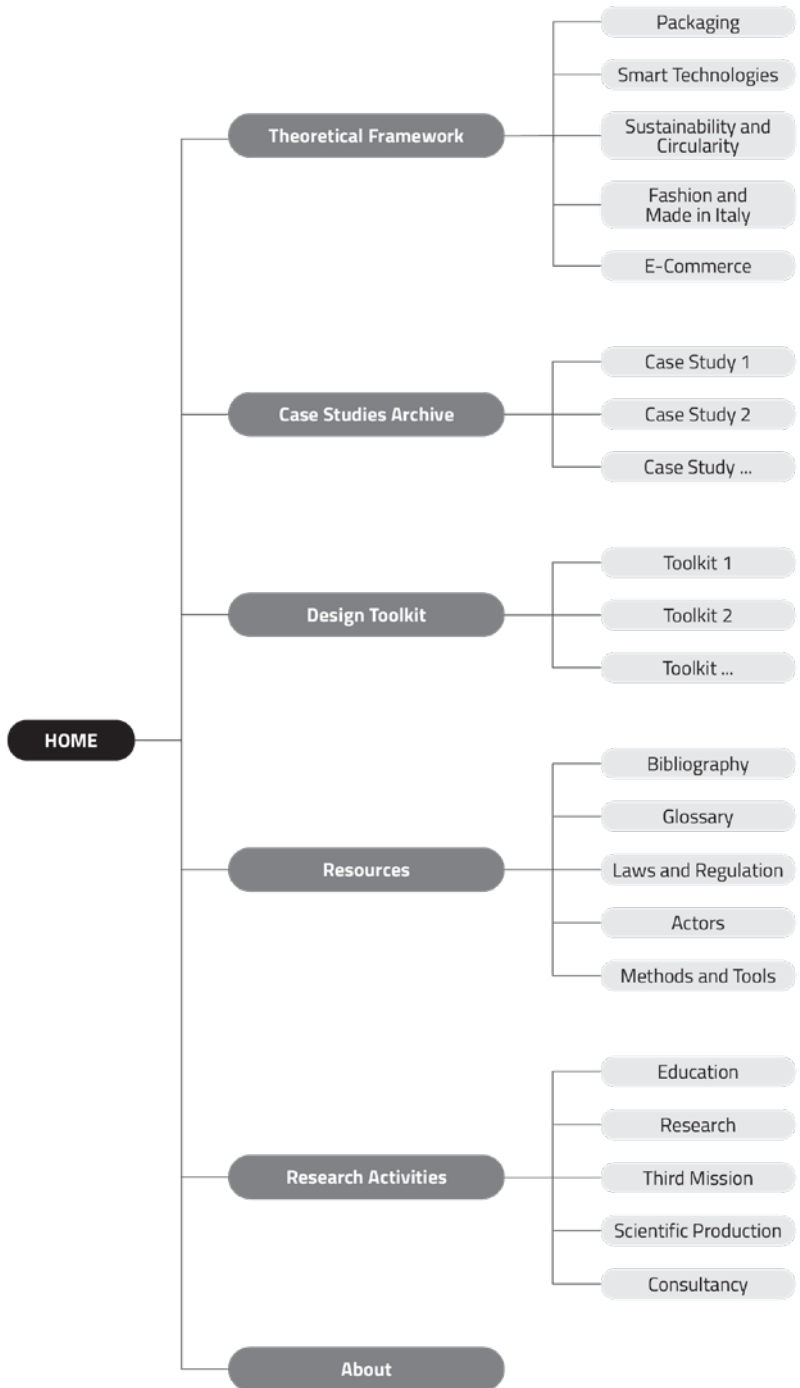
At its core, this project redefines packaging as more than a container. It becomes an active node within interconnected networks, capable of monitoring conditions, communicating data, and supporting decision-making processes across the value chain. This systemic reframing not only responds to the urgency of current crises but also consolidates the role of packaging as a driver of innovation, sustainability, and digital transformation.

In this scenario, the challenge is not only to frame packaging within systemic transitions but also to provide concrete tools that make such transitions operational. The need for shared knowledge, structured methods, and adaptable solutions has led to the development of a digital setting that embodies the principles outlined so far.

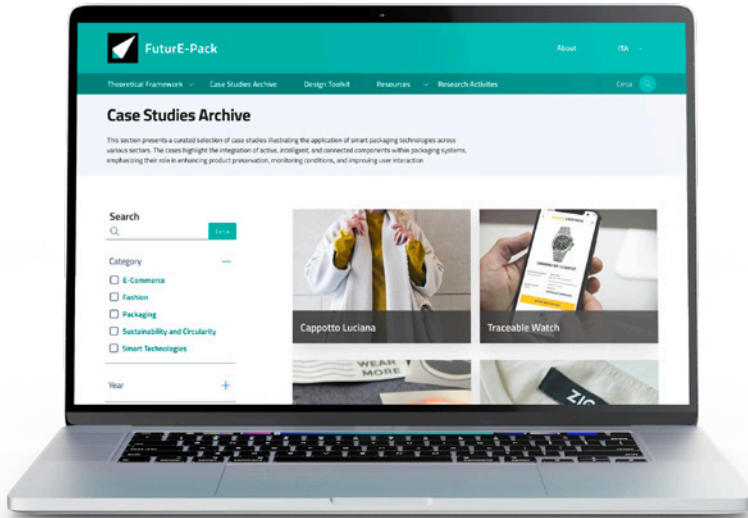
7.2. The FuturE-Pack interactive digital system

The reflections outlined highlight the need to translate systemic visions into operational tools that can support concrete design practices. Responding to this requirement, the FuturE-Pack digital platform is an interactive system designed to support companies, designers, and institutions in shaping smart and sustainable packaging innovation. It was conceived both as a design support tool and as a space for dissemination. As a design support tool, it enables professionals and organisations to experiment with informed, responsible, and collaborative processes, providing guidance and resources that address real sectoral needs. As a dissemination space, it contributes to the creation of a shared culture of sustainability by making knowledge, methods, and experiences accessible across disciplinary and professional boundaries. To embody this dual role, the interactive digital system has been structured into thematic areas (fig. 1) that facilitate targeted consultation, interdisciplinary engagement, and the progressive development of content over time.

- *Theoretical framework.* This area provides a conceptual foundation for the themes addressed by the project. It presents a multidisciplinary overview that brings together insights from the domains of packaging design, smart technologies, sustainability and circularity, Made in Italy and fashion, e-commerce. This area is conceived as a critical resource for users seeking to situate their work within current debates and transformations across these interrelated fields. By offering an updated and contextualised theoretical background, it lays the groundwork for informed design and research practices.
- *Case studies archive.* This area functions as a digital repository of selected projects and experiences, both commercial and experimental, in the field of smart and sustainable packaging (fig. 2). Each case is documented through detailed descriptions and visual materials, allowing for comparative analysis across diverse approaches and sectors. The archive aims to inspire innovation by showcasing practical applications of smart packaging strategies and by



1. Information architecture of the FuturE-Pack digital platform. Developed by the Authors within the FuturE-Pack project.



2. User interface of the FuturE-Pack digital platform displaying the case studies archive page. Developed by the Authors within the FuturE-Pack project.

encouraging the transfer of knowledge from best practices to new contexts of use.

- *Design toolkit.* This area constitutes the operational core of the platform. It offers a structured set of resources designed to support the design and prototyping of intelligent and low-impact packaging solutions. Its focus is on how smart packaging can respond to a range of real needs in different areas of impact and responsibility (see Chapter 5), based on specific functional requirements. For each digital need, a dedicated guide has been produced, containing a complete set of tools to assist the design process. These guides include a clear definition of the problem, precise design objectives, detailed operational guidelines, an overview of relevant smart technologies, examples of best practices, and a practical checklist to verify compliance and feasibility. The toolkit thus serves as a bridge between conceptual models and applied design, enabling users to translate complex scenarios into concrete solutions.
- *Resources.* This area provides a curated selection of support materials for study, research, and professional development. It includes thematic glossaries, regulatory frameworks, bibliographies, and technical documentation aimed at fostering deeper engagement with the platform's con-

tents. By offering access to structured knowledge, this area enhances the educational and scholarly dimension of the project, supporting users in their exploration of packaging innovation from multiple disciplinary angles.

- *Research activities.* This area highlights the academic and public engagement dimension of FuturE-Pack. It documents the scientific outputs, educational initiatives, and dissemination events undertaken throughout the project's development. This includes publications, seminars, workshops, and technology transfer activities, all aimed at strengthening dialogue between academia, industry, and institutions. Through this area, the platform not only presents the outcomes of its research but also promotes a broader culture of innovation in the packaging sector.

The platform's information architecture was developed according to a layered logic, where each area functions as a self-contained module while remaining interconnected through shared metadata. This structure enables a coherent navigation experience and supports the progressive expansion of content over time. The back-end is managed through a modular content management system that accesses information from a dedicated database. This configuration ensures scalability and consistency, while allowing for future integration of additional functionalities and structured datasets.

The user interface of FuturE-Pack was designed in accordance with the accessibility and usability principles outlined by *Designers Italia*,¹ the national design system for public digital services in Italy. The interface ensures clarity of layout, visual coherence, and ease of navigation across devices. It is optimised for mobile and desktop use and supports diverse interaction patterns typical of professional and industrial contexts. Particular attention was devoted to ensuring that information is accessible, readable, and logically organised across all user journeys, regardless of the point of access or professional background.

In summary, the digital platform performs a dual role. On the one hand, it acts as a design support tool that guides users through informed, systemic, and responsible design processes. On the other hand, it serves as a learning and dissemination space that encourages the creation of a shared language and

supports the development of a culture of sustainability within and beyond the packaging field. In essence, it is a digital infrastructure for responsible innovation, connecting people, knowledge, and tools to shape the future of packaging design in the context of the ecological and digital transition of Made in Italy.

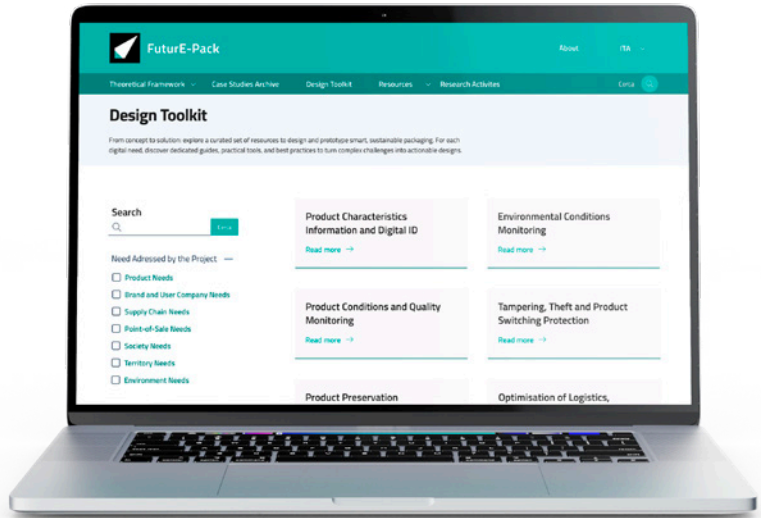
Among the different components of the platform, particular importance is given to the design toolkit, as it forms its operational core. By systematising functional requirements, digital solutions, and design guidelines, the toolkit transforms the platform from a knowledge library into a practical instrument for developing smart and sustainable packaging solutions.

7.3. The FuturE-Pack design toolkit

Among the key resources offered by the platform, the design toolkit occupies a central role. Conceived as an advanced instrument to support professionals and organisations, it facilitates the development of packaging solutions that are digitally enhanced, sustainability-oriented, and innovation-driven. Far from being a mere collection of operational materials derived from research, the toolkit not only provides guidelines, checklists, and resources, but operates as an adaptive system dynamically configured according to users' specific needs through a filter-based logic. Accessible via the platform's design toolkit area (fig. 3), it enables users to select the most suitable resources in a customised and goal-oriented manner. By identifying the specific design requirements to be addressed, users are guided through a process structured around interactive configuration principles. This approach helps define the most appropriate design path by isolating the precise criteria that the packaging solution is expected to meet.

A total of 33 design needs has been identified and grouped into clusters aligned with the various stakeholders within the packaging value chain. This categorisation aims to provide a systemic and multi-perspective understanding of the operational context. The classification system enables a multidimensional reading of packaging functions and facilitates the assignment of clear responsibilities across the actors involved. It is recognised, however, that certain design requirements may cut

3. User interface of the FuturE-Pack digital platform displaying the design toolkit page. Developed by the Authors within the FuturE-Pack project.



across multiple stakeholder domains. To address this complexity, a requirement–stakeholder matrix has been developed, mapping each criterion to one or more relevant stakeholders. This matrix highlights the recurrence and cross-cutting nature of certain needs, thereby enabling more targeted and context-sensitive resource selection.

Building on this classification, the toolkit is structured in a modular and standardised format, optimised for high usability by designers and sector professionals. This format ensures streamlined access to content and intuitive navigation, while preserving the technical depth and rigour required for effective implementation. Each module comprises a coherent and interconnected set of components, offering a comprehensive exploration of the specific design requirement in question. The layout and visual structure of the toolkit have been developed to promote communicative clarity, accessibility, and legibility, even for non-specialist users, while simultaneously supporting informed and responsible decision-making.

Each module opens with a concise title defining the design requirement, followed by the relevant stakeholder(s). An introductory component frames the application context and summarises the overarching objective, offering a conceptual interpretation of the topic. This is followed by an in-depth de-

scription of the requirement, outlining its relevance within the operational context, the design opportunities it creates, and its systemic implications. Subsequent components articulate specific design objectives, detailing how the project aims to address the identified need. These objectives are supported by operational guidelines that foster the coherent development of design responses, providing defined criteria and actionable recommendations. Each module also identifies applicable smart digital technologies, including RFID tags, QR codes, blockchain, artificial intelligence, and others, which can facilitate the achievement of the stated goals. A dedicated component presents real-world case studies that effectively address the selected requirement, offering practical insights. Where relevant, modules also provide links to the platform's case studies archive for further exploration. Each module concludes with a validation checklist, designed as an evaluation tool to assess the coherence, adequacy, and completeness of the proposed design solution.

Beyond the structure of individual modules, the toolkit is available in a hybrid format: online, users can interact directly with the configurator via the platform; offline, downloadable materials are provided in both PDF and Miro formats, enabling its use in collaborative environments such as workshops or co-design sessions. This dual availability allows the toolkit to adapt to a range of operational contexts, both during the conceptual ideation phase and throughout advanced stages of project development, ensuring the functional flexibility required in contemporary design practice.

By coherently integrating theoretical frameworks, operational tools, emerging digital technologies, and concrete case studies, the toolkit serves as a strategic and indispensable reference for the development of innovative, sustainable, and future-oriented packaging solutions. In addition to functioning as an organised repository of resources, the toolkit also serves as a decision-support system within the broader design process. By facilitating the explicit articulation of design requirements and mapping them against stakeholder expectations, the toolkit supports transparent and traceable decision-making. It assists designers and organisations in evaluating trade-offs, prioritising objectives, and selecting strategies that align with

sustainability goals, technical feasibility, and user needs. This deliberative framework fosters informed choices and promotes collaborative negotiation among actors with diverse perspectives and interests.

7.4. Towards a packaging innovation hub for circular and digital transitions

The FuturE-Pack digital platform represents both the culmination of a specific research project and the starting point for a broader trajectory. What began as a project to integrate design, sustainability, and digital technologies now evolves into a permanent infrastructure for knowledge, collaboration, and innovation in the packaging sector. It is the result of a joint effort by the University of Bologna, the Politecnico di Torino, and the University of Florence, carried out in collaboration with the three companies that took part in the experimentation phase: ZEROBARRACENTO, Astrakode, and Movopack.

This trajectory builds on the experience of the Packaging Innovation Observatory,² launched in 2019 by the Advanced Design Unit³ at the University of Bologna (see Chapter 2). This initiative originated with an international symposium⁴ for which the preparatory work gathered more than 300 cases of packaging innovation and established a network of universities, companies, designers, and institutions. Building on previous initiatives such as blogs, online archives, and other repositories, it was conceived as a structured effort to critically and systematically observe the packaging phenomenon, originating from a doctoral research at the University of Bologna (GIARDINA, 2024). Its primary objectives included mediating between heterogeneous forms of knowledge, developing shared design intelligence, and building networks between academic research and professional practice (CELASCHI et al., 2023).

Since then, the Observatory has collected over 650 case studies, analysed more than 200 documents, produced 18 publications, and formalised a scientific committee with four universities, while also promoting numerous dissemination events. From the outset, it was conceived as a design-driven R&I platform that combined desk and field research, taxono-

mies, and case study mapping to create a dynamic, open, and multidisciplinary infrastructure. Its methodology also emphasised mapping best practices, aggregating international case studies, and fostering cross-sectoral dialogue, laying the foundations for the collaborative approach later adopted by Spoke 1 of the MICS programme.⁵ These roots explain how FuturE-Pack can now evolve from monitoring into a truly collaborative digital platform.

FuturE-Pack inherits this legacy and projects it into the future. It will evolve into a new observatory, conceived not only as a monitoring tool but as a collaborative platform, an innovation hub where professionals, researchers, students, universities, and enterprises can co-design tools, share practices, and generate visions. Its collective origin explains why the new Observatory is conceived not simply as an academic initiative but as a collaborative hub, a platform where universities, enterprises, and other actors can work together across institutional and disciplinary boundaries. In this sense, the new Packaging Innovation Observatory will become a living laboratory: a space where innovation is observed, interpreted, and enacted, and where packaging is understood as an extended system that encompasses artefacts, processes, and socio-technical networks (GIARDINA, 2024).

This evolution also responds to the broader framework of Spoke 1 of the MICS programme, which is developing a digital portfolio platform to support the sustainable transformation of the Made in Italy manufacturing sector (JOSSE RAND et al., 2025). FuturE-Pack will be integrated into this portfolio, which is destined to become the digital infrastructure of the entire MICS. This integration will ensure that packaging innovation relates to other sectors and benefits from an interdisciplinary environment that fosters cross-sectoral synergies, knowledge exchange, and competence sharing.

Looking forward, the new observatory takes on a dual responsibility. On the one hand, it consolidates packaging as a strategic node in ecological and digital transitions, enabling systemic innovation across value chains. On the other, it reinforces design as an anticipatory and responsible practice. The challenge is not only to design for sustainability but to embrace regenerative approaches that restore and improve ecosystems and communities (SUCCINI et al., 2025). Moreover, crises

should not be regarded merely as obstacles but as opportunities for transformation, requiring design to continuously anticipate and reconfigure practices (CIRAVEGNA, 2020).

In conclusion, through its integration into the MICS digital portfolio and its role as the new Packaging Innovation Observatory, FuturE-Pack embodies a long-term commitment to sustain transitions through collaboration, shared knowledge, and responsible innovation. It is both the synthesis of research carried out so far and a projection into the future: continuing to shape packaging as a driver of ecological and digital transformation and as a field in which design responsibilities are constantly being renewed.

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Notes

- ¹ <https://designers.italia.it>
- ² <https://adu.unibo.it/osservatoriopack/>
- ³ <https://adu.unibo.it/>
- ⁴ <https://eventi.unibo.it/futuredesignpack-2019>
- ⁵ <https://www.mics.tech/en>

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This book presents the outcomes of the *FuturE-Pack* research project, developed within the *Made in Italy Circolare e Sostenibile (MICS)* extended partnership and funded by the Italian National Recovery and Resilience Plan (PNRR). It focuses on the application of smart solutions in packaging design, exploring the transformation of this field into a strategic domain for sustainability and innovation. Bridging design research, industrial practice, and digital technologies, it shows how Advanced Design and Systemic Design approaches can guide transitions towards circular production and responsible consumption. Combining theoretical perspectives with applied experimentation in the Made in Italy ecosystem, it offers models, tools, and case studies illustrating how intelligent and connected packaging can integrate ethical awareness and environmental goals with industrial competitiveness and cultural value.

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