

DIGITAL ADVANCED DESIGN

The background features several stylized green icons: a microscope in the upper right, a laptop in the lower left, a person icon in the middle right, and an open box in the lower center. A large green plant with many leaves is positioned in the center, partially overlapping the text and icons.

TRANSITIONAL
INDUSTRIAL
APPROACHES
FOR SUSTAINABLE
INNOVATION

edited by
Flaviano Celaschi
Laura Succini
Michele Zannoni

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Italia Domani
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Digital Advanced Design

Transitional Industrial Approaches
for Sustainable Innovation

edited by Flaviano Celaschi, Laura Succini, Michele Zannoni

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INTRODUCTION

*Flaviano Celaschi**, *Laura Succini**, *Michele Zannoni**

This research presents the launch of ten innovation fronts developed in parallel that will be followed in the ongoing projects by a phase of experimental testing and development of demonstrators, prototypes and living labs to validate methods and approaches for circular and sustainable design. The research is developed within *Spoke 1* of the extended partnership MICS (*Made in Italy Circolare e Sostenibile*), part of PNRR Mission 4 funded through the NextGenerationEU program with the aim of developing an innovation for the development of a new production system. With a focus on Digital Advanced Design, *Spoke 1* explores how design and digital innovation can support the sustainable and circular transformation of three key *Made in Italy* sectors—furniture, fashion and automation—by strengthening the skills of industrial designers through knowledge, digital tools and interoperable processes.

The research, dedicated to *Digital Advanced Design: technologies, processes and tools*, involves several departments of the University of Bologna and other Italian universities, national institutions, leading companies in the relevant sectors, and additional research groups and entrepreneurial entities activated through Cascade Calls.

Through four thematic clusters—*Digital Design for Manufacturing*, *Digital Design for Advanced Interaction*, *Digital Design for Knowledge Sharing*, and *Digital Design for Circular Materials*—the goal is to develop a portfolio of accessible digital tools that enable industrial designers to orchestrate complex choices oriented to sustainability and circularity from both tangible and intangible points of view, in continuous innovation along the production chains of *Made in Italy*. In addition, from ongoing research is emerging the figure of the *Transitional Industrial Designer*, a designer capable of connecting knowledge systems and production systems, through anticipatory actions, continuous

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and punctual data control systems and interdisciplinary contamination processes.

The publication closes with a preview of future developments related to Spoke's digital portfolio, a tool developed as an infrastructure to support the sustainable transformation of the Italian manufacturing system.

DIGITAL ADVANCED DESIGN AS A FRAMEWORK TO INTEGRATE KNOWLEDGE AND ACCELERATE INDUSTRIAL INNOVATION PROCESSES

Flaviano Celaschi, Laura Succini*, Michele Zannoni**

1. Digital Advanced Design within the *Made in Italy Circolare e Sostenibile* (MICS) Project

The PE11 *Made in Italy Circolare e Sostenibile*¹ (MICS)² Extended Partnership followed the goal set by the Next Generation Europe call to integrate several aspects that continue to limit industrial and social innovation today:

- Integration between different scientific sectors within the same university (to overcome the problem of knowledge closed in sectoral silos);
- Integration among experts of knowledge of the same scientific sector acting in different institutions and universities;
- Integration between academic research and applied research in companies or external laboratories, as well as sharing and collaboration among university researchers and industrial researchers-consultants working in companies;
- National collaboration on policies to support southern development in research and entrepreneurship;
- Gender rebalancing in research for innovation activities.

PE11 insists on the need for these different integration fronts to be supported as early as basic research (TRL 1-4) and expects the entire whole project to be developed in partnership between the actors described above in order to accelerate the process in a continuous *Open Innovation* perspective. This volume collects the scientific production carried out by a division (called Spoke 1) of this complex national research group. It consists by 32 researchers structured in 7 different departments of the Alma Mater Studiorum - University of Bologna, including the

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researchers working in the 4 external institutions/universities (CNR; University of Florence; Sapienza, University of Rome; Federico II, University of Naples). The team of researchers involved represents a dozen different scientific sectors and adds up to the work developed by 32 researchers, research fellows and PhD students, recruited with the resources of the call, as well as all researchers involved in the following leading companies based in Italy: Thales Alenia Space Italia, AEFPE group, SACMI, SCM group, Italtel S.p.A. To this large group are added the contributions obtained by involving 6 aggregated teams of companies and research institutions involved through the Cascade Calls.³ Thanks to this pool of actors, a total of 16 major basic research projects have been developed with the aim to increase the competitiveness of Made in Italy companies on the issues of sustainability and circularity.

The focus of our attention was the production processes and the products of three key Made in Italy sectors (Furniture, Fashion, Automation) that can achieve more efficient levels of sustainability and circularity and thus ensure that the Italian production system can face a market that tends to be more and more demanding (both domestic and export), and align with the requirements of reducing the ecological footprint on the Planet. The MICS Foundation has developed a three-year work plan that unfolds over eight Spokes (research lines covering different topics, such as materials, technologies, processes and organization, design, market and distribution). The University of Bologna, with the research group called Spoke 1, worked to the theme of *Digital Advanced Design*. Made in Italy products are the integrated result of sensitivity, cultures and centuries-old heritage, on the one hand, of a scientific approach, renowned performance, extreme customization, advanced technologies, controlled costs, precision and speed of response, on the other. So far, not as high attention and investment has been placed, generalizing the phenomenon, in the ecological impact and therefore in terms of equally high circularity and sustainability.

Spoke 1 focuses its efforts on fostering effective integration among the three key factors described above. In synergy with the other research it identifies Transitional Industrial Design as a strategic node in the innovation system envisioned

by the MICS Foundation. This refers to a professional, internal or external to the lead company in the process, who must be put in a position to enhance his or her sensitivity and skills in circularity and sustainability. This development occurs primarily by enabling digital access to knowledge, processes, tools, methodologies and stakeholder networks. Indeed, in the Fifth Technological Revolution, after the development and diffusion of data-enabling technologies, the effort to consider sustainability and circularity of the processes and goods produced is brought into focus. As the Spoke 1 research team, we can virtually represent an open linear chain describing the set of the combined steps in the process of the production chains. Knotting the ends of this chain generates a continuous circular path, in which each output (tangible or intangible) is bound to turn into inputs, either within the same process or into new and other productive and reproductive pathways. In this circular chain, we have hypothesized that the figure of an industrial designer capable and equipped to collect information in real time from each step of the supply chain is essential and becomes skilled in orchestrating this *concert of actors and steps* without losing control of knowledge and the possibility to correct production action in the various areas.

Industrial designers operating in the key sectors of Made in Italy come from diverse educational backgrounds (engineering, design, architecture, chemistry, IT, etc.) and therefore tend to adopt a predominantly vertical approach to the multiple critical factors that influence the creation of sustainable and circular value. Leveraging the potential of digital technologies, this research aims to expand the interoperable availability of knowledge, technologies, and processes, which in an integrated way, inform design decisions, strengthening the industrial designer's competencies in less consolidated fields of knowledge. We research on a cluster of tools that makes the interaction between vertical experts and decision-making synthesis subjects (entrepreneur, designer, manager, creative, customer) more agile and feasible. Our goal over the 36 months is to develop a portfolio of processes, tools, and targeted knowledge, digitally accessible to industrial designers of Made in Italy sectors, regardless of their training profile/educational background. This portfolio is intended to provide information that continuously and effec-

tively support synthesis decisions, particularly with regard to the sustainability and circularity challenges that are feasible at an industrial level.

In the basic research phase, the Spoke identified the following vertical and parallel work packages (WPs):

- Area of expertise on materials and chemical and biological processes;
- Area of expertise on mechanical and electronic technologies related to automation processes;
- Area of expertise on image processing and digital representation of reality;
- Area of expertise on logistics, packaging, wrapping and communication processes of products.

In addition to the following systemic integration WPs:

- Analysis of the solutions available within a portfolio of specialized digital practices;
- Analysis of the state of the processes, systems and tools in use in informed support for design synthesis decisions and evaluation of impact performance;
- Study of change and anticipation of medium-term scenarios to configure times and results.

Following the vertical research on individual projects, the activity was shifted towards creating interconnections between different parallel initiatives. The goal is to develop experiments applicable to the three key sectors identified in the call for proposals, allowing for the evaluation and refinement of the emerging results. The phases of exploitation and communication of the outcomes do not only occur at the end of the research, but were integrated throughout the entire process. This approach aims to disseminate not only the final results, but also the intermediate outputs—such as semi-finished products and research components—that can be exploited beyond the pre-established objectives, thus enhancing each intermediate phase as well as the underlying methodologies for their development.

2. Spoke 1. Methodology research

The challenges of circularity and sustainability are deeply embedded in the concept of “wicked problems” (RITTEL & WEBBER, 1973), understood as issues distributed across time and space that exert a profound influence on human life (MORTON, 2013).

Addressing such complex challenges demands a holistic vision, interdisciplinary collaboration, and a continuous search for innovative solutions. Within the broader context of business and industrial production, Spoke 1 approaches sustainability through two interrelated dimensions of responsibility: the tangible—including environmental and social factors—and the intangible, rooted in ethical, inclusive, and transparent practices.

To meet these demands, Spoke 1 adopts the *Responsible Advanced Design* (RAD) approach (SUCCINI & CIRAVEGNA, 2022; SUCCINI, 2023), which integrates intangible values—“ethics, inclusion, care, gender equality, transparency, responsible thinking, time, and open access—with tangible principles such as recyclability, reuse, and the selection of sustainable materials.” (SUCCINI et al., 2024, p. 100). RAD seeks to define new design paradigms capable of generating high social and environmental impact, while fostering competitive advantage by embracing the diversity of stakeholders, optimizing available resources, and enhancing the identity of local territories.

Thus, designing, implementing, and disseminating advanced digital design solutions extends beyond mere technological adoption: Spoke 1 envisions digital tools and systems as key drivers of circular and sustainable innovation across Made in Italy industries, empowering industrial designers to develop new product-service systems and strengthen their capabilities to navigate transitional phases.

The RAD approach addresses several key transitions, in particular:

- *Shift from the “supply chain” to the “value chain”*

The traditional supply chain focuses on the procurement of materials and the delivery of goods to the customer. In contrast, the new research process moves towards the concept of the “value network” (GIARDINA, 2023), disrupting the linear relationship between customer and supplier and

embracing an approach where collaboration, resilience, and transparency become crucial aspects of the transition.

- *Shift from efficiency to the concept of human and environmental prosperity*

This transition is based on redefining consumption models, improving minimum living standards, and raising consumer awareness of their role along the value chain. Human well-being within our current societies represents a challenge that demands new forms of design, production, and consumption, where sustainability, inclusion, and collaboration are key aspects of transformation processes.

- *Strengthening of open innovation*

Creativity, anticipation, and adaptability are the key words underpinning this development. Starting from the concept of collaborative innovation, it is necessary to conceive and implement new ways of working and doing business. The impact of cross-disciplinary and cross-sectoral contamination—involving academia, institutions, industry, and society—can benefit both the competitiveness of industrial sectors and the achievement of greater sustainability and circularity in products and services.

3. Spoke 1. Research clusters

In the overall development of the Spoke 1 project, the ten sub-projects initiated have given rise to four specific groups for the application of basic research:

- Digital Design for Manufacturing;
- Digital Design for Advanced Interaction;
- Digital Design for Knowledge Sharing;
- Digital Design for Circular Materials.

The main activities focus on human-machine interaction in transformative manufacturing, digital twins for textile design, circular materials for furniture, and system design tools for knowledge sharing.

The projects discussed encompass the design of physical, systemic, and symbolic elements and their impact on human

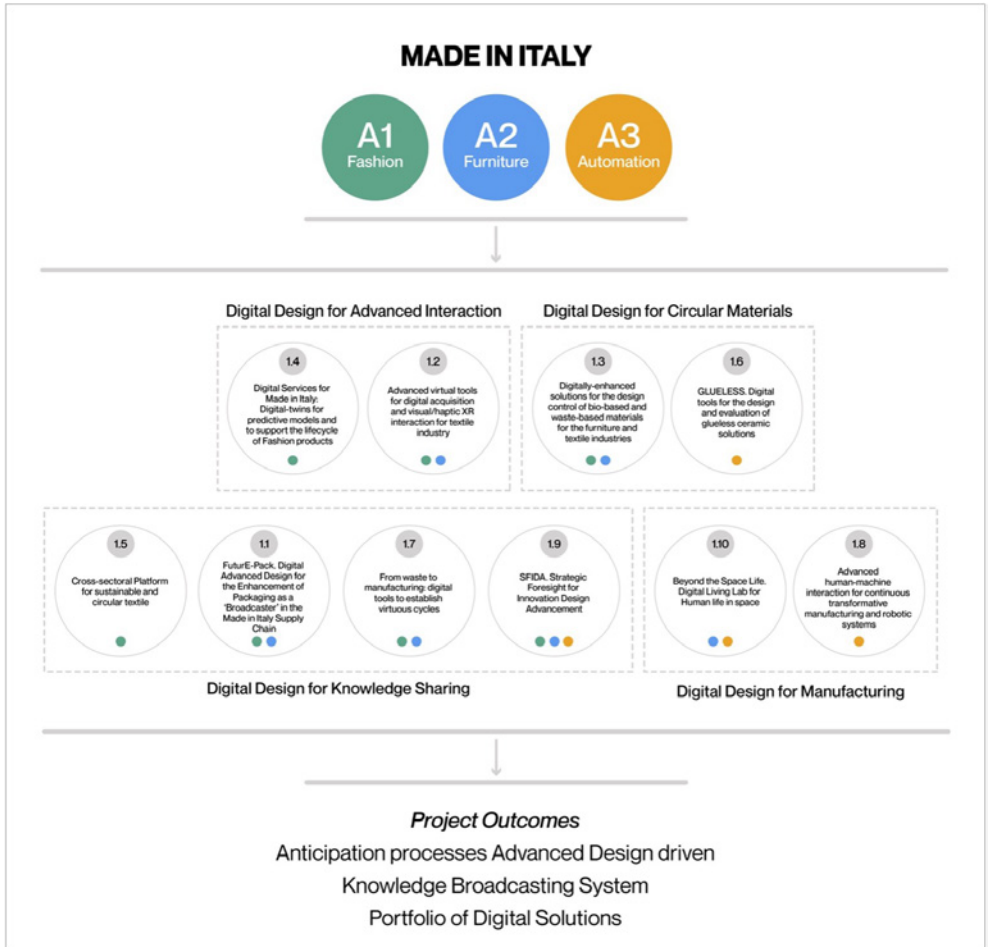
value and values. These include material objects, informational and communicative artefacts, services and experiences, new business models, and new ways of working based on cross-fertilization, all of which contribute to shaping the competitive identity of Made in Italy from the perspective of sustainability and circularity.

Based on these premises, the environment and digital transformation can be considered relevant for all companies pursuing growth, quality, and sustainability (SHINDE et al., 2014). Since the purpose of Spoke 1 is the study of technologies, processes, and tools for digital advanced design, all ongoing projects regard digital transformation as a profound and accelerated evolution of activities, processes, skills, and business models aimed at fully exploiting the changes and opportunities offered by digital technologies and their impact (BETCHOO, 2016) on businesses, organizations, and society.

To achieve these objectives, the research stream *Digital Design for Manufacturing* is oriented towards the design of digital models to enhance human-machine interaction, as well as robotic systems for transformative and continuous production; it also aims to improve human quality of life in extreme contexts, such as space habitats in microgravity conditions.

The thematic cluster *Digital Design for Advanced Interaction* focuses on the development of virtual tools for designers, particularly in the fashion sector, with the aim of enhancing haptic and visual simulations of fabrics within extended reality environments. In addition, it concentrates on the definition of digital twins to be used for simulation and predictive models, as well as to support the lifecycle of the fashion product design process.

The projects developed within the *Digital Design for Knowledge Sharing* research line are addressing the development of digital tools to facilitate knowledge gathering and information exchange, aiming to establish innovative methods of design, communication, and interconnection among different actors to promote virtuous cycles within the industry. Finally, the research strand *Digital Design for Circular Materials* research line is working on digital solutions for the design control and evaluation of biobased and waste-derived materials for the furniture and textile industries, as well as on more sustainable ceramic solutions (fig. 1).



1. Relationship among Thematic Clusters, Ongoing Projects and Spoke 1 Expected Outcomes.

All images are reproduced in color in the online edition of the book.

The four clusters share the following common objectives:

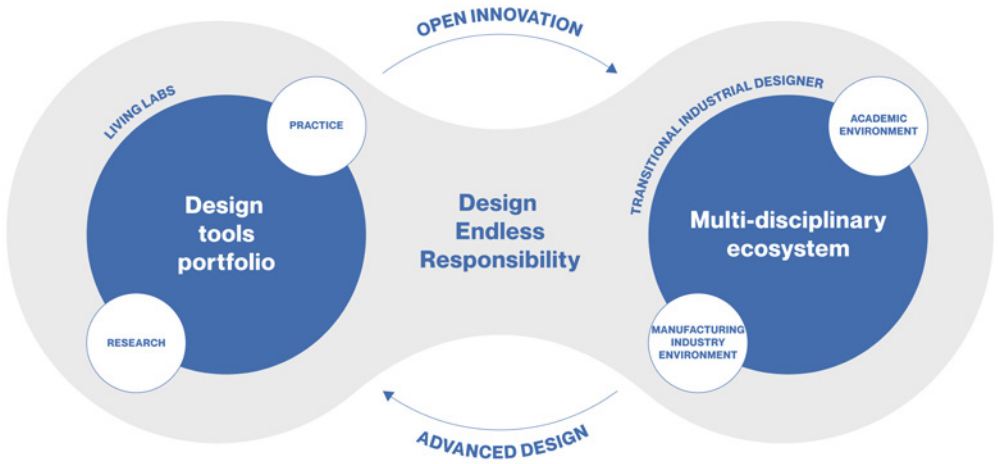
- To produce experiments and results aimed at developing a unified portfolio of digitally enhanced solutions to support, integrate, and validate decision-making, design, and production processes within the Made in Italy value chains;
- To activate and embed within the mindset of companies and designers anticipation processes driven by advanced design.

4. Towards the role of the Transitional Industrial Designer

Within these research clusters, the RAD approach provides a coherent framework for understanding innovation while emphasizing the transformative potential of adopting an integrated, anticipatory, and responsible mindset across the industrial ecosystem. This is achieved through the concept of *Design Endless Responsibility* (DER), where “the designer is called not only to connect and mediate the domains and stakeholders involved in the design process [...], but also to take into account the entire value chain, from ideation to end-of-life, considering the future impacts associated with each design phase.” (ZANNONI et al., 2024, p. 62).

DER serves as a system for assessing how, and to what extent, social, environmental, and relational impacts are addressed during the design process (fig. 2). This perspective is key in shaping the emerging figure of the *Transitional Industrial Designer* envisioned within Spoke 1.

The *Transitional Industrial Designer* thus acts as a mediator between production systems and knowledge systems, “taking into account the cultural, economic, and productive variables of the various ecosystems in which they operate, collaborating with industrial and academic stakeholders to redesign relationships, processes, and the use of resources.” (ZANNONI et al., 2024, p. 62). Moreover, the *Transitional Industrial Designer* leverages anticipation capabilities and impact analysis to develop design solutions aimed at promoting ecological and responsible transition. This designer must be able to work closely with industrial sectors and territorial communities, fostering more resilient and adaptable models in a continuously evolving environment (fig. 3).



2. The role of Design Endless Responsibility in the design process.



3. Characteristics of the Transitional Industrial Designer and its role in the territorial system.

In order to support the achievement of these objectives, seven Cascade Calls (BAC – in Italian *Bandi a Cascata*) have been launched since September 2024, involving companies and research centers predominantly located in Southern Italy.

These initiatives are designed to reinforce and expand the ongoing activities within the four research clusters, while simultaneously fostering innovation processes characterized by higher Technology Readiness Levels (TRLs).

This strategic approach not only facilitates the development of foundational models for sustainable innovation, but also enables the advancement of selected ideas toward experimental validation in real market conditions.

Conclusions

This book focuses on the first phase of Spoke 1's research activities (January 2023–November 2024) and provides a snapshot of the relationships, scientific investigations, and industrial research carried out within the ten projects that define it, presenting them according to the four research clusters previously introduced.

The publication closes with an essay dedicated to presenting the design process of the digital portfolio, its purpose, objectives and architecture. How this digital platform succeeds in collecting project outcomes and can become a system for the sustainable transformation of the Made in Italy manufacturing industry is described.

The seven BAC projects, however, are not described in this book, as they were launched during the final stages of the volume's drafting.

Notes

¹ MICS is an Extended Partnership financed by the MUR (Ministry of University and Research) thanks to the funds made available by the European Union as part of the NextGenerationEU program and represents one of the projects relating to Mission 4 of the PNRR "Education and Research."

² <https://www.mics.tech/en/home/>.

³ <https://www.mics.tech/progetti-bac/>.

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This book presents ten innovation fronts developed in parallel through research funded within Spoke 1 of the MICS (*Made in Italy Circolare e Sostenibile*) Partnership. Set within the framework of Digital Advanced Design, the project explores the role of design and digital innovation in promoting sustainable and circular transitions across various *Made in Italy* sectors, bringing together knowledge and expertise from academic, industrial, institutional, and professional fields.

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