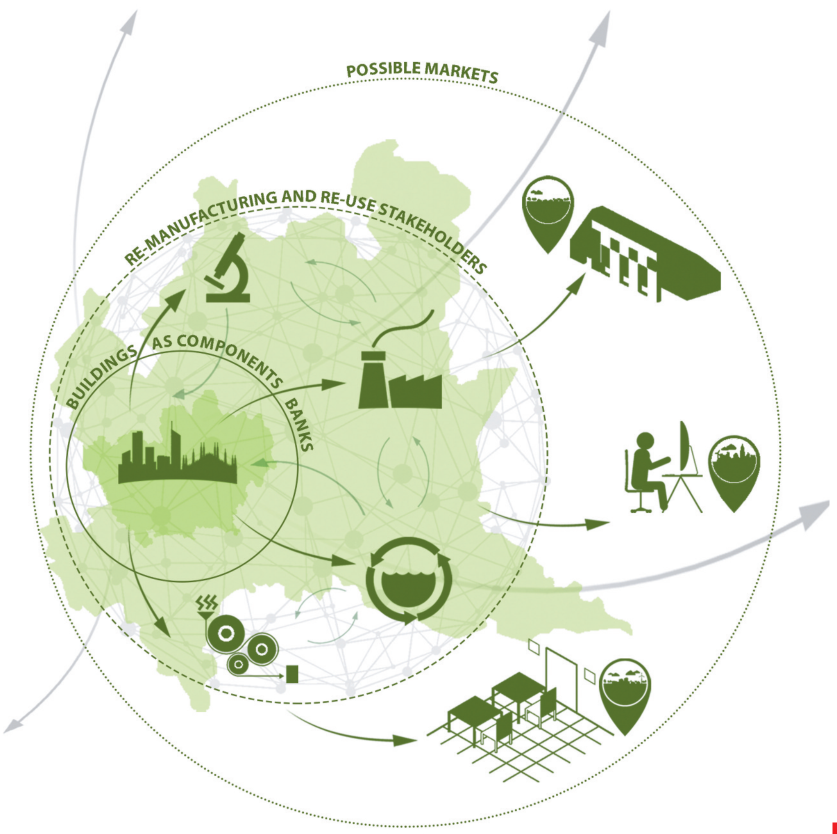
Re-manufacturing networks for tertiary architectures

Innovative organizational models towards circularity

edited by Cinzia Maria Luisa Talamo



Ricerche di tecnologia dell'architettura
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The book presents the results of the project "*Re-NetTA (Re-manufacturing Networks for Tertiary Architectures). New organizational models and tools for re-manufacturing and re-using short life components coming from tertiary buildings renewal*", developed at Politecnico di Milano (2018-2021) and supported by Fondazione Cariplo, grant n° 2018-0991 (Call "Circular Economy for a sustainable future 2018").

Isbn 9788835142232

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by *Serena Giorgi, Monica Lavagna*

13.1 Product life cycle information to enable reverse logistic

The manufacturing of most building products is a globalized process, often involving a complex supply chain, from raw material to final product. Usually, the producers are not aware of the material ingredients and sourcing of raw materials of certain parts of the product they manufacture. Thus, they remain uninformed about the entire supply chain and the several characteristics of the product (e.g. recycled content). After the production, from the use to the end-of-life phase, the products change ownerships, generally, without any monitoring on their use, maintenance, performance degradation. Currently, building products follow a linear approach and, at the end of their useful life, they are usually disposed in landfills, or, at best, they are downcycled (Giorgi *et al.*, 2017), as they are considered without any residual economic and performance value.

Before being sold, the building products are equipped with mandatory or voluntary certifications (e.g. the conformity marking CE is mandatory in the European Union; the EPD – Environmental Product Declaration – is a voluntary certification), technical information sheets, declared performance levels, and a shared and clear economic value. This information is important for the manufacturer in selling the product to the customer.

Subsequently, however, after the installation and the assembly on site, the building products suffer a "loss of identity", as the wealth of information is frequently not stored and preserved. This loss of knowledge occurs regardless of the time of use and the quality conditions of products. This practice determines that building products, at the end of their use, are "devoid" of any characteristic that makes them attractive to other potential future users.

Due to the complexity and fragmentation of the entire life cycle, that involves several phases carried out by different stakeholders, it is very difficult to know all product information during the entire life cycle (from material extraction to the disassembly after use and the end of life). The lack of knowledge of the product characteristics, often, hinder the potential extension of its useful life through the activation of a "reverse logistic". Revers logistic means the return management, after the sale and use of products, through a circular operation such as re-manufacturing, reusing, refurbishing, recycling, in order to recapture value at the end of product's useful lifecycle (Agrawal *et al.*, 2016; Macongue and Chinomona, 2022). Revers logistic moves the products back to the initial producer or to a new operator in the original value chain, or to another chain. To activate this circular dynamic, it is necessary to identify the value of product, recognized either by the original producer or by other markets. Consequently, it is necessary to know the (original) characteristics of the product, but also all the interventions that occurred during use and which may have compromised or maintained its characteristics and performances.

Keeping track of information along the life cycle is, therefore, a way to "maintain the value" of the product over time. This is particularly true in cases where the cycles of use are short, due to the temporary nature of the function in the building, so the product has not undergone degradation and effectively "preserves" its performances. Producers, re-manufacturers or potential reusers do not want to take the responsibility to reuse or re-sell products of which they do not know the characteristics, the supply chain and the life cycle operations (Chapter 5-6-7; Giorgi *et al.*, 2022).

The possibility to trace information relating to each specific material is fundamental to improve quality control and maintenance of value over time, increasing confidence in second-life products by users and re-workers. However, there are currently limitations in traceability and communication through the supply-chain.

13.2 Supporting tools for product traceability within a life cycle and circular perspectives

In this context, technology is a carrier to achieve the implementation of digital and intelligent transformation for supply chain transparency and material traceability, helping the activation of circular economy. Principally, BIM (Building Information Modelling) is identified as an enabling technology with great potential for the circular economy as it is possible to accumulate and keep information on the life cycle of products into a building (Eadie *et al.*, 2013). Through that digital technology, it is possible to trace the geometric and mechanical characteristics, the location, the age, and the expected service life of the products, to allow possible evaluation on potential products' reuse in a new project (Minunno *et al.*, 2018).

With the introduction of BIM technology, the key-players – such as architects, engineers, main contractors, subcontractors, facility managers – can use the same model for the design, the construction and the management. The initial characteristic of products stocked in a building, information about elements and the entire building system, can be stored in the BIM model. This information can be useful for the future management throughout the building life cycles and can be updated with information during the use, e.g., for each maintenance activity or requalification change.

BIM, as sharing information tool along the life cycle, becomes even more useful in the case of temporary uses of buildings and circular management of products (reuse, re-manufacturing, repurposing) through the life cycle by a network of operators.

To enable circular pathways and reverse logistics of products, multiple tools, often interoperable with BIM and conceived as web-based digital platform, are being developed and debated in the literature (Abruzzini and Abrishami, 2021; Atta *et al.*, 2021; Bertin *et al.*, 2020; Charef and Emmitt, 2021). For example, Material Passport is a tool that are most promoted and discussed by policies and stakeholders.

Material Passport (MP) can be developed as a web-based passport for registered buildings and construction objects. The aim is to create a common digital platform of knowledge about quantity and location of materials stocked in the built environment. The concept of preserving the (economic) value of materials is one of the main objectives of the MP. Through the MP, it is therefore possible to know the type of material and the quantity present in a specific building, the characteristics and the origin. Consequently, this information makes it possible to know the quantity of materials that become available after the first cycle of use, for possible reuse, re-manufacturing, repurposing or recycling.

An example of a MP already developed is Madaster (Rau and Oberhuber, 2019) set by Madaster Foundation with the scope to encourage intelligent design, facilitate the reuse of materials and eliminate waste. The platform Madaster (which collects all Madaster MPs) has a public interest, but the primary users are buildings asset owners, facility managers and design teams. The Madaster MP is interactive with BIM or excel source files, imported by users. Inside MP, all information about the building and materials are inventoried and documented. General information about the building are collected, e.g., location, size of the building, cadastral information, (if any) environmental labels present (e.g. BREEAM excellent), energy consumption. The Madaster MP provides the quantity of materials stocked inside the building, divided into "six part of building", based on their expected duration (based on the "six layers" of Stewart Brand): site, structure, skin, services, space plan, stuff. In addition, the Madaster MP shows the net financial value of each material. It is interesting for investors/owners to understand the value of materials inventory at the end of their life cycle. The economic evaluation provides a forecast of demolition costs and the transport costs of the end-of-life material, in comparison with the value of the same raw material. The comparison of cost and value provides the awareness of the economic advantage (or disadvantage) of the potential reuse of material. Currently, MP shows, in particular, that metals and glass products (which are also materials often used for interior office spaces) maintain a positive value over time, representing a possible gain for investors. Madaster evaluates also, for each building equipped with MP, a "circularity indicator" (CI), between 0 and 100%.

To support the traceability activities, there are also other kind of tools. For example, the RFID (Radio Frequency Identification) technology would allow products to be "chipped" not only allowing to keep memory directly on the product characteristics, but also to potentially map the routes (transport), e.g. favouring reverse logistic collection. This technology allows to attribute a unique electronic identity to the product: authenticating it, tracing its life cycle, following it in its production, distribution and use phases, collecting and crossing data (Big Data) along this path generated by multiple actors involved, in a dynamic and conscious process of co-creating value through information (see Chapter 11).

The information contained in the memory of the chip can be modified and updated over time, in order to keep track of transformations or ownership passages to which the product is subjected during its life cycle: with the RFID tag, the information follows the product, from the beginning to its disposal, becoming a narrative label.

In this case, traceability can enable a logistical optimization for collecting heterogeneous products on dissassembling sites, intervening in a targeted manner and selecting only the material or products of interest. Moreover, in the case of reverse logistic, the logistic management of returning products can be optimized, mapping their real time distribution on the territory.

These tools are particularly important in the context of temporary uses, where the traceability of information related to the life cycle is simpler, considering that the activities along the whole life cycle can be monitored. The use of tools able to keep and share information can be the necessary support to overcome the barriers related to the lack of awareness of products performances and the difficulty of detecting flows of available materials, which emerged from the interaction with stakeholders during roundtables for the applicability of proposed circular organizational models (see Chapter 5, 6, 7).

Therefore, the collection of information, through the use of digital technologies, can constitute an important knowledge on use, assembly-disassembly, transport, etc. This information can help to create a product life cycle "management" chain and support the manufacturer to extend control over the entire life cycle, monitoring actions outside the productive plant, optimizing processes and activities toward reuse/re-manufacturing. This management can be carried out by the producer of origin or shared between several operators across the network. In this case, the exchange and updating of information constitute an indispensable link to enable circular actions.

13.3 Necessary improvements of life cycle traceability information towards sustainability

New circular strategies could apparently bring environmental benefits in a single phase of the life cycle, however, by shifting environmental impacts to other phases. For example, to solve the problem of construction and demolition waste, often, circular strategies lead to the promotion of recycling, considering the environmental benefit of avoiding landfill disposal, but without considering the environmental implication of the recycling process activities (transport, reprocessing, etc.). Hence, the traceability and collection of environmental information along the whole life cycle of circular products is important also to evaluate the sustainability of circular re-actions and circular organizational models. However, information on product life cycle sustainability is not yet systematically collected, not even in MPs (like Madaster).

The building products at the end of building life cycle have "embedded" environmental burdens (related to its production, assembling, maintenance and so on), that constituted an important element in the balance of the product. Consequently, the product "information profile" have to be related not only to its residual economic value or its residual performance, but also to the environmental burdens that it already generated during its life.

Early disposal of products (as occurred in case of temporary use or tertiary architecture) creates an increase in the environmental burdens, related to every production of short-life products. By contrast, multiple life cycle of products, through reuse/re-manufacturing, can "avoid the environmental impacts", related to the manufacture of new products and the disposal of end of life products. In fact, the reuse/re-manufacturing of a product determines the opportunity to avoid new impacts for the creation of a new product, constituting an important environmental benefit.

The Material Passport or traceability tools have an important role in keeping track of the environmental information on the product, allowing to know the impacts incorporated along its life cycle, but also to know important aspects that can affect the modelling of impacts (e.g. in relation to the material composition, to the presence of scarce material resources, to the recyclability potential, to the ability of storing carbon, to the disassembly conditions).

From a life cycle point of view, it is necessary to trace all information regarding:

- the raw materials/recycled materials and their source (including transports);
- the production of the product, as well as the product composition, the environmental profile of production phase, if possible obtained from the EPD (Environmental Product Declaration) of the product itself;
- the distribution of products (logistics) to the building site;
- the technologies of assembly, during the building construction phase, and the condition to disassembly and reuse;
- the management of the product, inventorying the maintenance works and partial replacement occurred throughout the use phase;
- the service life and durability, verifying the real cause of disposal, whether due to obsolescence or really due to performance degradation;
- the end-of-life management (e.g. reverse logistic), mapping the typical end of life scenarios for the specific product and related transports;
- the reuse/re-manufacturing/repurposing activities, eventually occurred, and number of cycles of use (in a circular perspective).

If this information were constantly tracked for all products, there would be a process of enrichment of the information related to the phases of the life cycle that are currently poorly documented (in particular the use phase).

The activation of the traceability of life cycle information creates a double advantage. On the one hand, it returns a knowledge value that helps to preserve information over time, allowing the activation of circular dynamics (reuse/re-manufacturing/repurposing) aimed at sustainability. On the other hand, the collection of information along the life cycle constitutes a knowledge value. For example, during the use phase the collection of information would help to know the real durability of the elements (beyond the producers' declarations, which identify indicative scenarios of durability or even "eternal" durability), understanding the real reasons of the end of life and residual performances after temporary use. Hence, this knowledge value would help the planning of improvement scenarios towards sustainable construction and management practices of circular buildings and reuse/re-manufacturing practices of products.

13.4 Potentiality of traceability tools and the role of operators across building process

The use of digital technologies for the traceability of life cycle information not only affects the knowledge processes, but also affects the design and management of the operational processes. It also affects decision-making processes, considering the role of life cycle information to support decision towards an effective circularity and environmental sustainability.

From an operational point of view, traceability tools involve various operators who cooperate horizontally along the life cycle of the building, in particular:

- designers, who have the task of tracing the information during the design phase;
- suppliers, who know the source of product materials and their characteristics;
- manufacturers, who know the characteristics and performance of final products;
- builders, who carry out the assembly phase and know also the technique for disassembly;
- facility managers or users who have to keep the track of use, maintenance, modification or replacement cycles that the product and building undergo during the service life;
- end-of-life managers, who manage the condition for a reverse logistic, towards reuse, re-manufacturing and recycling routes;
- re-manufacturers, who transform and process products to extend their useful life cycle.

However, due to the multiple stakeholders involved, the continuous updating of the inventory over time, and therefore the maintenance of correct life cycle information, is not easy. For this reason, recently, the integration of BIM and Blockchain technology (as complementary platforms) is a hot topic discussed in literature. Indeed, blockchain can safely store privacy-sensitive data and aid to exchange effective and truthful information (Turk and Klinc, 2017; Liu *et al.*, 2019), enabling the involvement of users who are core players for building/products management. Blockchain is a new application mode of computer technology, which allows its participants to transfer assets over the internet without centralized third parties (Liu *et al.*, 2019). It is a distributed data structure, that is replicated and shared among the members of a network, where the IoT combination is considered powerful to cause significant transformations in different sectors to enable new organizational models (Christidis, 2016).

The collaborations established between the actors of the value chain allow the collection of information over time, defining the history of the products. In this way, the information goes beyond the memory of the individual operator, and it is kept along the life of the product, through the various cycles of use. The sharing of information along the life cycle and over time (especially in the case of short life cycles and reuse/re-manufacturing/repurposing) allows a continuous updating of knowledge and the possibility for the various operators belonging to the reverse logistics to become aware of the actions carried out along the chain. For example, to enable reuse/re-manufacturing/repurposing process, blockchain technology allow to communicate prescriptions (e.g., modularity, connections, decided during the design phase) or indications for assembly/use/maintenance/disassembly to the other operators in the chain, in a process of continuous improvement.

In this context, digital technology becomes an enabling means to support circular networks in which stakeholders can operate in a context where information sharing and communication facilitate the entire supply chain, along the entire life cycle of products. Moreover, traceability tools are particularly important to extend the useful life cycle of products through reuse/re-manufacturing/repurposing strategies in the direction of environmental sustainability, supporting the control and the assessment of life cycle input and output flows.

In parallel, it is still necessary to improve the integration of different kind of information and activate specific training for supply chain operators to allow systemic data collection.

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Alessandra Zanelli, Architect, PhD, is Full professor of Technology of Architecture at the Department of Architecture, Built Environment and Construction Engineering (DABC) of Politecnico di Milano. She has been involved in many research projects co-financed by national and international bodies, focusing on the sustainable innovation of ultra-lightweight and flexible materials in architecture. She is Regional Representative for Italian Universities of the No-Profit Research Network: TensiNet – the thematic network for upgrading the built environment in Europe through tensile structures. Since 2015 she is founder and coordinator of Textiles HUB, the Interdepartmental Laboratory on Textile materials and Polymers at Politecnico di Milano that involves four departments, more than 40 researchers of 10 scientific research fields, cross-collaborating and sharing knowledge and facilities, with the final aim of enhancing the experimental application of textiles and polymers in architecture, interior design, as well as in nautical, aerospatial and automotive sectors.

Luciano Zennaro, Architect, he is registered to the Milan Order of Architects and with the Milan Order of Engineers as civil and environmental engineer. Graduated in Architecture at Politecnico di Milano in 2006, he follows his university studies, gaining experience in several institutional Real Estate companies such as Cushman & Wakefield (2005-2007), Deutsche Bank (2007-2008) and Immobiliare Lombarda – Fondiaria SAI (2008-2015). In 2015 he founds a technical firm focused on building due diligence, land and Real Estate feasibility studies, evaluations, architectural and urban planning and construction management. Since 2018 he collaborates with the Department of Architecture, Built Environment and Construction Engineering (DABC) of Politecnico di Milano, performing teaching and research activities.

This book deals with re-manufacturing, recondition, reuse and repurpose considered as winning strategies for boosting regenerative circular economy in the building sector. It presents many of the outcomes of the research *Re-NetTA (Re-manufacturing Networks for Tertiary Architectures). New organisational models and tools for re-manufacturing and re-using short life components coming from tertiary buildings renewal*, funded in Italy by Fondazione Cariplo for the period 2019-2021.

The field of interest of the book is the building sector, focusing on various categories of tertiary buildings, characterized by short-term cycles of use.

The book investigates the most promising strategies and organizational models to maintain over time the value of the environmental and economic resources integrated into manufactured products, once they have been removed from buildings, by extending their useful life and their usability with the lower possible consumption of other materials and energy and with the maximum containment of emissions into the environment.

The text is articulated into three sections.

Part I BACKGROUND introduces the current theoretical background and identifies key strategies about circular economy and re-manufacturing processes within the building sector, focusing on tertiary architectures. It is divided into three chapters.

Part II PROMISING MODELS outlines, according to a proposed framework, a set of promising circular organizational models to facilitate re-manufacturing practices and their application to the different categories of the tertiary sectors: exhibition, office and retail. This part also reports the results of active dialogues and roundtables with several categories of operators, adopting a stakeholder perspective.

Part III INSIGHTS provides some insights on the issue of re-manufacturing, analyzed from different perspectives with the aim of outlining a comprehensive overview of challenges and opportunities for the application of virtuous circular processes within building sector. Part III is organized in four key topics: A) Design for Re-manufacturing; B) Digital Transformation; C) Environmental Sustainability; D) Stakeholder Management, Regulations & Policies.

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La passione per le conoscenze