Green Manufacturing Open

Re-NetTA Project: organizational models for promoting re-manufacturing chains of building products in the Lombard manufacturing district

---Manuscript Draft---

<table>
<thead>
<tr>
<th>Manuscript ID:</th>
<th>GMO-2023-081001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manuscript Title:</td>
<td>Re-NetTA Project: organizational models for promoting re-manufacturing chains of building products in the Lombard manufacturing district</td>
</tr>
<tr>
<td>Manuscript Type:</td>
<td>Research Article</td>
</tr>
<tr>
<td>Special Issue:</td>
<td>Life Cycle Engineering for Improving the Sustainability of Re-manufacturing</td>
</tr>
<tr>
<td>Keywords:</td>
<td>Circular Economy, Circular Organizational Models, Design for re-manufacturing, Tertiary buildings, Architectural Technology, Building sector</td>
</tr>
<tr>
<td>Corresponding Author(s):</td>
<td>Salvatore Viscuso</td>
</tr>
<tr>
<td>Corresponding Author' Email:</td>
<td><a href="mailto:salvatore.viscuso@polimi.it">salvatore.viscuso@polimi.it</a></td>
</tr>
<tr>
<td>Corresponding Author's Department:</td>
<td>Architecture, Built Environment and Construction Engineering</td>
</tr>
<tr>
<td>Corresponding Author's Institution:</td>
<td>Politecnico di Milano</td>
</tr>
<tr>
<td>Country/Region:</td>
<td>Italy</td>
</tr>
</tbody>
</table>

Order of Author (Only first three authors will be listed): 2

<table>
<thead>
<tr>
<th>Author's Name:</th>
<th>Nazly Atta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Order of Author:</td>
<td>3</td>
</tr>
<tr>
<td>Author's Name:</td>
<td>Anna Dalla Valle</td>
</tr>
<tr>
<td>Funding Agency and Grant Number:</td>
<td></td>
</tr>
</tbody>
</table>
Research Article

Re-NetTA Project: organizational models for promoting re-manufacturing chains of building products in the Lombard manufacturing district

Salvatore Viscuso¹, Nazly Atta¹, Anna Dalla Valle¹, Serena Giorgi², Monica Lavagna³, Cinzia Talamo⁴

¹Assistant Professor at Politecnico di Milano, Department of Architecture, Building environment and Construction engineering (DABC), Via G. Ponzio 31, 20133 Milano, Italy
²Research Fellow at Politecnico di Milano, Department of Architecture, Building environment and Construction engineering (DABC), Via G. Ponzio 31, 20133 Milano, Italy
³Associate Professor at Politecnico di Milano, Department of Architecture, Building environment and Construction engineering (DABC), Via G. Ponzio 31, 20133 Milano, Italy
⁴Full Professor at Politecnico di Milano, Department of Architecture, Building environment and Construction engineering (DABC), Via G. Ponzio 31, 20133 Milano, Italy

Correspondence to: Prof. Salvatore Viscuso, Politecnico di Milano, Department of Architecture, Building environment and Construction engineering (DABC), Via G. Ponzio 31, 20133 Milano, Italy. E-mail: salvatore.viscuso@polimi.it; ORCID: 0000-0003-2681-8719

Abstract

The article presents some of the outcomes of the research “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”. The research investigates strategies, new expertise and stakeholder networks for the application of circular economy in the building sector and proposes new organizational models and tools for re-manufacturing and reuse of short-life building elements and products coming from renewal interventions in tertiary buildings (office, exhibition, retail). The research has been developed by a multidisciplinary group composed of professors and researchers from the Architectural Technology area. Searching for the most promising conditions for the application of the proposed organizational models and the development of a market of remanufactured products, the research involved various categories of stakeholders of tertiary buildings (designers, facility managers and owners), building product and systems manufacturers as well as new possible operators for re-manufacturing in both the industrial and third sector.

The paper proposes three Circular Organizational Models, developed through a cross-sectoral analysis of successful key features of reuse/re-manufacturing activities. Subsequently, the Circular Organizational Models are discussed in their application in the building sector, introducing some key results emerged by the dialogue with stakeholders. Moreover, the paper outlines main drivers and barriers for the specific context of the tertiary building sector (exhibition, office and retail) in terms of policies, investments opportunities, technologies and innovations, standards and certifications.

Keywords: Circular Economy; Circular Organizational Models; Design for re-manufacturing; Tertiary buildings; Architectural Technology; Building sector.

© The Author(s) 2020. Open Access This article is licensed under a Creative Commons Attribution 4.0 International License (https://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, sharing, adaptation, distribution and reproduction in any medium or format, for any purpose, even commercially, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made.

www.gmojournal.com
INTRODUCTION

Today the building sector plays a pivotal role in driving the transition towards a circular economy. The European Commission’s recognition of the building sector as a “Priority area” underscores its significance in addressing specific challenges regarding circular economy principles. On one side, the statistics from Eurostat highlight the substantial impact of the building sector on waste generation, with its accounting for a significant 33.5% of total waste produced across economic activities and households in the EU-28 in 2014. This emphasizes the need for innovative approaches to reduce waste and promote resource efficiency within construction processes [1]. On the other side, the building sector holds a substantial economic importance: it represents a major contributor to employment, with around 18 million direct jobs linked to it, and contributes significantly to the EU GDP, accounting for about 9% [1]. These economic dimensions emphasize the potential for the building sector to drive circular economy practices that generate new job opportunities, foster social benefits, and enhance both energy and resource efficiency.

The integration of new circular economy strategies within the building sector has the potential to address environmental, economic and social challenges and to generate positive outcomes such as job creation, reduction in resource use and waste generation, energy saving and decarbonization. European regulations require to intervene in the preliminary stages of the building process with appropriate strategies aimed at extending the useful life of products, lengthening their first lifecycle and/or guaranteeing multiple reiterated lifecycles overtime [2]. The generation of construction waste could be limited overcoming this linear view of the building process.

This paper focuses on circular strategies and proposes organizational models aimed at preserving both the economic value and the environmental resources embedded within manufactured products once they have been removed from the buildings owing to renewal interventions. These models, based on the principles of circular economy, aim at extending the lifespan and value of products through the application of the following 5 re-actions, according to the standard BS 8887-2:2009: re-manufacturing, recondition, reuse, repurpose.

The field of investigation and application of the research is the tertiary sector (offices, retails, exhibitions). The reason for this choice is due to the fact that the very frequent renewal of spaces (offices, retails) and the temporary nature of the events (temporary shops and exhibitions) involve short cycles of use of parts of the building (finishes, walls, furniture) and the generation of a large quantity of waste [3]. The geographical area of investigation in the Re-NetTA research was the Lombardy region, where the tertiary sector is significantly present, and the renewal activities are particularly intensive with considerable quantities of construction and demolition waste generated [4].

In Lombardy, the ever-growing scenario of the tertiary buildings, and their intensive renewals, depends on some main crucial aspects that must be considered in order to understand the emergency in boosting circular economy strategies. For instance, it is possible to cite: the transition from an economy based on industrial production to another one based on finance and services; the increasing capillarity of transport infrastructures that is making areas far from the city center accessible, consequently changing the traditional location of corporate headquarters and shopping malls; the attractiveness of the city of Milan for foreign companies and investors; the enormously increased rental costs and the tendency of many big companies to centralize their headquarters to optimize management and operational costs [5].

Currently, and for the following years, new settlements - bigger than 5,000 sqm - will be realized in the City of Milan, for a total potential amount of around 2,390,000 sqm of new office spaces (Porta Nuova 217,000 sqm; City Life 150,000 sqm; Milano Fiori 100,000 sqm; Adriano Marelli 21,555 sqm; Area Falck 150,000 sqm; Progetto Symbiosis - Ortes 100,000 sqm; Santa Giulia 120,000 sqm; Feltrinelli 9,000 sqm) [6]. As a result, the performance gap between new and old stocks is destined to spread. Such a huge quantity of newly available assets must be considered with the already high presence of vacant buildings in the city and in its direct surroundings, estimated at around 1.2 million sqm of empty spaces that are right now obsolete [7]. Moreover, the pandemic emergency has enabled a debate about the use of workspaces and many companies are experimenting forms of partial remote work: corporate strategies will reflect on the
demand for spaces, not only in quantitative terms but also in qualitative terms with the consequence of an increasing activity of renewal of obsolete assets. [8]. Focusing on each of the three tertiary sectors investigated by the research, some current practices can be highlighted, which determine large quantities of waste generated in medium-short cycles, with landfill disposal of materials and products still with good residual qualities.

In the office sector, the CAT-A and CAT-B delivery standards play a significant role, particularly in Europe. CAT-A (Category A) Delivery is a standardized approach to preparing commercial office spaces for tenants [9]. It involves the basic construction and fit-out of a commercial office space to a certain level of functionality and comfort. The primary objective of CAT-A Delivery is to provide a blank canvas that meets the necessary building regulations and provides essential services to tenants. Elements included in CAT-A Delivery typically include the “Shell and core” of the building (including the exterior walls and roofs) and the Mechanical and Electrical Systems. CAT-B (Category B) Delivery follows CAT-A and involves the detailed fit-out and customization of the office space according to the tenant's specific requirements: it includes personalizing the space to align with the tenant's brand, culture, and operational needs. Elements typically covered in CAT-B Delivery encompass the space layout and partitions, finishes, electrical and audiovisual systems, furnishings and branding.

The combination of CAT-A and CAT-B Delivery standards enables flexibility for tenants to create a workspace that meets their specific requirements while benefiting from the standardized foundational infrastructure provided by the building owner. It's important to note that while this delivery model offers flexibility and customization options, the corresponding models material flows (organized through a linear process “from cradle to grave”), also raises concerns about sustainability, waste management, and environmental impact, especially for products and materials with reduced life span. As the commercial real estate industry evolves, there is growing attention to sustainable design, efficient resource use, and waste reduction throughout the entire lifecycle of office spaces.

Retail and exhibition sectors generate a significant amount of waste due to their frequent stylistic renewals and temporary events. Retail spaces often undergo rapid changes in their design and layout as a marketing strategy to keep up with changing consumer preferences and trends [10]. This frequent restyling leads to a significant number of discarded materials. Retailers change their interior aesthetics regularly to project a fresh and updated image to customers, in order to attract more foot traffic and maintain client interest. The discarded materials from these frequent renewals are often of high quality, with good technical performance and residual value. However, due to the swift pace of changes, they are disposed of as waste. Unfortunately, a common fate for these high-quality materials is ending up in landfills. This not only results in the waste of valuable resources but also contributes to environmental degradation.

Focusing on temporary events, they often create a substantial amount of waste due to the short duration of these events and the resources required to set up elaborate stands, displays and booths. A substantial portion of the waste generated consists of building components with high potential reusability [11]. Event organizers and exhibitors could work together to prioritize the use of reusable materials and modular designs that can be easily assembled and disassembled for multiple events [12].

Encourage retail and exhibition industries and customers to take responsibility for the end-of-life phase of their products needs to overcome the traditional organizational models based on “take-make-disposal” of materials, as mentioned above for the CAT-B office delivery. The Re-NetTA research aims to define circular strategies and new organizational models and tools for re-manufacturing and reuse of short-life building elements and products coming from renewal interventions in office, exhibition and retail. In the following paragraphs, the authors describe the conceptualization process of novel circular approaches and the point of view of stakeholders, including manufacturers, service providers, policymakers, and the third sector. This collaborative effort can lead to innovation, knowledge sharing, and collective problem-solving.

METHODS
In order to boost a sustainable and resilient transition towards circular economy approaches in tertiary building practices by promoting long-term value retention of products and life cycle extension of resources, the research first investigated the re-manufacturing strategies that are playing a key role to make other industrial sectors more sustainable [13]. The analysis of consolidated practices of different industries (aerospace, automotive, machinery, electrical and electronic, heavy-duty, and off-road, etc.) highlighted strategies and approaches to transfer and adapt to the building sector [14]. This wider analysis of the State of Art made it possible to identify some persistent factors that can represent the basic key conditions for the application of the re-actions in the building sector and supported the authors to identify the promising fields to investigate as pilot during the research. The main recurrent factors in literature are summarized below:

- **Material Reclamation and Reuse**: exploring innovative methods for deconstructing buildings to recover valuable materials and components, which can then be repurposed and reintegrated into new construction projects. This approach reduces the demand for virgin resources and minimizes waste [15].

- **Design for Disassembly**: introducing design principles that make it easier to disassemble and recover materials from buildings at the end of their life cycle. This approach encourages modular and easily separable building components [16;17].

- **Product-as-a-Service**: proposing a shift from selling products outright to offering them as services, where manufacturers retain ownership of the products and are responsible for maintenance, repair, and eventual end-of-life management [18;19].

- **Digital Twin Technologies**: leveraging digital twins to create virtual representations of buildings and their components, enabling better tracking, maintenance, and management of materials throughout their lifecycle [20;21].

- **Circular Supply Chains**: developing circular supply chain networks that prioritize the reuse and reintegration of materials, fostering collaboration among various stakeholders [22].

- **Local Resource Networks**: establishing localized networks for sharing and exchanging materials and components, reducing the need for long-distance transportation, and minimizing associated environmental impacts [23].

- **Green Financing and Incentives**: exploring financial mechanisms and incentives that encourage the adoption of circular practices within the construction industry, such as tax benefits for reusing materials or incorporating circular design principles [24].

- **Education and Training**: introducing educational initiatives and training programs to raise awareness and build capacity among industry professionals regarding circular economy concepts and practices [14].

The research was structured as outlined in Figure 1: (i) the identification of the most promising fields in the building sector with the highest potential for re-manufacturing application; the definition of the paradigm shifts needed for activate circular processes; (ii) the analysis of circular models in use in other sectors to understand the key features for their success; (iii) the conceptual development of three circular organizational models designed for the building sector (and in particular for tertiary architecture); (iv) the engagement of stakeholders to refine the organizational models according to industry needs and the constraints of the real context [25;26].

**Figure 1.** Flow chart of the topics involved in the research.
**Identifying Promising Fields in the Building Sector**

The first task identified which specific areas within the building sector hold the most promise for adopting circular economy principles. This involves assessing different segments of the construction industry and pinpointing those that have the highest potential for applying remanufacturing processes [27].

Starting from the problem statement described in the Introduction, the tertiary sector is one of the areas with the greatest production of waste and therefore deserves particular attention in an attempt to reduce these waste flows. At the same time, it is a sector also characterized by several favorable conditions for taking used products or components, restoring them to like-new condition, and then reintroducing them into the market, due to:

- **Short Renewal Times and Frequent Reconfigurations.** In sectors like exhibitions, retail, offices, and hospitality, interior spaces are often redesigned and reconfigured relatively frequently. This leads to accelerated obsolescence of equipment and interior fittings. Re-manufacturing can help extend the lifespan of these components, reducing waste and the need for constant replacement [3].

- **Temporary Usage Patterns and Shortened Lease Contracts.** The trend towards flexible working environments, co-working spaces, and short-term leases means that office spaces and other commercial venues may have higher turnover rates. Re-manufacturing allows for the efficient reuse of materials and components as spaces are reconfigured or new tenants move in, aligning well with the dynamic nature of these sectors [28].

- **Availability of Disused Components with High Residual Performance.** Tertiary buildings often have a wealth of components, such as interior furnishings and equipment that are no longer needed due to renovations or upgrades. These components might still have significant value and performance potential. Re-manufacturing represents an opportunity for extracting value from these components, reducing waste, and creating a sustainable supply of materials [29].

- **High-Value Raw Materials and Dry Assembly.** Many components in the tertiary sector are built using high-value raw materials, which makes reusing and re-manufacturing them economically attractive. Additionally, the fact that these components are often dry assembled (easy to disassemble without extensive damage) facilitates the re-manufacturing process, as disassembly is a crucial step in the restoration process [17].

- **Market Demand for Sustainable Solutions.** As awareness of environmental issues grows, businesses and consumers are increasingly seeking sustainable and eco-friendly solutions, especially in the tertiary sector. Re-manufactured components can appeal to this market demand by offering high-quality products with reduced environmental footprints [30].

Incorporating re-manufacturing practices into the tertiary sector could contribute to more efficient resource utilization, reduced waste generation, and overall sustainability. However, challenges such as developing efficient collection and disassembly processes, establishing quality standards for re-manufactured components, and creating awareness among stakeholders would need to be addressed for successful implementation.

**Defining Paradigm Shifts for Circular Processes**

This task recognized the paradigm shifts that have allowed other sectors to successfully transition to circular processes. These changes could be technological, economic, regulatory, or cultural. By identifying them, it is possible to gain insights into how the building sector might need to adapt and evolve to embrace circular economy principles effectively.

1. **Disown Ownership and Product-as-a-Service Model.** This approach involves a change in basic assumptions from traditional product ownership to offering products as services. Customers no longer buy products; instead, they purchase access to the product's functionality. Ownership remains with the provider, and customers pay for the product's availability and usage. Payment methods can include
pay-per-use, pay-per-period, or pay-per-performance systems. This model encourages longer product lifetimes and reduces the demand for constant new purchases [28].

2. Servitization and Value-Added Services. Servitization involves transitioning from selling standalone products to offering bundled solutions that include both products and value-added services. Services become a central element of the offering, contributing to the product's extended useful life. Regular maintenance becomes part of the package, enhancing the product's performance and longevity. By maintaining a service history, the potential for re-manufacturing at the end of the product's lifecycle can be easily assessed [31].

3. Industrial Symbiosis and Waste-Resource Logic. Industrial symbiosis promotes cross-industry collaboration and resource exchange to optimize resource management. Different industries cooperate to share materials and products, treating waste from one sector as a valuable resource for another. This approach fosters long-term synergistic relationships and enhances resource utilization, reducing waste and promoting sustainable practices [32].

4. Design for Re-manufacturing. This approach focuses on designing products with re-manufacturing in mind. Products are designed for easy disassembly, cleaning, reprocessing, and reassembly. Strategies like modularity and readily available spare parts contribute to the product's durability and re-workability. By addressing design considerations upfront, re-manufacturing processes can be streamlined, making it more feasible to extend product lifecycles [33].

The above-described paradigms collectively emphasize the shift from a linear "take-make-dispose" model to a circular model, where products and materials are kept in use for longer periods, minimizing waste and environmental impact. By implementing these strategies, industries can create new business models, strengthen stakeholder relationships, and contribute to more sustainable and circular practices [34].

Analyzing successful Circular Models applied in industrial sectors

The research investigated the key features of the circular economy models that have proven successful in industrial sectors representing paradigm shifts in the manufacturing approaches. The aim of this investigation is to analyze the key features, which have the potential to be transferred to the building sector.

The selection of the key features pursued a dual goal [25;26]. Firstly, it enabled the representation and description of existing organizational models by utilizing combinations of the identified key features. Secondly, it supported the conceptualization of new circular models centered around re-manufacturing and the other re-actions: the new models were developed by combining various configurations (A1, A2, A3, B1, B2, etc.) of the selected key features.

The configurations can be summarized as follows [25;26]:

A. Original Product Design. This refers to designing products with the intention of easy disassembly, repair, and re-manufacturing. The design should prioritize modularity and the use of standardized components to facilitate future re-manufacturing processes.

B. Product Procurement. This refers to the process of acquiring the initial products, which might be used or discarded items, to be re-manufactured. These items will undergo the re-manufacturing process to transform them into market-ready products.

C. Product Collection. This refers to the systematic collection of used or end-of-life products from consumers or other sources, which are then brought into the re-manufacturing loop. This step ensures a steady supply of items to be re-manufactured.

D. Re-manufacturing Actors. This refers to the entities or individuals involved in the re-manufacturing process, including technicians, engineers, and other professionals who disassemble, repair, refurbish, and reassemble the products to extend their lifecycle.

E. Re-manufactured Product Design. This refers to the design process is specifically for re-manufactured products. This involves creating products that meet quality standards while integrating reclaimed components and materials from the original products.
F. **Product-Service Distribution.** This refers to the methods and channels through which re-manufactured products are distributed to consumers or users. This may involve traditional retail, e-commerce, or other innovative distribution methods.

G. **Product Ownership.** This feature focuses on ownership models that promote product stewardship, such as leasing, subscription services, or shared ownership. The emphasis is on maintaining the product over time rather than disposable ownership.

H. **Revenue System.** This refers to the business model and revenue streams associated with the circular re-manufacturing process. This could include revenue from product sales, re-manufacturing services, subscriptions, and other related sources.

I. **Market Destination and Segment.** This refers to identifying the target markets and customer segments for re-manufactured products. Understanding the demand and preferences of these markets helps tailor the re-manufactured products to meet their needs.

---

**Developing Circular Organizational Models for the building sector**

Leveraging existing knowledge and lessons learned from other sectors, the research outlined three Circular Organizational Models designed to promote circularity within the building sector, specifically focusing on tertiary architectures. These models leverage re-manufacturing and reuse practices to align with the key features mentioned above. The proposed circular models are developed in the perspective of the paradigm shifts and are derived from successful practices in both the building sector and other industries where re-manufacturing is well-established, as described in Table 1 [26].

---

**Table 1. Key-feature of the Circular Organizational Models OM1, OM2, OM3**

<table>
<thead>
<tr>
<th>Key features</th>
<th>Possible configurations</th>
<th>OM1</th>
<th>OM2</th>
<th>OM3</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Original product design</td>
<td>A1 Product designed for re-manufacturing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A2 Product not designed for re-manufacturing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A3 Product not designed for re-manufacturing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>B1 Surcharge-based mechanism</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>B2 Buy-back mechanism</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. Product procurement</td>
<td>B3 Direct-order mechanism</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>B4 Service contract mechanism</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>B5 Leasing mechanism</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Product collection</td>
<td>C1 Enabled by “collectors” activity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>C2 Performed autonomously by re-manufacturer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>C3 Hybrid solutions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. Re-manufacturing actors</td>
<td>D1 Original Equipment Re-manufacturer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>D2 Contracted Re-manufacturer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>D3 Independent Re-manufacturer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. Re-manufactured product design</td>
<td>E1 Product re-designed for re-manufacturing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>E2 Product not re-designed for re-manufacturing but with facilitating features</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>E3 Product not re-designed for re-manufacturing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F. Product-service distribution</td>
<td>F1 With a partner intermediation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>F2 With a dealer intermediation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>F3 Performed autonomously by re-manufacturers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G. G1 Ownership is transferred to the customer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
OM1. Rent Contract as Support for Re-manufacturing

The first model suggests incorporating re-manufacturing practices through rental contracts. Instead of traditional ownership, stakeholders could engage in rental agreements for construction components or materials [26]. At the end of their useful life, these items would be returned for re-manufacturing or refurbishment. This approach shifts away from the traditional single-use model where products are used and discarded after one cycle. Instead, it embraces a multiple-use approach by enabling products to undergo multiple usage cycles through re-manufacturing (Figure 2).

This model encourages manufacturers to design for durability and ease of disassembly, as well as motivates clients and investors to prioritize sustainable materials. In fact, in this model, the original manufacturer collaborates with a provider to design and create products that are meant to be rented to customers, rather than sold. The provider is responsible for renting out the products to customers and collecting them at the end of the rental period. The used products are then returned to the original manufacturer for re-manufacturing, restoring them to their original condition and performance. This process creates a circular value chain, where products are used, re-manufactured, and then used again, promoting sustainability, and reducing waste.

Compared to current organizational models, that are mainly based on the customers’ ownership and responsibility of product waste, the OM1 model encourages manufacturers and providers to prioritize the design and manufacturing of products with durability and maintainability in mind. This approach aims to extend the lifespan of products and enable multiple usage cycles before they reach the end of their useful life. The retention of embedded resources within products and the ability to facilitate several usage cycles can lead to both environmental benefits, by reducing resource consumption and waste, and economic benefits, by generating a consistent revenue stream through the rental service [35].

OM2. All-Inclusive Solution to Support Re-manufacturing

The second organizational model involves an all-inclusive solution to support re-manufacturing. In this model, the product is sold along with a set of life-extension services that are performed during the product's use phase. The customer pays for both the product and the services aimed at extending its useful life. These services can include cleaning, repair, maintenance, replacement, and re-manufacturing [26].

This model is based on a close partnership between the product supplier (provider) and the service supplier specialized in re-manufacturing (re-manufacturer). The provider supplies the product to the customer, while the re-manufacturer provides ongoing services related to the product's maintenance and life extension (Figure 3).

Both the provider and the re-manufacturer benefit from this collaboration (win-win partnership). The provider can offer all-inclusive solutions to customers by leveraging the re-manufacturers technical expertise in repair, maintenance, and re-manufacturing. The re-manufacturer, in turn, benefits from the provider's marketing connections and product commercialization efforts to attract more customers.
The second model differs from the first one in terms of its product life-extension strategy. While the first model focuses on enabling multiple reuse cycles of the same product, even by different customers, the second model aims to extend the initial product use cycle by fostering long-term relationships with the same customer. This approach, often referred to as the "loyalty strategy" [21], aligns the product's duration of use with its useful life, minimizing the waste of residual performance.

The goal of the loyalty strategy is to create sustainable and mutually beneficial long-term relationships between the supply side (provider and re-manufacturer) and the demand side (customer). By maximizing the useful life of the product through effective maintenance and re-manufacturing, this model contributes to reducing waste and improving resource efficiency. **On the contrary of current trends**, it aligns with sustainability goals by reducing the need for premature disposal of products. Moreover, the promotion of extended use and efficient life-extension services enhances customer satisfaction and loyalty [36].

**OM3. Alternative/Secondary Markets for Re-manufactured Products**

This model explores the creation of alternative or secondary markets specifically for re-manufactured construction products. The model focuses on two main strategies: product reuse in secondary markets and product repurposing for different markets [26]. This involves taking products that have been used in the primary market, reworking or repurposing them, and then selling them in secondary or different markets (Figure 4).

The primary goal of the model is to prevent waste generation by reusing or repurposing post-use products, thereby contributing to a circular economy. An independent re-manufacturer is responsible for carrying out the necessary operations to recover post-use products and prepare them for their next use cycle. The dealer acts as an intermediary in the market, distributing the re-manufactured products to end customers. A deposit-based payment system can be implemented to incentivize customers to return products after use. It encourages end users to return products, ensuring circularity.

**The successful implementation of the model, that is currently present on the market only in specific condition (e.g., in case of no-profit activities),** requires collaboration and coordination efforts between the re-manufacturer and the dealer, as well as other stakeholders. This involves logistic management and assessing market opportunities for product redesign and repurposing. On the demand side, clients are expected to embrace the circularity concept and accept the deposit-based payment system and regenerated products [37].

![Figure 2. Rent contract as support for re-manufacturing – organizational model [25].](image)
Engaging Stakeholders for refining the Circular Organizational Models

After the development of their conceptual structure, the three circular organizational models were detailed and tested through collaborative efforts involving key stakeholders within the tertiary field. Roundtable sessions and focus groups facilitated active engagement and input from various stakeholders including investors, clients, manufacturers, construction companies, installers, and facility managers. This collaborative process ensured that the proposed circular models are practical, feasible, and aligned with the real context constraints and the needs and perspectives of the relevant industry participants [2].

A total of 27 stakeholders have been involved in various ways (interviews, focus groups, roundtables, conferences). Among these, 16 companies have significantly contributed to the development of the research and the evaluation of organizational models. These companies have actively participated in workshops and roundtables. The researchers carefully selected stakeholders based on representativeness within the sector and the level of innovation and maturity of their practices. These criteria of selection have ensured that the stakeholders involved were relevant and able to bring valuable insights into the investigation process [34].
As a primary selective criterion, the research involved stakeholders from the Lombardy region, which is the reference geographical area. This localized approach allowed for more effective collaboration and a deeper understanding of regional dynamics. Furthermore, the involvement of operators from different subsectors such as exhibitions, offices, and retail allowed to take into account the specificities of products that are normally characterized by short-term life cycles.

The selection included a variety of actors, involved in for-profit companies, third-sector actors (cooperatives), and trade associations with diverse roles within the respective supply chain: designers, outfitters, manufacturers, general contractors, trade associations, sellers, maintainers, etc. The selected stakeholders' roles are complementary, ensuring that the entire supply chain within each sector was represented and considered in the discussions [26]. Considering their diverse backgrounds:

1. Producers and Designers:
   a. Highlight the potential for innovative design and production techniques that enable longer product lifecycles and easier disassembly for recycling or re-purposing;
   b. Emphasize the market demand for sustainable products and how circular design can enhance brand reputation and customer loyalty;
   c. Discuss how collaboration can lead to the sharing of best practices and knowledge, fostering creativity and driving the development of more circular products.

2. Contractors and Policymakers:
   a. Discuss the role of regulations and policies in incentivizing circular practices, such as Extended Producer Responsibility (EPR) laws or tax incentives for eco-friendly products;
   b. Address potential regulatory barriers that currently hinder the adoption of circular models and propose ways to streamline or adapt these regulations to encourage circularity;
   c. Highlight the potential economic benefits of a circular economy, including job creation, reduced waste management costs, and improved resource security.

3. Investors:
   a. Point out the growing interest among investors in sustainable and socially responsible projects, which can attract funding for circular initiatives;
   b. Display examples of successful circular economy business models that have delivered both environmental and financial returns on investment;
   c. Emphasize the long-term viability and risk mitigation associated with circular practices, as they can reduce reliance on scarce resources and volatile commodity markets.

RESULTS AND DISCUSSION

At the end of the whole path, in particular from the interaction and dialogue with the stakeholders, interesting feedback emerged on the subject of the applicability of circular economy strategies, as well as the applicability of the defined circular organizational models. This paragraph outlines the cases and views of the stakeholders from the different fields. The collaboration among players presented an opportunity to highlight the mutual potential for activating new circular organizational models and circular strategies. Some key points [27;34] discussed during debates and roundtables can be summarized as follows:

- Identifying Barriers. The identification of the existing barriers that hinder the adoption of circular organizational models is an important step toward the application of circularity. These barriers include a lack of awareness, policy and regulatory challenges, financial constraints, and technological limitations. Understanding and acknowledging these challenges helped the participants produce effective solutions.
- Sharing Expertise. Each stakeholder brings unique expertise to the table. During debates and roundtable, producers, designers, contractors, policymakers, and investors shared their knowledge and experiences in their respective domains to develop comprehensive and sustainable solutions.
- Cross-Sector Collaboration. The participants explored opportunities to enter new potential markets in different sectors. For example, second-life products from the tertiary sector could find applications in
the residential sector. This cross-sector collaboration not only opens new markets but also contributes
to resource optimization and waste reduction.

- **Policy Support.** Policymakers play a crucial role in fostering a circular economy. They can provide
  incentives, regulations, and policy frameworks that promote the adoption of circular organizational
  models. The stakeholders highlighted the importance of involving policymakers for introducing
  supportive measures.

- **Investment Opportunities.** Investors are looking for sustainable and socially responsible projects find
  opportunities in circular economy initiatives. The collaboration should explore investment avenues
  and financial incentives to drive circular economy projects forward.

- **Technology and Innovation.** Embracing innovative technologies and innovative practices is a
  meaningful change in promoting circularity. Participants discussed the potential of technology in
  facilitating material recycling, product refurbishment/remanufacturing, and waste reduction.

- **Communication and Awareness.** Effective communication and public awareness campaigns are
  essential for gaining public support and acceptance for circular economy initiatives. The collaboration
  can strategize ways to communicate the benefits of circular models to the broader audience.

- **Standards and Certifications.** Developing standards and certifications for circular products help build
  consumer trust and confidence. The stakeholders discussed the possibility of creating industry-wide
  standards for second-life products.

- **Circular Supply Chains.** Collaborations can explore the creation of circular supply chains, where
  materials and products are continuously reused, refurbished, remanufactured and recycled, reducing
  the need for new resource extraction.

Specificities also emerged in relation to the individual application areas involved, i.e. offices, retail and
exhibitions.

**Office Sector**

The stakeholders involved in this discussion represented diverse viewpoints from the production,
commercial, and regulatory sides of the office building sector. They offered a comprehensive overview of
their perspective: they confirmed that the frequency of restyling of the workplaces to achieve marketing
and rebranding images is every 2/3 years approximately, even if systems and building products (movable
walls, furniture, dry assembled interior fittings, etc.) have a duration of performance at least 10/15 years.
They also confirmed recent sector studies, showing that strip-out works during office refurbishment create
63 tons of material per 1000 sqm [38]. The primary material components are plasterboard, carpet, ceiling
tiles, glass, metals, and furniture.

Some main concerns highlighted by the selected representative interlocutors from the building office sector
deal with the technological and logistic barriers. The existing supply chain network is perceived as still
lacking the technical competencies and business skills required for re-manufactured products to be
considered viable in the market and for the economic sustainability of the reverse logistic network.

Stakeholders collectively view the current supply chain network as insufficiently prepared to embrace
circular practices. This network is seen as still not enough mature to replace current large-scale practices
with circular ones for office sector fit out and building due to factors linked to economic viability and
logistic challenges. The viability of circular practices by existing players is hindered by economic
considerations and the absence of a robust planning and production network. These barriers at present can
prevent the transition from a linear supply chain to a closed-loop one.

In order to overcome these obstacles, all stakeholders agreed that introducing a new player within the
supply chain could promote the adoption of circular practices. Existing commercial players and
manufacturers lack the necessary knowledge and competencies in re-manufacturing processes. The new
player should offer a competitive business proposition for circular solutions and establish a structured
reverse supply chain to ensure cost-effectiveness and widespread adoption.
Another critical element for the successful implementation of circular practices is the establishment of a robust and structured reverse supply chain. This would facilitate cost-effective practices and the widespread adoption of circular solutions in the industry: in fact, shifting from traditional linear practices to circular ones might entail initial costs and uncertainties that deter some stakeholders.

Finally, the existing regulatory framework for the Italian office building sector is stringent and plays a crucial role in determining the market viability of building products. Safety-related aspects and structural characteristics are of paramount importance in evaluating product quality. The evolving nature of the regulatory system needs to be considered when developing new business and market relations.

In summary, stakeholders from the office building sector in Italy identified key challenges related to the adoption of re-manufacturing practices. These challenges involve technical competencies, supply chain readiness, economic viability, and regulatory compliance. Stakeholders agree on the need for changes in the regulatory framework as well as new operators with re-manufacturing expertise and the establishment of a robust reverse supply chain [35;36;37].

The successful of stakeholder engagement concerned not only the identification of barriers and drivers for the application of circular organizational models in the office sector, but also the creation of a new active network of operators interested to circularity. In fact, the mutual dialogue between stakeholders has activated an experimental circuit of re-manufacturing in Lombardy.

Thanks to the network, it was possible to intercept a flow of materials leaving an office renovation activity before they became waste and sent to landfill. The network, in particular, collected the products still in good condition (diverting it from landfills) in order to reuse, repurposing and remanufacturing and put them back on alternative/secondary markets.

Exhibition Sector

Referring to the exhibition field, the stakeholders, who have been involved in the research, shared the opinion that the fundamental logic and structures presented in the three proposed organizational models were already practiced within the exhibition sector. However, during the discussions and roundtables, certain relevant issues and insights emerged as possible improvements of the models in relation to the needs and realities of the exhibition sector.

The stakeholders confirmed that, despite the efforts of outfitting suppliers to increase the lifespan of the rented components, the exhibition sector is still generating a high amount of waste. This implies that the waste issue is not completely resolved and that there might be other factors contributing to the waste generation apart from the lifecycle of the rented components [11]. The waste generated in the retail sector includes various items such as customized furniture, interior partitions, coverings, and finishing products. These may no longer be suitable for their original purpose but might still possess value in other applications. Luxury shops face additional issues because their interior finishing products often involve high-quality materials, exclusive manufacturing processes, and unique design elements: this makes their waste disposal particularly wasteful and environmentally damaging.

The major strength of the proposed organizational models for exhibition outfitters is the ability to engage in long-term planning with customers. By actively involving customers in the design phase and considering their input, the outfitters can develop collaborative relationships and secure long-term contracts. This helps maintain consistent customers over several years, leading to a stable client base. The outfitters claim to have the necessary skills and competencies to handle most of the products required by customers. The dynamic and varied nature of demand also necessitates an effective collaboration with suppliers for design and technical support. Regarding the end of product life, the outfitters find various paths for the products that are no longer reusable after several use cycles. They explore secondary market channels, such as outlets, especially for medium- and high-end products. The growth of e-commerce delivery has expanded the market for these products to foreign customers as well.
However, there are some barriers to the suitability of this organizational model. The time factor within the exhibition context poses challenges. Trade fair regulations and procedures might prioritize time and cost reduction over environmental concerns, leading to non-eco-sustainable disassembly practices. Involving event planners becomes crucial to implementing reuse and remanufacturing processes considering the time for appropriate assembly, use, and disassembly. Another challenge arises in the case of products that are highly personalized for specific customers, making it difficult to reuse them for others and extend their lifespan. Overcoming this challenge requires finding a balance between modularity and customization during the detailed design phases.

Overall, the proposed organizational model offers significant benefits through long-term planning and collaboration with customers, suppliers, and event planners. However, challenges related to time constraints and personalized products need to be addressed to fully leverage the model's potential for sustainable and circular practices [35;36;37].

In this context, discussions with stakeholders revealed the potential to develop highly reversible products in order to facilitate disassembly in a short time, avoiding damaging the product and enabling quality reuse and remanufacturing.

The successful of stakeholder engagement concerned, in this case, the experimentation of reversible solutions for wall systems of the exhibition. An industrial partner shared materials and know-how to develop reversible solutions and activate product remanufacturing activities.

**Retail Sector**

The retail sector lacks a comprehensive understanding of its waste production on a global scale. This means that the amount of waste generated by retail activities is not being effectively monitored or managed. The interviewed stakeholders (trade associations and suppliers) proved that the retail spaces are being renewed every two years, and products are replaced seasonally. This high frequency of renovation and replacement contributes to more waste generation and a higher demand for new resources.

Considering the frequent strip out in the retail field, the research identified potential alternative or secondary markets for re-manufactured products in the residential buildings, in the hotels (for furniture or another mobile outfitting), and in the low-cost retail shops (e.g., outlet). However, any re-manufacturing chain that involves the retail network can be complex due to various responsibilities associated with the performance assessments and certification for re-manufactured products.

In this direction, ensuring product information availability throughout its useful life is important for future re-use. However, monitoring product conditions is resource-intensive and currently not widely practiced in the retail context, characterized by the fast obsolescence and frequent substitutions of products.

Lastly, the trend of product customization is significant in the retail context: this trend might hinder the acceptance of re-manufactured goods compared to innovative solutions and limits the reuse of customized products that can be associated with a brand. In particular, the products that are strongly characterized by the brand identity are not easily feasible for other customers in the same area and, at the same time, branded products cannot be used in other markets or sectors. Hence, reusing these products as they are might not be possible, for which a remanufacturing intervention toward future reuses that modifies the image may be necessary to protect the originality of the brand. Re-purposing strategies are seen positive and in an increasing trend as corporate social responsibility practices in the retail sector.

To address challenges, the proposal of closed-loop value chain models, with the owner that remains in charge of the re-manufacturing process, can point out transparent and available product information. This can facilitate collaboration between stakeholders and encourage experimenting with new settings. Technical actors involved in re-manufacturing may face performance assessment and certification challenges, particularly when dealing with products whose ownership and origin are not within the remanufacturer's control.
Another opportunity – that is currently implemented within the social policies of some fashion brands – is represented by delivering end-of-useful-life products to alternative or secondary markets. Retailers focused on offering low-cost products, such as outlet or secondary low-cost shops, can provide an additional avenue for these products to find new homes. These retailers often cater to budget-conscious consumers who might be more open to purchasing repurposed items at lower prices.

In conclusion, the stakeholders’ interviews highlighted the intricate relationship between customization, re-manufacturing, supply chain management, and the need for transparent product information throughout the lifecycle. They suggested that while customization is a prevalent trend, finding ways to incorporate re-manufacturing into the closed-loop value chain requires careful consideration and collaboration among various players in the supply chain [35;36;37].

Leverages and Barriers of the Circular Organizational Models

This section outlines both the positive aspects (leverages) and the obstacles (barriers) that the three organizational models for circularity might encounter in general or in the specific investigated fields (offices, exhibitions, and retail). The paragraph also suggests some general perspectives and conclusions drawn from the interactions with stakeholders.

Regarding the leverages, it is possible to underline the following issues.

**Long-lasting business partnerships.** In the exhibition fitting sector, the relationships established between outfitters and clients are characterized by a multi-period duration, leading to long-lasting business partnerships. This fosters customer loyalty and enables virtuous circular practices such as multiple use cycles of products and the activation of reverse supply chains between customers and outfitters or partnered re-manufacturers.

**Product ownership and closed-loop supply chain.** In situations in which (as in the exhibition sector), the provider tends to retain product ownership, it is possible a higher level of control over product and material flows in a closed-loop supply chain system. This may be very beneficial for implementing circular practices.

**Market dynamics and trends.** The office building sector is experiencing a revision of space layout, leading to a rethinking of whole office work. This presents an opportunity to start practices of circularity, to pursue the flexibility in the use of multifunctional spaces and to activate new operators for re-manufacturing. Clients and owners can also boost circularity by including new requests within the invitations to tender in two directions: on one side requiring circularity and re-manufactured systems and equipment, on the other side requiring solutions and products designed for disassembly and remanufacturing in accordance with key indicators of circularity.

**Re-purposing strategies:** Some players in the retail sector are already adopting re-purposing strategies as part of their corporate social responsibility practices. These projects aim at generating new destinations for products with low residual economic value, gaining relevance in large-scale organizations that prioritize sustainability-related activities, and having sufficient resources to allocate to such initiatives.

However, some barriers remain to be overcome, which are major challenges for future research and innovation. They are listed below.

**Modularity vs. Customization.** Finding the right balance between product modularity and customization is crucial for businesses involved in exhibition fittings, office general contracting, and retail space design. Too much customization might hinder efficiency and cost-effectiveness of circular practices, while too much modularity might sacrifice unique design elements.

**Regulatory Frameworks and Certifications.** Existing regulations can hinder the viability of re-manufactured products, particularly in the fields where safety standards are stringent and differ from country to country.
**Cost-Driven Logic.** Some manufacturers prioritize cost-effectiveness, which can limit the exploration of alternative, more circular solutions.

**Tight Timetables.** In the exhibition sector, event organization timelines often do not allow for proper disassembly and recovery of products, discouraging circular activities based on accurate disassembly.

**Volume of Material Flows.** Considering the building sector, the material flows coming from maintenance, renewal, or demolition processes may be insufficient to justify new industrial processes, and it is very challenging to predict quantities and product types on the medium-long time.

**Economic Disadvantage.** Re-manufactured products need to demonstrate economic advantages over new ones, as they may obtain the market acceptance if they are succeeded to be competitive for quality or for price. At present, it is very difficult to predict exactly the costs of remanufacturing owing to the many conditions of uncertainty.

## CONCLUSIONS

The research starts from the awareness that in the building sector, the environmental cost of raw materials has led to a shift in focus from the natural context to the technological one. This suggests that materials used in buildings should be seen as potential resources that can be reclaimed and reused when the building reaches the end of its life. To implement circularity, resources need to be tracked and managed throughout their entire life cycle, from production to eventual reuse or recycling. This approach, often referred to as "cradle-to-cradle," ensures that materials are continuously looped back into the production cycle [39].

Triggering downstream circularity mechanisms on buildings not born for circularity is a difficult undertaking, which risks leading to actions more oriented towards recycling than reuse. Instead, designing for reuse and remanufacturing makes it easier to trigger an effective and sustainable circularity of resources. This perspective finds interesting application for those parts of the building (e.g., finishes) and for those uses of the building (offices, retail, exhibition) characterized by medium-short cycles of use, from which derive products that are still of good quality and have residual performances.

Shifting to circularity involves adopting new organizational models. This could include models based on product-service relationships, leasing, or renting. As the circular economy gains prominence, there's a growing need for professional figures who can bridge the gap between different stages of the product lifecycle – from production and use to disposal and re-manufacturing. These interface figures act as connectors, ensuring seamless communication and coordination among various stakeholders. The emergence of new interface actor also gives rise to a demand for professionals with specialized skills. For example, experts who understand both the technical aspects of product design and the intricacies of re-manufacturing processes can optimize products for easier disassembly and reassembly. These professionals might be industrial designers, materials engineers, dismantlers or even supply chain experts with circular economy knowledge.

In this perspective, some organizations operating within the third sector can be recognized as very promising for re-manufacturing because of some of their characteristics. In fact, they can be very flexible and organized in network able to activate on the territories and link various categories of logistic operators (disassemblers, urban miners, transporters) and artisans (blacksmiths, carpenters, window manufacturers, painters, etc.). This type of organizations, based on artisanal skills, with their flexibility can be particularly suitable to operate in a situation of fragmentation, where products coming out of use-cycles can be aggregated in small batches, not concentrated on the same territory, with different characteristics and residual performance. Surely these third-sector organizations need to be empowered (e.g., through digital tools and platforms supporting the networking activities and mismatching between supply and demand) in order to become successful networks for remanufacturing.
The transition to circularity also requires a regulatory framework that supports and encourages the adoption of circular supply chains. New regulations may be needed to address aspects such as ownership, responsibilities, certification of remanufactured products, as it is happening to set the technical feasibilities that control the Design for Disassembly [40]. Furthermore, tools that can support the shifting toward reuse and re-manufacturing are traceability systems, that allows to know the original characteristic of the product during the life cycle.

Finally, among numerous factors, the economic and environmental aspects are highlighted as significant drivers for the adoption of circular practices. The research emphasizes the importance of retaining the economic value and the environmental resources in recovered products, which can stimulate the adoption of circular supply chains. In parallel, it is necessary to assess in advance the effective sustainability of the Circular Organizational Models. In a perspective of circularity and management of the life cycle of resources, evaluation methods such as life cycle assessment and life cycle costing can support choices towards sustainability and can therefore be tools to be promoted to help stakeholders configure strategies and effective organizational models declined for the respective specific application situations.

DECLARATIONS

Acknowledgments

The authors would like to thank all the stakeholders that participated in the debates and round tables of the Re-NetTA research.

Authors’ contributions

Methodology investigation and data curation: All; writing—original draft preparation: Viscuso S, Atta N, Dalla Valle A, Giorgi S; writing—review and editing: Lavagna M, Talamo C; supervision: Lavagna M, Talamo C. All authors have read and agreed to the published version of the manuscript.

Availability of data and materials

Not applicable

Financial support and sponsorship

The work is part of 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”).

Conflicts of interest

The authors declare no conflict of interest.

REFERENCES


823
Dear Editorial Office,

Thank you for giving us the opportunity to submit a revised draft of my manuscript titled “Re-NetTA Project: organizational models for promoting re-manufacturing chains of building products in the Lombard manufacturing district” for consideration by the Special Issue of Green Manufacturing Open “Life Cycle Engineering for Improving the Sustainability of Re-manufacturing”.

Here is a point-by-point response to the comments:

1. The introduction is lengthy, it needs to be condensed. The short paragraphs can be merged. Highlight the research gap and need. Make sure you present a critical discussion, not a descriptive summary of the topic.

   Thank you for pointing this out. We agree with this comment. Therefore, we have merged paragraphs of the introduction and described more gap and need (rows 94-139). We also moved the last part of the Introduction in the Method section (rows 141-174).

2. Did the author develop the new organization models? If so, what are the differences/advantages compared with old ones?

   We have, accordingly, done/revised/changed/modified the descriptions of OM1, OM2 and OM3 to emphasize the advantageable differences compared to the current models and practices (rows 316-317; 345; 361-362).

3. The paper provides lots of insights and comments, which are meaningful to current remanufacturing sectors. I suggest drawing a figure to illustrate the link between the involved topics.

   We agree with this and have incorporated your suggestion throughout a research map (figure 1).

4. Besides, the editorial office has also found that the manuscript duplication rate reached 24%, and the similarity of each article has reached 16% (the similarity report has been attached and you could check it at: https://oaepublishstorage.blob.core.windows.net/attachments/GMO_2023_081001_simlarity_docx_docx.pdf).

   As we have mentioned before, based on feedback from science citation databases and our company’s strong commitment to academic integrity, we have increased the requirement for manuscript similarity to 20% and the similarity of each article could not exceed 5%. We believe that this will help ensure that our journal always maintains the highest academic quality and integrity. We also believe
that scholars like you would uphold a stringent approach to academic work. Consequently, we kindly request your reduce similarity as requested.

Thank you for pointing this out. We revised the manuscript to reduce similarity. After these modifications, we checked it using a plagiarism detection tool. You can check the report at: https://polimi365-my.sharepoint.com/b:/q/personal/10187375_polimi_it/EV9Rq5kxNx1CtIfY74VapBkB9q2s-yXxh_WFw2nQ3-1XrQ?e=ABxnnh

We look forward to hearing from you regarding our submission and to responding to any further questions and comments you may have.

Sincerely,

Arch. Salvatore Viscuso

POLITECNICO DI MILANO | DABC
Via G. Ponzio 31 - Building 14, 20133 Milan (Italy)
Tel: +39 02 2399 5713
www.polimi.it - www.abc.polimi.it