

The Infrastructural Turn in Material Design: Material as a Service and the Future of Sustainable Industry

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Abstract

Contemporary design operates within a critical transition marked by environmental pressures, technological acceleration, and the need for systemic sustainability. In this context, materials are relational entities embedded in cultural, territorial, and environmental significance. Particularly within the Made in Italy production system, rethinking material management is crucial to address the limitations of linear, extractive models. This paper introduces *Material as a Service* (MAAS) as an infrastructural paradigm that extends the previous *Material-Service* approach, framing matter as an active node within circular and distributed ecosystems. MAAS enables materials to become traceable, configurable, and regenerable, bridging data, design practices, and local supply chains. Through this lens, design expands its role from shaping objects to orchestrating relational infrastructures where matter, data, and systems interact. The *Transitional Industrial Designer* emerges as a mediator between technological, cultural, and territorial dimensions, supporting SMEs in the transition toward circular and responsible production. By activating material as an infrastructure, MAAS provides a framework for generating cultural, relational, and regenerative values, paving the way for distributed material ecosystems in contemporary industry. To operationalize the paradigm, the pilot case *Glueless* is presented, a collaborative experiment that explores how MAAS can reveal new application opportunities and values for emerging materials.

Keywords

Material as a Service
Design Infrastructure
Circular Transition
Transitional Industrial
Designer
Made in Italy

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industriale
industrial design
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diid DSI No.3 – 2025
10.30682/diidmics25i

INTRODUCTION: WHY AN INFRASTRUCTURAL TURN?

In the midst of an epochal transition, marked by four main issues of our contemporaneity: population increase, climate crisis, geopolitical instability and technological acceleration (United Nations, 2019; UN Climate Change, 2022) the designer that try to research in their project the goal on a real sustainability are called upon to renegotiate its relationship with matter. In this uncertain and layered scenario where matter is no longer - nor can it be anymore - a mere functional variable or a resource to be optimized, but a relational device, a carrier of history, value and transformative possibilities lie underline the chose of the designers.

Indeed, humanity today finds itself operating within a set of planetary boundaries (Rockström et al. 2009) that delimits a safe operating space for the stability of the biosphere and the well-being of human societies (Loorbach et al., 2017). Growing environmental pressures, the urgency of industrial decarbonization (Geels et al., 2017; European Commission, 2021), and the rise of digital infrastructure and data-driven logics (Jensen et al., 2023), impose rethinking production and consumption patterns (Lees-Maffei, 2009), which are no longer sustainable in their extractive and linear form (Stahel, 2016). In the context of *Made in Italy*, a widespread (Perrino, 2025) and culturally dense (Micelli, 2011) production system, such rethinking takes on peculiar traits. Here, matter is historically interwoven with territory (Becattini, 2000; Van De Mierop, 2015) with artisan know-how (Micelli, 2011), with symbolic narratives (Falconi & Graber, 2019) and productive genealogies that go beyond the logic of efficiency. Yet despite the rhetoric of quality and sustainability, materials management often remains anchored in linear and predictive models (Karana et al., 2015; Stoneham, 2009), unable to accommodate the complexity of contemporary cycles. Materials continue to be treated as closed, decontextualized objects, incapable of activating networks, generating connections, and becoming infrastructure. Despite the emergence of new regulatory frameworks, such as the recent *Digital Product Passport* (European Union, 2024), materials management is still anchored in a linear, technical and fragmented vision, unable to activate systemic transformations. Tangible data, while increasingly accessible, struggle to translate into situated design knowledge, generating a gap between information infrastructure and transformative practice. To bridge this gap, a new paradigm capable of integrating traceability, accountability, and regeneration is needed.

In this framework, the *Material-Service* paradigm (Pasini et al., 2025) represented a first attempt to disrupt this vision, taking matter as a situated and adaptive element, and paving the way for a more conscious design, capable of integrating digital, spatial and cultural logics. The evolution of the systemic challenges that cross industry and society today requires critical repositioning, which goes beyond the application dimension to affect the theoretical foundations of design (Ceschin, 2013). It is in this scenario that the proposal of a *Material as a Service* (MAAS) is placed: not as a logical evolution of the previous paradigm, but as an overcoming of it through the adoption of an infrastructural perspective.

Building on these assumptions, this paper explores the theoretical and operational scope of the transition from *Material-Service* to *Material as a Service*, outlining the systemic implications of an infrastructural conception of material. The paper aims to show how this vision can redefine the ways in

which materials are designed, managed and valued within contemporary industry, and how design can become the cultural director of this transition, acting as a bridge between technological innovation, environmental responsibility and local intelligences.

In this scenario, design assumes a central role not only as an interpretative discipline, but as an operational and enabling device of the transition to more responsible, traceable and circularity-oriented production systems (Geissdoerfer et al., 2017; Murray et al., 2017). It is no longer a matter of designing finished objects, but of configuring relational infrastructures through which materials can circulate, transform and regenerate, activating value at different stages of their life cycle. Design thus operates as an interface between matter and context, capable of translating data, normative constraints, tacit knowledge and local resources into open and situated material systems. This function is enacted within a broader ecosystem of actors (including engineers, material scientists, manufacturers, policymakers and communities) who collaboratively contribute to the activation and governance of material infrastructures.

As part of this paper, design is understood as an enabling practice capable of making the complexity of matter visible and actionable in the industrial context. In this perspective, the *Material as a Service* paradigm offers itself as a concrete opportunity to redefine the role of industrial design in contemporary *Made in Italy*, orienting it toward the construction of dynamic, traceable and shared material infrastructures.

The reflections presented in this contribution are developed within the research activities conducted by *Spoke 1*¹ of the *MICS Extended Partnership - Made in Italy Circolare e Sostenibile*, funded under the PNRR. The investigation moves from the emergence of a growing trend to rethink the relationship with materials in a systemic and situated key (Karana et al., 2015), highlighting an increasingly active, transformative and strategic role of the designer in product development processes. In particular, this dynamic shows itself to be central in intercepting and exploiting emerging needs from high-potential market niches, contributing to the construction of innovative and culturally rooted production models for the renewal of *Made in Italy*.

FROM MATERIAL-SERVICE TO MATERIAL AS A SERVICE (MAAS): A CONCEPTUAL SHIFT

THE PROBLEM OF DESIGN ACCESSIBILITY

The paradigm shift leading toward the development of circular and innovative materials lies, even before technology, in a different design attitude toward material. In the past, especially in large industrial settings, material transformation was pursued through innovation in production processes (Norman, 2007). One need only think of the strategy of Apple, which built part of its brand identity by working on the aesthetics and precision coming from full milling of aluminum. This approach, however, is inaccessible to most designers and Small and Medium Enterprises (SMEs), who are forced to wait for innovation to become democratized and scalable. This is the context for

¹ Research line: Digital Advanced Design: technologies, processes, and tools.
<https://www.mics.tech/en/spokes/spoke-1/>

the proposal of an alternative paradigm: *Material as a Service* (MAAS), that is, a design logic in which material is made accessible, configurable and adaptable through enabling infrastructures and digital tools to support design. One of the main critical issues is rooted in the challenging nature for designers to operate within complex material processes, historically the exclusive domain of technical and industrial skills.

While it is now common in the contract furniture sector to customize raw materials through inexpensive and scalable CNC machining, this has been made possible by the spread, over time, of established design skills such as three-dimensional parametric drawing, which are now widely shared and accessible. Trickier, however, is the designer's ability to intervene at the level of chemical composition or industrial material processing. In these areas, design still operates in a speculative dimension, opening up spaces for advanced experimentation. However, a scenario in which the production parameters of a material become accessible to the designer through dedicated digital interfaces is plausible and desirable, configuring a new form of decision-making ability of the designer in co-defining the material. Alongside this limitation of theoretical and operational accessibility is the equally critical knowledge of existing and available materials. Despite the growing proliferation of digital databases dedicated to circular economy materials (such as MaterialDistrict², Materiom³, Circular Material Library⁴, Material ConneXion⁵, or Circularise⁶) their use holds marginal in the daily lives of designers, partly due to poor interoperability with design processes, limited spatial contextualization, or usability still oriented to technical profiles. This is compounded by the difficulty of accessing information about potentially reusable waste materials (fixed within marketplace platforms such as Sfridoo⁷ or Cyrkle⁸), which are often unmapped, non-standardized, or lacking adequate design semantics. This gap between material culture and digital tools highlights the need for a paradigm shift in the relationship between designer, material, and information infrastructure.

From this perspective, MAAS represents a critical and operational horizon for making production increasingly human-centered (Norman, 2013; Manzini, 2015), and responsive to emerging needs. It makes it possible to overcome the traditional delay with which material innovation moves from the domain of the industrial elite to that of the everyday project, offering new tools for creative and responsible control of matter.

MATTER AS A SERVICE INFRASTRUCTURE

The concept of matter has gone through a deep transformation in recent decades: from a physical and functional entity to an active component of complex value systems. This theoretical and operational evolution is reflected in a trajectory from matter understood as a substance to be transformed, to the concept of material service system (Manzini, 1999; Aurisicchio, 2019) in which material is seen as part of a broader strategy of service and relationship. On this line was grafted the following elaboration of the material-service

² <https://materialdistrict.com/material/>

³ <https://materiom.org>

⁴ <https://circularmateriallibrary.org/>

⁵ <https://www.materialconnexion.com/>

⁶ <https://www.circularise.com/>

⁷ <https://sfridoo.softr.app/resource>

⁸ <https://www.cyrkl.com/en/marketplace>

paradigm (Pasini et al., 2025), which proposed a situated, relational and cultural reading of the material in the project, especially in production contexts related to *Made in Italy*. Today, facing the growing complexity of industrial systems and environmental and digital challenges, the need for a further conceptual leap emerges: *Material as a Service* (MAAS) represents this new configuration, in which matter is not only service support but itself relational infrastructure, traceable, configurable and regenerable.

This shift calls for a rethinking of the role of matter in design: from object to subject, from support to interface, from substance to service. And in this semantic and strategic shift, design is called upon to expand its action, no longer only centered on the selection or application of existing materials, but also on the activation of material systems in which value, use and meaning take form in the relationship between resources, actors and contexts, thus integrating new strategic and systemic possibilities within established design practices.

Thinking of matter *as a service* means conceiving it as an active node within a distributed design ecosystem, where information, uses, transformations and regenerations are dynamically intertwined. It means empowering matter with a traceable biography, making it an interface, a protocol, an enabling environment. It means, finally, giving back to design the task of orchestrating these complex systems, making matter a field of mediation between technique, culture and politics.

In this way, the concept of Material as a Service is in continuity with the vision of “circular service ecosystems” (Fehrer et al., 2024), in which material, digital and cultural resources flow within layered, self-organizing and reflexive systems, whose transition requires the shared reconfiguration of institutions, relationships and infrastructures. Such ecosystems, regenerative and situated, represent a concrete horizon for imagining production models capable of decoupling value and extraction, fostering the emergence of circular and distributed service logics (Bocken et al., 2016).

In this perspective, matter is no longer understood as an asset to be owned or transformed, but as an enabling resource to be integrated and reactivated within relational and dynamic architectures. The logic of service (Lusch & Vargo, 2014; Lusch et al., 2017) allows matter to be read as an integral part of a process of value co-creation, in which actors, data and contexts are outlined as interdependent elements of the same ecosystem. Design, as a practice of mediation and activation, takes on the task of making such configurations visible, accessible and transformable, activating matter as a living, contextual infrastructure.

By saying so, infrastructure is arranged as a set of distributed, temporary and situated relationships that make possible the activation of matter as a service, without coinciding solely with digital platforms or technical devices. As Star and Bowker (1999) point out, infrastructures are all the more powerful the more invisible they are, rooted in everyday practices and tacit knowledge.

Material as a Service proposes itself, in this sense, as a design infra-structure, a cultural and operational net capable of nurturing and regenerating material cycles through adaptive, transdisciplinary and place-based modes.

Design, on its mission, does not merely mediate between actors and systems (Celaschi 2009), but takes on an eminently cultural role, generating new tangible systems and making the invisible visible. Following Escobar’s (2018) vision, situated and relational design becomes transformative practice, capable of activating ecologies of meaning and matter. Material as a Service is then framed as a critical device, capable of redefining the very conditions of

designing and inhabiting matter, by making materials traceable, reconfigurable and context-responsive, and by enabling their continuous circulation and reactivation within distributed ecosystems where value is co-created among multiple actors.

MAAS AS DESIGN INFRASTRUCTURE: MATTER, DATA AND SYSTEMS

The paradigm outlined in this contribution proposes to move beyond the idea of matter as a simple input to be selected or optimized, and instead take it on as a living component of a complex design system. In this view, matter is configured as an activator of relationships, transformations and meanings, capable of generating value through its connection with data, actors and infrastructure. Design is called upon not only to operate on form or function, but to intervene in the way matter itself enters into circulation and takes part in the processes of production, distribution and regeneration (Manzini & Vezzoli, 2003; Vezzoli et al., 2022).

Considered an active node within an integrated design ecosystem, the model consists of three interdependent components:

- **Matter** understood sure as physical substance (Miller, 2005), but matter also endowed with memory, relationships and regenerative potential. It includes its chemical and morphological composition, its geographic and cultural origin, its biography of production and use, and its capacity to transform itself or be reintroduced into new cycles. In this perspective, matter is also a vector of local narratives and identities, a symbolic and semiotic element as well as a technical one. It is conceived as a real relational entity, a carrier of origins, territorial memories, sensory qualities and environmental impacts distributed in time and space (Ingold, 2007).
- **Data** that make up the information grammar (Bowker & Star, 1999) of the material, making it readable, comparable and traceable throughout its life cycle (Paliwal et al., 2020). This includes data on composition, origin, durability, environmental and social impacts, reparability and recyclability. But also design metadata, transformation protocols, and usage scenarios. Data are not neutral: their availability, quality and accessibility determine the degree of agency that designers, manufacturers and users can exercise over the subject matter.
- **Systems** supporting the interaction between matter and data, an infrastructure composed of digital and organizational systems (Cardin et al., 2023): tracking and sharing platforms (such as blockchain or digital twins), design interfaces (plugins, CAD/CAM software, configurators), open standards and interoperable protocols. These are integrated with the socio-institutional systems that manage the use of the subject matter: regulations, exchange rules, local policies, collaborative networks. Together, these elements are the foundation of the infrastructure that makes possible the access, activation and re-signification of the subject matter in the project.

These three axes (matter, data, and systems) define the backbone of the MAAS ecosystem, making its technical-design configuration possible. However, in order to translate this model into practices capable of impacting real systems, it is necessary to broaden our focus to up till now less explored

but strategically relevant dimensions of design. In this direction, it is proposed to place alongside the structural reading of the paradigm into a series of complementary axes, which make its scope explicit. The following dimensions (Context, Time, Accessibility and Culture) do not constitute an additional layer, but a necessary design depth to make *Material as a Service* a truly operational paradigm, inclusive and capable of interacting with the specificities of territories, supply chains and production cultures. These considerations came out from a deep analysis of more than 50 circular economy materials and case studies.

- **Context** - The territorial and situated dimension of the material
The MAAS ecosystem cannot disregard the local dimension. The geography of matter (made up of environmental constraints, production cultures, short or long supply chains, and resource availability) profoundly affects its traceability, transformability, and meaning. Matter is never neutral: it is always situated, anchored in a territory, and acts as an interface between the ecology of places and design strategies.
- **Time** - The temporal dimension of matter
Matter as a service implies a management of time different from that of the linear cycle. It is necessary to think in terms of design temporality, that is, of the different states that matter can go through: from pre-use (waste, refuse, residue), to use (performance, transformations), to post-use (reactivation, re-entry, narrative).
- **Accessibility** - Who can use and transform matter
The ecosystem under analysis is activated only if we also question who has the right and ability to access and modify it. Accessibility concerns the availability of data, but also the technical skills, the available infrastructure, and the market logics that regulate the use of materials, democratizing access to matter and allowing a plurality of actors (small businesses, artisans, local communities) to take an active part in the system itself.
- **Culture** - The symbolic, narrative and intangible dimensions (Borgmann, 1992)
Matter, especially in the context of *Made in Italy*, is also the bearer of cultural, aesthetic and historical values, which the MAAS paradigm must be able to accommodate and activate. Designing in a service logic means translating these values into products but also building narrative and communicative devices that restore meaning, memory and symbolic quality.

Within this framework, design is called upon to play a key role not only in the selection of matter, but in the design of the cultural and operational infrastructure that enables its activation as a service. A designer is no longer limited to selecting materials from a closed catalog but participates in the configuration of an ecosystem in which matter becomes traceable, customizable, situated, and open to variable scenarios of use. Designing then means creating the conditions for matter to be responsibly and contextually read, understood, narrated, and transformed.

However, the development of such an ecosystem runs up against the fragmented nature of current regulatory and technological solutions. While tools such as the *Digital Product Passport* (DPP), as already seen, are an important step toward informed and shared materials management, their actual implementation is still partial. Infrastructure deficits, technological

barriers, lack of common standards, and poor accessibility for SMEs limit their effectiveness. The information approach is often reduced to technical fulfillment, lacking a real transformative impact on design and production practices.

Therefore, the MAAS paradigm stands as an enabling framework that can move beyond mere regulatory compliance and shape active and generative information governance. Tools such as the material passport, blockchain traceability, open material databases, and collaborative platforms for flow tracking are key elements in building shared and interoperable infrastructures. However, these tools remain largely underutilized or not integrated into day-to-day design practices, especially in the contexts of SMEs or *Made in Italy* supply chains.

Some sectors have begun to experiment with early forms of MAAS. In the circular fashion sector, platforms such as Fibersort⁹ make materials intelligible and traceable throughout the entire lifecycle, enabling processes of repurposing and customization. In the construction sector, the use of material passports is already advanced, for example in regenerative architecture projects (such as Madaster¹⁰ in the Netherlands), where every material is digitally filed and made reusable.

These examples confirm that *Material as a Service* is not a theoretical abstraction, but an operational horizon toward which design can steer concrete practices, combining data, material culture and digital tools in a circular, relational and responsible vision.

FROM DESIGNERS TO ENABLERS: BUILDING MATERIAL ECOSYSTEMS FOR SMES AND TERRITORIES

Over the past three decades, design has progressively internalized the environmental debate, helping to define a responsible approach to sustainability (Escobar, 2018). In parallel, the adoption of the human-centered paradigm has shifted the focus toward user needs, making experience and usability guiding principles for the design of products and services (Norman, 2004). However, at a time when the climate crisis and resource pressures impose a profound restructuring of production systems, the centrality of matter returns to the forefront as a foundational element of sustainability, longevity and circularity of artifacts.

Material, rather than responding to an individual need, now embodies a collective need: that of designing in a way that is compatible with the planet's environmental limits and resources. Yet despite its importance, the material frequently remains bound by aesthetic and narrative logics, subject to the rapid cycles of visual innovation and cultural trends. In this scenario, the designer exercises a decision-making role in the choice of materials, but rarely actively participates in the innovation processes that govern their production, composition or regeneration. This disconnect reduces the transformative potential of design concerning tangible systems.

It is in this zone of tension that the emerging figure of the *Transitional Industrial Designer* (TID) (Zannoni et al., 2024) is located: a professional and cultural profile that does not simply select materials, but integrates their

⁹ <https://www.fibersort.com/>

¹⁰ <https://madaster.com/>

systemic, dynamic and relational dimensions. The Transitional Industrial Designer acts as a mediator between technologies, data, production contexts and social instances, operating within complex and circularity-oriented ecosystems (Ehrenfeld & Gertler, 1997). In this sense, he becomes a key actor in the transition to a Material as a Service model, contributing to the design of materials as actionable infrastructures and not just as resources to be consumed.

This role emerges as particularly strategic within small and medium-sized enterprises, where the interaction between tangible culture, local supply chains and production capabilities requires figures capable of connecting different levels of knowledge and vision. In a context such as *Made in Italy*, which is fragmented but highly identity-driven, the TID is configured as a bridge between technological innovation and cultural continuity, between global environmental needs and situated solutions. Its design action does not end with product design, but extends to the design of processes, information infrastructures, and collaborative networks necessary to regenerate material cycles in a sustainable way. To respond effectively to these challenges, the *Transitional Industrial Designer* must develop a cross-cutting skill set capable of supporting the complexity of the Material as a Service paradigm and translating it into operational practices in real-world contexts. These are skills that require an extensive repositioning of the figure of the designer in the contemporary industrial system, embracing a vision of design as a curatorial and systemic practice of matter. Indeed, the designer is called upon to take care of, activate and make material resources connective, transforming them into dynamic nodes within broader production ecosystems. In this light, the TID must be able to read matter in its infrastructural dimension, interpret its trajectory, understand its environmental, social, and cultural implications, and prepare the conditions for its traceability and regeneration. This is a significant change of approach: from the control of form to the governance of the life cycle, from the configuration of the object to the design of the relationships that matter activates in time and space.

Fundamental to this framework is the development of design data literacy, that is, the ability to read, interpret and use data related to the composition, circularity and environmental impact of materials. This is complemented by the expertise in collaborative tools and platforms, enabling them to operate within distributed networks, interacting with databases, traceability interfaces and interoperable protocols.

Finally, the designer's role in the MAAS transition is linked to a renewed ethic of responsibility: an extended responsibility (Succini et al., 2024) that covers the entire life cycle of matter, from its origin to its reuse, passing through use, transformation, maintenance, and disposal. The designer is called to apply a design sensibility capable of combining technical choices and cultural visions, restoring to matter the possibility of being not only a functional support, but an active agent of sustainable transformation.

This evolution of the designer's role has not only theoretical repercussions but opens concrete scenarios for the Italian production system. The *Material as a Service* paradigm, if appropriately declined, can be a strategic lever to strengthen the resilience and competitiveness of SMEs on several levels. First, by making the use of secondary materials, from waste or by-products of other supply chains, more accessible, traceable, and reactivatable through dedicated platforms. Second, by facilitating the emergence of inter-sectoral collaborations, in which design acts as a connector between heterogeneous production worlds, stimulating contamination between languages,

technologies and material cultures. Finally, by helping to consolidate economies of proximity and models of territorial regeneration, based on shared infrastructure, short supply chains, and context enhancement. A future scenario, still partially explored today, is that of production districts interconnected by shared material infrastructure, where data, materials and design skills circulate among companies, research institutions and cultural actors. A concrete example of this direction is represented by the 1.6 *Glueless* project, developed within Spoke 1 of the MICS Extended Partnership and carried out in collaboration with SACMI and the Department of Architecture of the University of Bologna, specifically the *Advanced Design Unit* (ADU). The project faced the company with a new material, initially lacking a defined application purpose. Thanks to the designers' contribution, it was possible to explore its qualities, identify its potential uses, and imagine emerging market niches capable of enhancing it. The path took the form of the creation of a traveling installation (**Fig. 1, Fig. 2, Fig. 3**), created in collaboration with designer Lorenzo Palmeri¹¹, which tells, through ceramic games and material experimentation, the ability of design to activate new imagery and paths of valorization for materials that have not yet been codified. In this sense, the installation acted as an operational pilot of the MAAS paradigm by expanding the material's design space: moving beyond its established role in tiles and surface applications, experimental tests stressed its mechanical, tactile and expressive performances to reveal unexplored functional and experiential opportunities, thus enabling the emergence of new application scenarios. The choice to present the project as a traveling installation was a way to activate the material within multiple territorial and industrial contexts: by encountering different audiences, stakeholders and usage cultures, the material was able to renegotiate its identity and value in each stop, exemplifying how MAAS infrastructures emerge through distributed and situated interactions.



Fig. 1
Traveling installation as exploratory MAAS pilot – Public activation of the 1.6 Glueless material to expand perception of its potential beyond traditional tile uses. Where: Made in Italy Innovation Forum organized by Fondazione MICS in Cernobbio, at Villa Erba. Image source: MICS Foundation

¹¹ <https://www.lorenzopalmeristudio.it/>

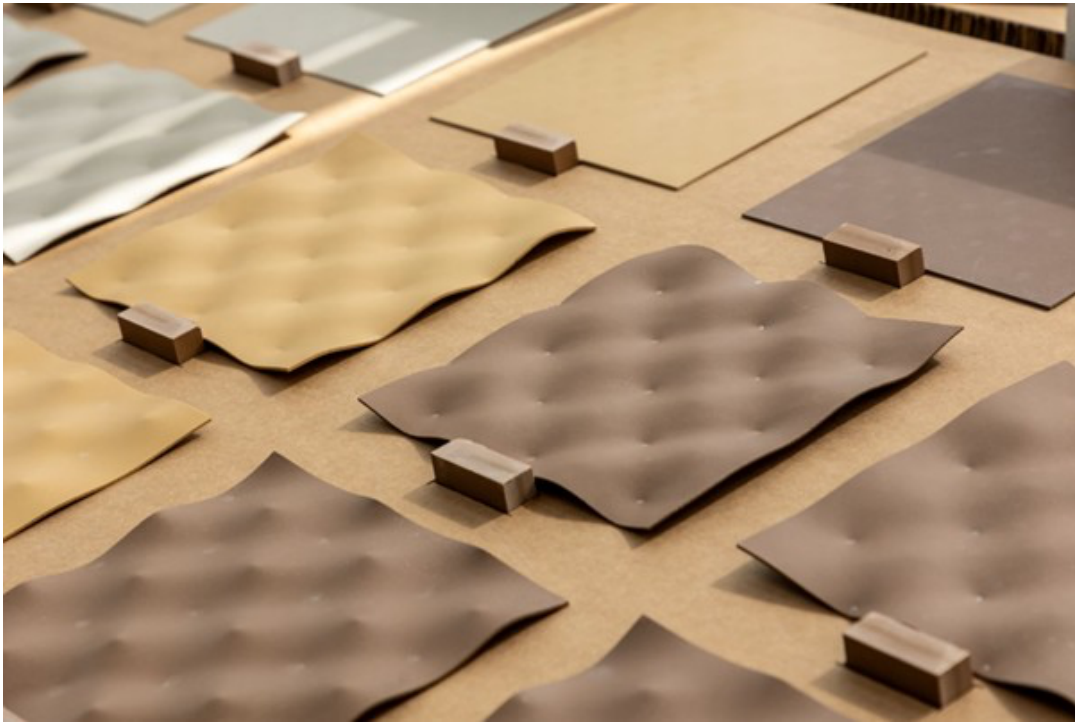


Fig. 2
 Experimentation with material textures and surface behavior. Design-driven tests aimed at uncovering new expressive and application possibilities for the material. Image source: MICS Foundation

This case demonstrates how the *Material as a Service* approach, if mediated by design, can turn into an enabling infrastructure for SMEs, capable of generating not only economic value, but also cultural, territorial and relational value. This exploratory activation made the material a vehicle for cultural, territorial and relational value creation: it reconnected the material to the identity of the ceramic district and its specialized know-how, generated new narratives capable of expanding its symbolic and experiential potential, and fostered collaboration between designers, industrial actors and local communities interested in developing alternative applications.



Fig. 3
 Bending and deformation experiments. Mechanical stress tests demonstrating how the material can support non-conventional geometries and fabrication strategies. Image source: MICS Foundation

FROM BARRIERS TO RELATIONS: ADVANCING MAAS THROUGH DESIGN-LED TRANSFORMATION

The adoption of the Material as a Service paradigm today represents a concrete vision for rethinking production models from a regenerative and relational perspective. However, its widespread implementation requires a substantial cultural, technical and infrastructural repositioning. There are many barriers to overcome: from the lack of digital infrastructure, especially in SMEs and marginal territorial contexts, to the fragmentation of material and project data, which are often scattered, non-interoperable or lacking shared standards. These are compounded by cultural resistance rooted in linear and predictive models, which struggle to recognize the material as a living, actionable and transformable element over time. Moreover, issues related to data governance (including data ownership, cybersecurity, access rights and system interoperability) remain unresolved, especially in distributed ecosystems where multiple actors contribute to and rely upon shared information layers.

Yet the European and national context offers emerging opportunities to support this transition. Funding related to the Green Deal, PNRR and Horizon Europe programs open concrete spaces for design experiments capable of connecting research, business and territories. At the same time, the spread of open source platforms, collaborative databases and tools such as the Digital Product Passport are helping to build a more transparent and accessible information infrastructure. Finally, growing environmental awareness on the part of users, businesses and institutions generates a favorable climate for the spread of alternative models based on traceability, accountability and circularity.

For these opportunities to translate into systemic change, a structured intervention is needed at the policy level: common standards for material traceability must be defined, interoperability between tools and platforms must be encouraged, and the training of professionals capable of acting at the intersection of design, technology and material culture must be promoted. This evolution also requires shared regulatory frameworks and clear agreements on intellectual property, especially when material compositions, transformation protocols and digital data are co-developed across companies and institutional actors.

It is in this direction that the present contribution aimed to place itself, proposing Material as a Service not only as a technical or digital innovation, but as an infrastructural paradigm capable of redefining the relationships between material, design and the production system. Within this scenario, design designs material relationships, enabling infrastructures and value systems. The figure of the Transitional Industrial Designer assumes a central role by acting as a mediator between resources, data and contexts, helping to make materials actionable, legible and culturally situated. Nonetheless, such a transition requires collaborative governance models that allow SMEs to participate without disproportionate economic burdens, overcoming adoption barriers linked to cost, lack of skills and operational uncertainty.

Finally, this perspective opens a fertile space for extending the MAAS paradigm beyond the boundaries of the manufacturing industry. Urban systems, educational platforms, institutional and cultural contexts can all benefit from a conception of material as relational infrastructure: capable of activating new forms of collaboration, regeneration and meaning. In this

sense, Material as a Service aims to be a cultural vision for inhabiting the complexity of the present and designing more responsible and interconnected futures. Future steps of this research will focus on validating the paradigm through real-world testbeds within industrial districts, developing interoperable digital prototypes for material traceability and mapping, and assessing how MAAS-based business models can generate economic, environmental and socio-cultural value over time. These actions will support the consolidation of a replicable and scalable roadmap, enabling MAAS to evolve from conceptual framework to operational infrastructure across diverse territories.

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Acknowledgments

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.

The paper is the result of a joint effort of all three Authors. However, “Introduction: Why an Infrastructural Turn?”, “Matter as a service infrastructure” and “From Barriers to Relations: Advancing MAAS through Desing-led Transformation” is attributed to all Authors; “The problem of design accessibility” is attributed to M. Zannoni; “MAAS as Design Infrastructure: Matter, Data, and Systems” and “From Designers to Enablers: Building Material Ecosystems for SMEs and Territories” to V. Pasini.

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Fig. 4
Acoustic performance investigation. Functional experimentation revealing opportunities in fields unrelated to the material's original industrial context. Image source: MICS Foundation