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

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Abstract

In view of the circular economy transition, the building sector is facing the challenge of overcoming conventional organizational models that follow a "take-make-dispose" in favor of circular models, exploiting re-manufacturing to close the loop. Starting from the analysis of re-manufacturing practices well affirmed in other industrial sectors and the lesson learned in terms of key features, the paper focuses on circular strategies and new organizational models and tools for short-life building products coming from renewal interventions in office, exhibition, and retail. In particular, three novel circular models are presented, based on the cross-sectorial successful key features of reuse/re-manufacturing activities and the point of view of stakeholders, including manufacturers, service providers, policymakers, and the third sector. This collaborative effort took place in the context of the research "Re-NetTA - Re-manufacturing Networks for Tertiary Architectures - New organizational models and tools for re-manufacturing and reusing short-life components coming from tertiary building renewal", leading the knowledge sharing among the involved players to support innovative solutions.

Keywords: Circular economy, circular organizational models, design for re-manufacturing, tertiary buildings, architectural technology, building sector

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INTRODUCTION

Today, the building sector plays a pivotal role in driving the transition towards a circular economy. The recognition by the European Commission of the building sector underscores its significance in addressing specific questions regarding circular economy principles. On the one hand, the statistics from Eurostat highlight the substantial impact of the building sector on waste generation, accounting for a significant 33.5% of total waste produced across economic activities and households in the EU-28 in 2014[1]. This emphasizes the need for innovative approaches to reduce waste and promote resource efficiency within construction processes. On the other side, the building sector holds substantial economic importance: it represents a significant 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 energy and resource efficiency[2].

The paper focuses on circular strategies and proposes organizational models to preserve the economic value and the material resources embedded within manufactured products once they have been removed from the buildings owing to renewal interventions[3,4]. In particular, the outcomes of the project Re-NetTA are disclosed.

The research was developed by a multidisciplinary group led by the Architectural Technology area. The scope of investigation and application is tertiary buildings, focusing on offices, retail, and exhibition sectors. This selection depends on the widespread renewal of spaces (offices, retail) and the temporary nature of the events (temporary shops and exhibitions) involving short cycles in the useful life of parts of the fit-out products, such as finishing, walling, and furniture materials; this trend generates a large quantity of waste, because of their low aptitude to be rebranded and adjusted to a different fit-out design[5]. The productive district investigated in the Re-NetTA research is 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[6].

In Lombardy, the ever-growing scenario of tertiary buildings and their intensive renewal depends on the crucial aspects that must be considered to understand the emergency in boosting circular economy strategies[7]. 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, which 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[8].

Currently, and for the following years, new settlements - more extensive than 5,000 m^2 - will be realized in the City of Milan, for a total potential amount of around 2,390,000 m^2 of new office spaces (Porta Nuova 217,000 m^2; City Life 150,000 m^2; Milano Fiori 100,000 m^2; Adriano Marelli 21,555 m^2; Area Falck 150,000 m^2; Progetto Symbiosis - Ortles 100,000 m^2; Santa Giulia 120,000 m^2; Feltrinelli 9,000 m^2)[9]. As a result, the performance gap between new and old stocks is destined to spread. Such a vast quantity of newly available assets must be considered with the already high presence of vacant buildings in the city and its direct surroundings, estimated at around 1.2 million m^2 of empty spaces that are now obsolete[10]. Moreover, the pandemic emergency has enabled a debate about the use of workspaces, and many companies are experimenting with 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 the increasing activity of renewal of obsolete assets[11]. Focusing on each of the three tertiary sectors investigated by the research, the current practices determine massive quantities of waste generated in medium-short cycles, with landfill disposal of materials and products still having good residual qualities.

In the office sector, the Category A (CAT-A) and Category B (CAT-B) delivery Standards play a significant role in lease/rental agreements. CAT-A Delivery is a standardized approach to preparing commercial office spaces for tenants[12]. It involves the basic construction of a commercial office space to a certain level of functionality and comfort. Its primary objective is to provide a blank canvas that meets the necessary building regulations and offers 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 Delivery follows CAT-A and involves the detailed fit-out and customization of the office space according to specific requirements of tenants: it includes personalizing the space to align with their 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 is important to note that while this delivery model offers flexibility and customization options, the corresponding model material flows (organized through a linear process "from cradle to grave") nowadays raise concerns about sustainability, waste management, and environmental impact, especially for the large quantities of waste products 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 significant waste due to 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[13]. This frequent restyling leads to a considerable number of discarded materials. Retailers change their interior aesthetics regularly to project a fresh and updated image to customers, 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 results in the waste of valuable resources and contributes to environmental degradation.

Focusing on temporary events, they usually create substantial waste due to their short duration and high resources required to set up elaborate stands, displays, and booths. Much of the waste generated comprises components with high reusability potential[14]. On the contrary, current voluntary Standards recommend organizers and exhibitors work together to prioritize the use of reusable materials and modular designs that can be easily assembled and disassembled for multiple events[15].

The research article follows the structure outlined in Figure 1. After identifying the most promising industrial fields in the building sector with the highest potential for re-manufacturing applications, the authors present an overview of current circular models in other industrial sectors, focusing on the recurring key features that enable their success (Section "Analyzing successful circular models and frequent re-manufacturing key features applied in other industrial sectors"). Starting from this analysis, Section "Conceptualizing organizational models for the tertiary building sector (OM1 - OM2 - OM3)" describes the conceptual development of three circular organizational models designed for the building sector (and in particular for tertiary architecture), which integrate the above-mentioned constant key factors. The

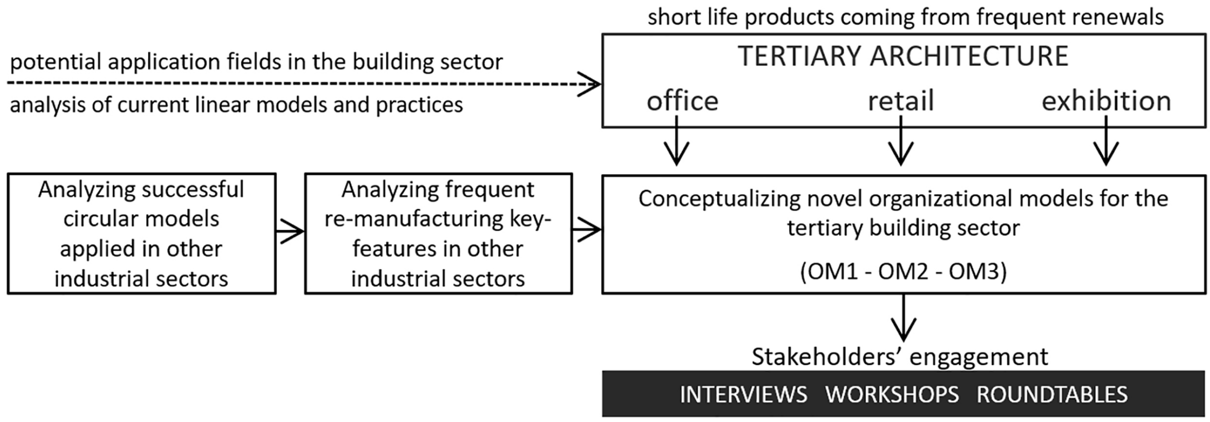

Figure 1. Flow chart of the research steps.

proposed models aim to extend the lifespan and value of products by applying the following four reactions, according to the standard BS 8887-2:2009 (Design for manufacture, assembly, disassembly and end-of-life processing - Terms and definitions): re-manufacturing, recondition, reuse, repurpose[16].

Finally, the engagement of stakeholders permitted the organizational models according to industry needs and the constraints of the actual context[17]. Searching for the most promising conditions for the application of the proposed organizational models and the development of a market of re-manufactured products, Section "Engaging stakeholders in refining the circular organizational models" describes the point of view of various stakeholders active in the field of tertiary buildings. The network includes construction manufacturers and new operators for re-manufacturing in both the industrial and third sectors to determine the leverages and barriers of these circular scenarios.

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 pivotal role in making other industrial sectors more sustainable. The analysis of consolidated practices[18] of different industries (aerospace, automotive, machinery, electrical, and other emerging sectors) highlighted strategies and approaches to transfer and adapt to the construction sector. In particular, the analysis of the State of Art focused the attention on the identification of the most frequent key features in the diverse industrial sectors and emerging markets, such as:

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 standardized components to facilitate future re-manufacturing processes.

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

C. Product collection. This pertains 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 denotes 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. Product-service distribution. This indicates 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.

F. 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.

G. Revenue system. This points 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.

H. Market destination and segment. This means 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.

After analyzing the re-manufacturing models in the current industry, three circular organizational models were detailed and assessed 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 were practical, feasible, and aligned with the actual context constraints and the needs and perspectives of the relevant industry participants[2].

Twenty-seven stakeholders have been involved, of which sixteen companies significantly contributed to the research, taking an active part in the conceptualization of the proposed circular models. The authors have carefully chosen these companies based on their representativeness within the sector and the level of innovation and maturity in their practices. These selection criteria have ensured that the involved stakeholders were relevant and could bring valuable insights into the investigation process[3].

As a primary selective criterion, the research involved stakeholders from the Lombardy region, 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 us to consider the specificities of products typically characterized by short-term life cycles.

The selection included a variety of actors involved in for-profit companies, third-sector cooperatives, and trade associations, with diverse roles within the respective supply chain: designers, outfitters, manufacturers, general contractors, distributors, and maintainers. The roles of selected stakeholders are complementary, ensuring that the entire supply chain within each sector was represented and considered in the discussions. 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 repurposing;
(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 sharing best practices and knowledge, foster creativity, and drive 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 complications that currently block the adoption of circular models and propose ways to streamline or adapt policies that 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.

Once all relevant stakeholders were identified, their vision towards a closed-loop approach to resources was investigated through two main stages, moving from the particular to the general. Indeed, they are first involved through one-to-one interviews to understand the specific needs, concerns, and expectations of each stakeholder regarding the circular organizational model and prioritize their interest in the transition. Secondly, panel activities were organized with an increasing number of participants, starting with a focus on roundtables up to the final project conference. In this way, the interrelationship between the stakeholders follows a growing complexity, bringing even more diverse perspectives and expertise over time, according to the greater variety of involved actors. The stakeholders were limited to a maximum of three companies during the focus group, which provided an opportunity to start the debate and align stakeholders in understanding the rationale behind the shift and the long-term advantages of re-manufacturing. After that, roundtables were set up as brainstorming sessions to encourage open communication and collaboration and give important insights into the circular models. Opinions and suggestions, namely the input from stakeholders throughout the process, were carefully collected to acknowledge and address any concerns raised by stakeholders. Finally, all stakeholders contributed to the final project conference, aiming to inform the public about the most promising re-manufacturing scenarios applied to the tertiary sector of the construction industry and stimulate their implementation in practice.

In this framework, it is worth mentioning that the interactions with stakeholders aligned with Politecnico di Milano's ethical code at all the various stages. The scope and purpose of interviews were clearly explained, along with how the information will be used, ensuring voluntary participation and the chance of withdrawal at any time without consequences. In addition, stakeholders were assured that their responses were kept confidential and that their identities were anonymized in any publications (as in this paper) except by explicit request. The debate was based on questions that were culturally sensitive and respectful of diverse perspectives and backgrounds, framing questions neutrally to avoid influencing responses and any matters perceived as intrusive or offensive. The authors gave special attention to fostering an environment where stakeholders feel comfortable expressing their views, allowing them to express opinions and experiences freely without steering their answers. In the end, by sharing a summary of the findings, stakeholders were provided feedback about how their input contributed to the research processes.

RESULTS AND DISCUSSION

Analyzing successful circular models and frequent re-manufacturing key features applied in other industrial sectors

Looking more closely at the details of the market size of re-manufacturing activities by the EU region, the research investigated the key features of the circular economy models (A-H) that have proven successful in industrial sectors, thus representing paradigm shifts in the manufacturing approaches. The aim was to identify which selected key features have the potential to be transferred to the building sector.

The selection of the industrial sectors pursued a dual goal. Firstly, it started analyzing the market scale of their businesses, the product size, and the re-manufactured goods within the total sector sales[19]. The business data of the analyzed sectors, as represented in Table 1, were then used to find similarities with the tertiary building sectors. Secondly, the analysis of the case studies enabled the representation and description of existing organizational models[20] by utilizing diverse combinations [Table 2 and Figures 2-4].

In analyzing samples of re-manufacturing practices across various industrial sectors, the following trends characterize the application contexts with a higher success rate for re-manufacturing implementation:

– Design for disassembly and re-manufacturing (A). This approach focuses on designing products with re-manufacturing in mind. Products are designed for easy disassembly, cleaning, reprocessing, and reassembly. Strategies such as modularity and readily available spare parts contribute to the durability and re-workability of products. By addressing design considerations upfront, re-manufacturing processes can be streamlined, making it more feasible to extend product lifecycles[51,52].

– Servitization and value-added services (B). Servitization involves transitioning from selling standalone products to offering bundled solutions that include products and value-added services. Services become a central element for durable and high-value products. Regular maintenance becomes part of the package, enhancing the product performance and longevity. Maintaining a service history can quickly assess any potential re-manufacturing process at the end of the product lifecycle[53,54].

– Circular supply chains (C). Developing circular supply chain networks that prioritize the reuse and reintegration of materials, fostering collaboration among various stakeholders[55].

– Local resource networks (D). Establishing localized networks for sharing and exchanging materials and components, reducing the need for long-distance transportation, and minimizing associated environmental impacts[56].

– Product-as-a-service model (E). 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 end-of-life management[15,57].

Table 1. Re-manufacturing business statistics in Europe in 2015

	Aerospace	Automotive	Electrical/Electronic	Heavy-duty/Off-road	Machinery	Others*
Turnover (€bn)	12.4	7.4	3.1	0.4	1.0	5.4
Firms	1,000	2,363	2,502	37	513	688
Employment (x000)	71	43	28	4	6	42
Core (x000)	5,160	27,286	87,925	457	1,010	10,568
Intensity (% of total sector sales)	11.5%	1.1%	1.1%	1.4%	0.7%	6.1%

*Fashion, transport and consumable goods.

– Disown ownership (F). This approach involves changes in basic assumptions from traditional product ownership to offering products as services. Customers no longer buy products; instead, they purchase access to the product functionality. Ownership remains with the provider, and customers pay for the product availability and usage. Payment methods can include pay-per-use, pay-per-period, or pay-per-performance. This model encourages longer product lifetimes and reduces the demand for constant new purchases[15,58].

– Novel financing models and incentives (G). Launching regulatory mechanisms and financial incentives that encourage the implementation of circular practices in the construction process, such as benefits for customers in reusing materials or adopting circular design principles[59].

– Stable market demand (H). Working within stable technological cycles permits adopting cost-effective models with constant upstream and downstream flows[60]. This opportunity facilitates the management of multiple use cycles during their useful life before being discarded and recycled.

Conceptualizing organizational models for the tertiary building sector (OM1 - OM2 - OM3)

Leveraging existing knowledge and lessons learned from other sectors, the research outlined three organizational models designed to promote circularity in the fit-out of the tertiary sector.

Starting from the best practices in other industrial sectors where re-manufacturing is more mature and structured[18-50], these models were developed based on combinations of key features.

Considering the peculiarities of the tertiary architecture, the three proposed models combine the key features that, in the previous analysis of the other markets, enabled an intrinsic industrial competence for re-manufacturing, in which:

– A durable production is typically comprised of high-value and resistant components;
– The technology cycles of these products are longer than their use cycles, indicating stability;
– The availability of regeneration technology makes it possible to perform product re-manufacturing;
– Products leased or delivered “as a service” are preferred over those delivered “as hardware”.

The models outlined for the tertiary building sector and the corresponding alignment with the selected key features are detailed in Table 3[17]. Note that OM1, OM2, and OM3 have been developed on a regional scale since they have been outlined and assessed with the support of the stakeholders involved in the research that operates in the Lombardy region. However, they can be scaled to local, national, and international levels with necessary related adjustments.

Table 2. Key features selected in industrial sectors

Key features	Configurations	Aerospace	Automotive	Electrical/Electronic	Heavy-duty/Off-road	Machinery	Others*
A. Original product design	A1 Product designed for re-manufacturing	[21-23]	[24,25]		[38,39]		[47-49]
	A2 Product not designed for re-manufacturing		[26,27]	[28-33]		[40,41,44, 45]	
	A3 Product not designed for re-manufacturing but with facilitating features	[21-23]		[34,35]	[36,37]	[42,43,46]	[50]
B. Product procurement	B1 Surcharge-based mechanism		[26,27]		[38,39]	[42,43]	
	B2 Buy-back mechanism		[24,25]			[40,41]	
	B3 Direct-order mechanism			[28-31]	[36,37]	[44,45]	[48,49]
	B4 Service contract mechanism	[21-23]				[46]	
	B5 Leasing mechanism			[32-35]			[47-50]
C. Product collection	C1 Enabled by "collectors" activity		[24,25]	[30,31]		[42,43]	[47-49]
	C2 Performed autonomously by re-manufacturer	[21-23]		[32-35]	[36-39]	[40,41,44-46]	[48-50]
	C3 Hybrid solutions		[26,27]	[28-29]			
D. Re-manufacturing actors	D1 Original equipment re-manufacturer	[21-23]		[32-35]	[36-39]	[42,43]	[47-49]
	D2 Contracted re-manufacturer			[30,31]	[36,37]	[44-46]	[50]
	D3 Independent re-manufacturer		[24,25]	[28-29]			[48]
E. Product-service distribution	E1 With a partner intermediation		[26,27]			[40,41]	[47,48]
	E2 With a dealer intermediation		[24,25]	[30,31]		[42,43]	
	E3 Performed autonomously by re-manufacturers	[21-23]		[28-29]	[36-39]	[44-46]	[49,50]
F. Product ownership	F1 Ownership is transferred to the customer	[21-23]		[28-31]	[36,37]	[23-28]	[48,49]
	F2 Ownership is retained by the provider			[32-35]			[47-50]
	F3 Ownership is transferred to the customer with provider extended responsibilities		[24,27]		[38,39]	[46]	
G. Revenue system	G1 Traditional single payment		[24,25]	[28-31]	[36,37]	[44-46]	[48,49]
	G2 Deposit-based single payment (with surcharge)		[26,27]		[38,39]	[40-43]	
	G3 Performance payment (Pay-per-use, Pay-per-period)	[21-23]		[32-35]			[47-50]
H. Market destination and segment	H1 Same market destination and segment of the original product	[21-23]	[24,27]	[28-33]	[36-39]	[40,41,44-46]	[47-50]
	H2 Same market destination as the original	[21-23]	[24,27]	[34,35]		[42,43]	[49]
	I3 Different market destination from the original product			[34,35]			[49]

*Fashion, transport and consumable goods.

Table 3. Key features selected for conceptualizing the Organizational Models OM1, OM2, OM3

Key features	Configurations	OM1	OM2	OM3
A. Original product design	A1 Product designed for re-manufacturing	√	√	
	A2 Product not designed for re-manufacturing			
	A3 Product not designed for re-manufacturing but with facilitating features (e.g., modularity, standard dimensions)			√
B. Product procurement	B1 Surcharge-based mechanism			√
	B2 Buy-back mechanism			
	B3 Direct-order mechanism			
	B4 Service contract mechanism		√	
	B5 Leasing mechanism	√		
C. Product collection	C1 Enabled by “collectors” activity	√		√
	C2 Performed autonomously by re-manufacturer			
	C3 Hybrid solutions		√	
D. Re-manufacturing actors	D1 Original Equipment Re-manufacturer	√		
	D2 Contracted Re-manufacturer		√	
	D3 Independent Re-manufacturer			√
E. Product-service distribution	E1 With a partner intermediation	√	√	
	E2 With a dealer intermediation			√
	E3 Performed autonomously by re-manufacturers			
F. Product ownership	F1 Ownership is transferred to the customer			√
	F2 Ownership is retained by the provider	√	√	
	F3 Ownership is transferred to the customer with provider extended responsibilities			
G. Revenue system	G1 Traditional single payment	√		
	G2 Deposit-based single payment (with surcharge)			√
	G3 Performance payment (Pay-per-use, Pay-per-period)		√	
H. Market destination and segment	H1 Same market destination and segment of the original product	√	√	
	H2 Same market destination as the original			√
	H3 Different market destination from the original product			√

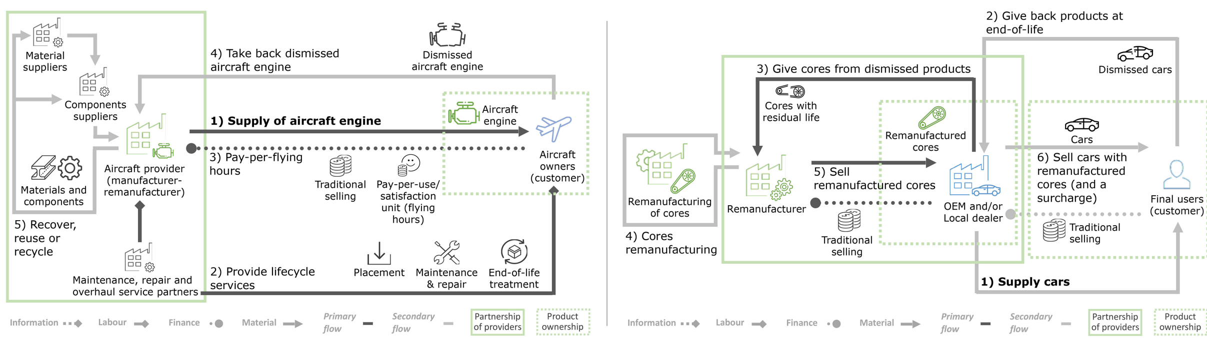

Figure 2. System maps of aerospace and automotive case studies[20].

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[17]. These items would be returned at the end of their service life 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, enabling products to undergo multiple usage cycles through re-manufacturing [Figure 5].

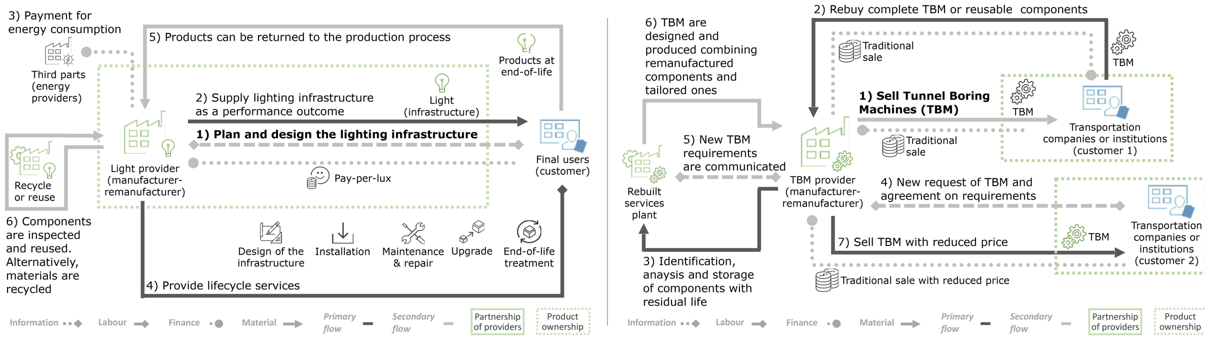

Figure 3. System maps of electrical and heavy-duty case studies[20].

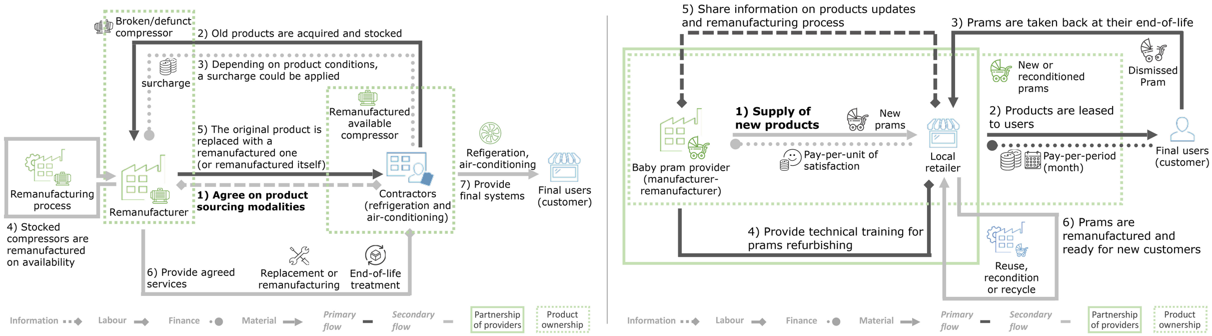

Figure 4. System maps of HVAC and baby pram case studies[20]. HVAC: Heating, ventilation, and air conditioning.

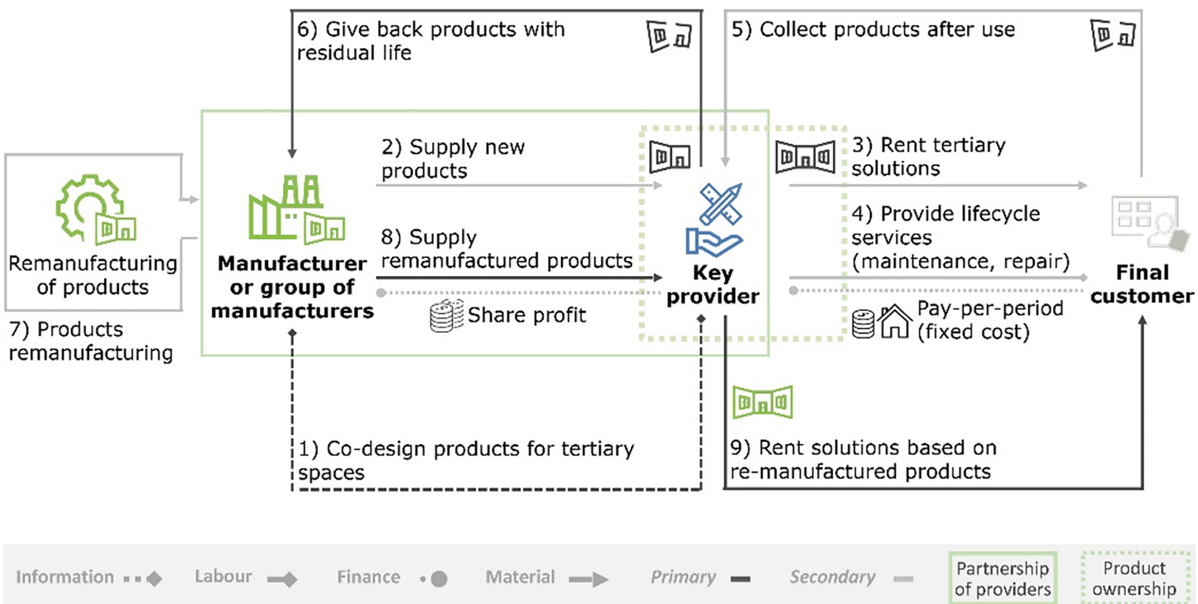

Figure 5. Rent contract as support for re-manufacturing - organizational model[61].

This model encourages manufacturers to design for durability and disassembly and motivates clients and investors to prioritize sustainable materials. In this model, the original manufacturer collaborates with a provider to design and create products 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 used again, promoting sustainability and reducing waste.

Compared to current organizational models based on the ownership and responsibility of customers for product waste, the OM1 model encourages manufacturers and providers to prioritize the fabrication and distribution of products with long durability and simple maintainability. This approach aims to extend the product usability and enable multiple usage cycles before they end their useful life. Retaining embedded resources within products and facilitating 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[61].

The OM1 model is mainly established for temporary construction assets, especially the market of high-value products such as interior furnishings and building systems, such as lighting. However, in recent years, it has also expanded to certain architectural technologies, such as mobile partitions and reversible flooring, to provide space flexibility and the cost-effectiveness of solutions distinguished by short usage but with high residual performance.

The second organizational model involves an all-inclusive solution to support re-manufacturing. In this model, the product and a set of life-extension services performed during its use phase are sold. The customer pays for the product and the services to extend its usability. These services include periodic checking and cleaning assistance, repair, maintenance, replacement, and re-manufacturing[17].

This model is built on a strong collaboration between two parties - the product supplier (provider) and the service supplier specializing in re-manufacturing (re-manufacturer). The provider is responsible for supplying the product to the customer, while the re-manufacturer provides continuous services related to maintaining and extending the product life [Figure 6].

This collaboration benefits both the provider and the re-manufacturer (win-win partnership). The provider can offer all-inclusive solutions to customers by leveraging the technical knowledge of re-manufacturers about the commercialized products. The re-manufacturer, in turn, benefits from the marketing connections and product commercialization efforts of the provider to attract more customers.

The second model has a different strategy for extending the life of the product compared to the first model. The first model focuses on enabling multiple reuse cycles of the same product by various customers, whereas the second model aims to extend the initial product use cycle by fostering long-term relationships with the same user. This approach is often referred to as the “loyalty strategy”[21], and it aligns the duration of product use with its useful life, thereby reducing the waste of residual performance.

The loyalty strategy aims to create sustainable and mutually beneficial long-term agreements between the supply side (provider and re-manufacturer) and the market demand (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. Contrary to current trends, it aligns with sustainability goals by reducing the need for premature product disposal. Moreover, promoting extended use and efficient life-extension services enhances customer satisfaction and loyalty[62].

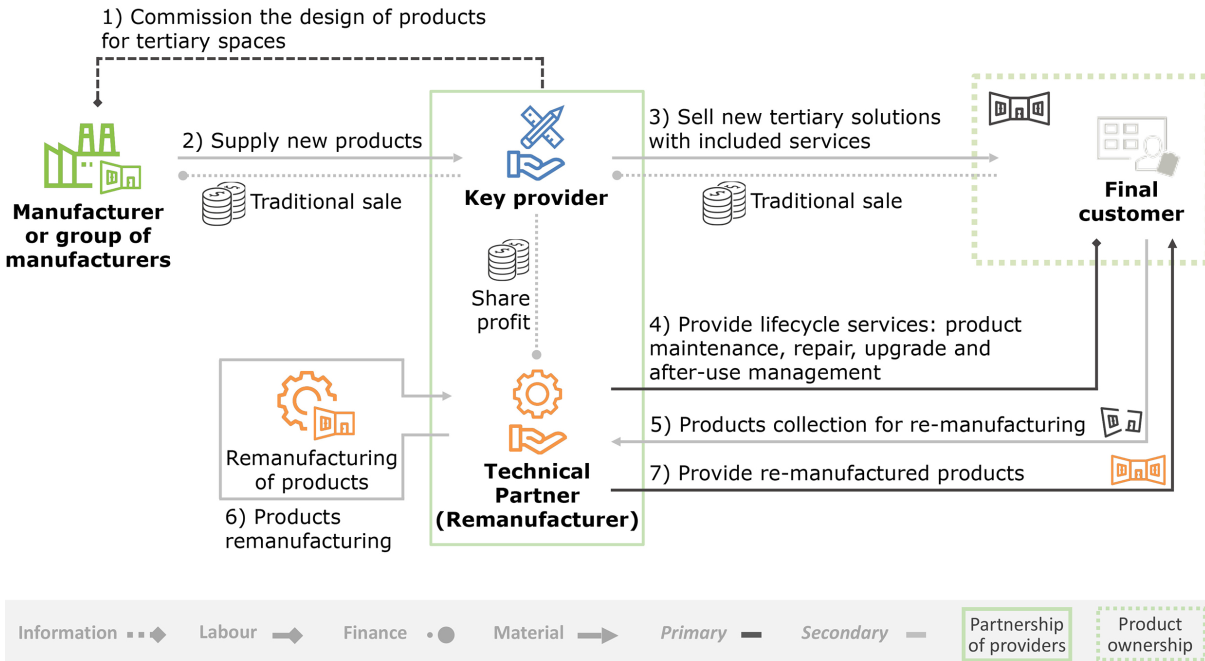

Figure 6. All-inclusive solution to support re-manufacturing - organizational model[62].

The OM2 model is currently implemented in the exhibition market. Many setup providers experience minimal client turnover, with most of them participating in a set of annual fair events for several years. This scenario allows to establish and enhance collaboration between the parties by signing long-term contracts. Here, by involving various stakeholders (encompassing design, production, and re-manufacturing), construction solutions are offered to be flexible enough to be adapted to multiple locations and supported by integrated package services.

The last model explores the creation of alternative or secondary markets specifically for re-manufactured construction products. The model focuses on two primary strategies: product reuse in secondary markets and product repurposing for different markets[17]. This involves taking products used in the primary market, reworking or repurposing them, and then selling them in secondary or different markets [Figure 7].

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 conducting the necessary operations to recover post-use products and prepare them for their subsequent use cycle. The dealer acts as an intermediary in the market, distributing the regenerated products to the 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, which is currently present on the market only in specific conditions (e.g., in case of no-profit activities), requires strong collaborative coordination between the re-manufacturer, the dealer, and 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 a deposit-based payment and the use of re-manufactured products[63].

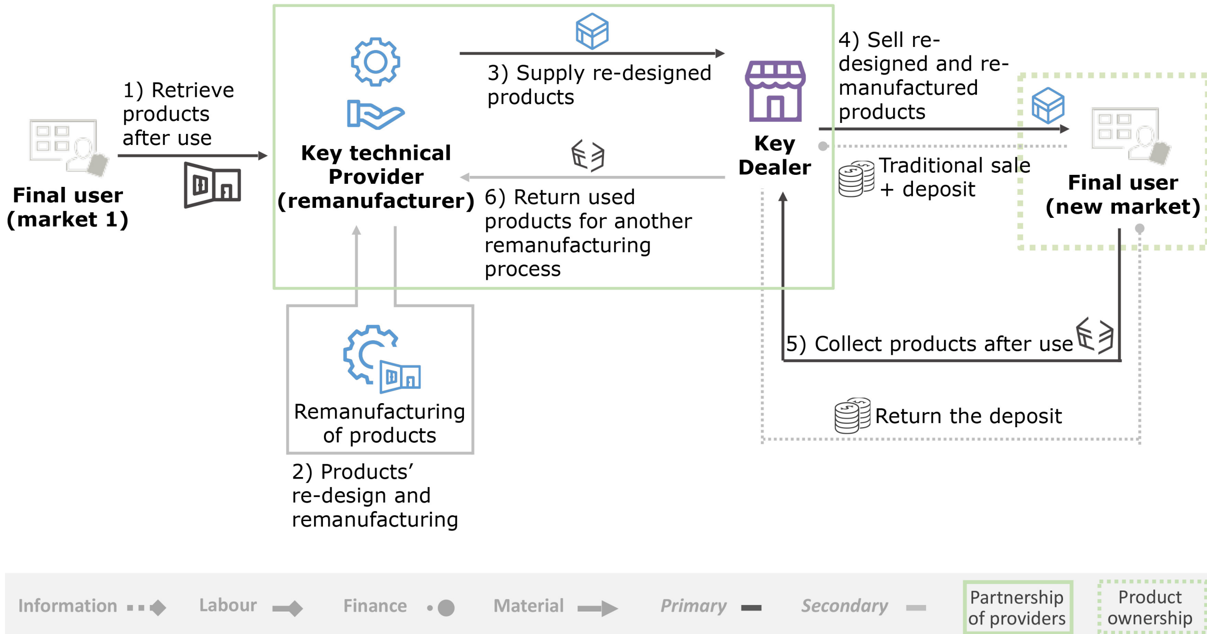

Figure 7. Alternative/secondary markets for re-manufactured products - organizational model[63].

The OM3 model is experienced in secondary construction markets, also known as second-hand or resale markets, through joint and, as appropriate, community-driven initiatives that facilitate the exchange or donation of construction products among individuals, builders, and organizations. The buying and selling of previously owned goods and assets (after their initial sale in the primary market) is fundamental for extending the product lifecycle, reducing waste, and providing economic opportunities.

Engaging stakeholders in refining the circular organizational models

This paragraph outlines the perspectives and opinions of various stakeholders from the diverse tertiary market fields. Through collaboration, they could identify opportunities for activating new circular organizational models and strategies[64]. Key points discussed during debates and roundtables can be summarized as follows:

– Identifying barriers. The participants produced effective solutions by identifying the obstacles that delay the adoption of circular organizational models and understanding and acknowledging these challenges. These barriers include a lack of awareness, policy and regulatory challenges, financial constraints, and technological limitations.

– Sharing expertise. Each stakeholder brings unique expertise to the table. During debates and roundtables, 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 industry could find applications in the residential sector. This cross-sector collaboration opens new markets and 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 in introducing supportive measures.

– Investment opportunities. Investors seek sustainable and socially responsible projects to find opportunities in circular economy initiatives. The collaboration should explore investment avenues and financial incentives to encourage circular economy projects.

– 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/re-manufacturing, 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 helps 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, re-manufactured, and recycled, reducing the need for new resource extraction. Specificities also emerged concerning the individual application areas, i.e., offices, retail, and exhibitions.

Office sector

During the discussion, stakeholders from various backgrounds within the office building sector shared their perspectives. They confirmed that workspaces are restyled every 2-3 years to maintain marketing and rebranding efforts, even though systems and building products such as movable walls, furniture, and dry assembled interior fittings have a performance duration of 10-15 years. Recent sector studies have shown that strip-out works during office refurbishment produce 63 tons of material per 1,000 m[265]. The primary materials include plasterboard, carpet, ceiling tiles, glass, metals, and furniture.

The main concerns highlighted by the selected representative interlocutors deal with the technological and logistic barriers. The existing supply chain network is perceived as 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 logistics network.

Stakeholders collectively view the current supply chain network as insufficiently prepared to embrace circular practices. This network is still not mature enough to replace current industrial practices with circular ones for designing the fit-out of offices due to issues linked to economic viability and logistic challenges. Economic considerations and the absence of a robust planning and production network hinder the viability of circular practices for existing players. These barriers can prevent the transition from a linear supply chain to a closed-loop one.

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.

In order to tackle the challenges faced, everyone involved has agreed that introducing a new entity into the supply chain could help encourage the adoption of circular practices. The current commercial players and manufacturers do not possess the necessary knowledge and skills required for regenerating products. The proposed new entity should present a driven business proposal for circular solutions and establish a well-organized reverse supply chain to ensure that the approach is cost-effective and widely adopted.

Another critical element for successfully implementing circular practices is establishing a strong and coordinated reverse supply chain. This would facilitate cost-effective practices and the widespread adoption of circular solutions in the industry. Shifting from traditional linear practices to circular ones might entail initial costs and uncertainties that deter stakeholders.

Finally, the existing regulatory framework for the Italian office building sector is stringent and crucial in determining the market capability of products. Safety-related issues and structural characteristics are of paramount importance in evaluating product quality. Reused products present a problem of lack of certifications; therefore, the designer or manufacturer must assume responsibility for the performance of the reused product. 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 critical challenges in adopting 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, new operators with re-manufacturing expertise, and the establishment of a robust reverse supply chain[61-63].

The success of stakeholder engagement concerned not only identifying barriers and drivers for the application of circular organizational models in the office sector but also creating a new active network of operators interested in circularity. 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 were sent to landfills. The network collected the products that were still in good condition (diverting them from landfills) to reuse, repurpose, re-manufacture, and put them back on alternative/secondary markets.

Exhibition sector

Referring to the exhibition field, the stakeholders 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, specific relevant issues and insights emerged as improvements of the models about 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 entirely resolved and that other factors apart from the lifecycle of the rented components might contribute to the waste generation[11]. The waste generated in the retail sector includes assorted items such as customized furniture, internal partitions, coverings, and finishes. These may no longer be suitable for their original purpose but 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 primary 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 years, leading to a stable client base. The outfitters claim to have the necessary skills and competencies to meet the product quality standards of 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 the first use cycle. They explore secondary market networks, such as outlets, especially for medium- and high-end goods. The growth of e-commerce delivery has also expanded the market for these products to foreign customers.

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 re-manufacturing practices considering the time required for appropriate assembly, use, and demounting. Another challenge arises in the case of highly personalized products for specific customers, making it difficult to reuse them for others and extend their lifespan. Overcoming this challenge requires balancing modularity and customization during the detailed design phases.

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 must be addressed to fully leverage the model potential for sustainable and circular practices[61-63].

In this context, discussions with stakeholders revealed the potential to develop highly reversible products that facilitate disassembly briefly, avoid damaging the product, and enable quality reuse and re-manufacturing.

In this case, the successful stakeholder engagement concerned the experimentation of reversible solutions for the exhibition's wall systems. An industrial partner shared materials and knowledge to develop reversible solutions and activate product re-manufacturing activities.

Retail sector

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

Considering the frequent retail strip-outs, the research identified potential secondary markets for re-manufactured products, such as residential buildings, hotels, and low-cost retail shops. However, any re-manufacturing chain involving 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 is available throughout its useful life is essential for future reuse. However, monitoring product conditions is resource-intensive and currently not widely practiced in retail, characterized by fast obsolescence and frequent substitutions of products.

Lastly, 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 associated with a brand. In particular, branded products are not always easily accessible to customers in the same area, and branded products cannot be used in other markets or sectors. Hence, reusing these products as they are might not be possible, for which a re-manufacturing intervention toward future reuses that modify the image may be necessary to protect the originality of the brand. Repurposing is an increasingly popular strategy for practicing corporate social responsibility in the retail industry.

To address challenges, the proposal of closed-loop value chain models, with the owner having control 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 may face performance assessment and certification challenges when re-manufacturing products whose initial ownership is outside their control.

Another opportunity - currently implemented within the social policies of a few fashion brands - is delivering end-of-life products to alternative or secondary markets. Retailers that offer low-cost products, such as outlets or secondary shops, can provide an additional way 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 interviews with stakeholders 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[61-63].

CONCLUSION

The research started 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 building materials should be seen as potential resources that can be reclaimed and reused when the building ends its life[66]. Encouraging industries and customers of the tertiary sector to take responsibility for the end-of-life phase of their products needs to overcome the traditional organizational models based on “take-make-dispose” of materials, e.g., for the CAT-B office delivery. However, as evidenced by the investigated fields of offices, exhibitions, and retail, the practice of the three organizational models for circularity encounters a set of both positive aspects (leverages) and obstacles (barriers) to be aware of and bear in mind.

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

– Long-lasting business partnerships. In the industry of exhibition fitting, the relationship between outfitters and clients is built on a long-term basis, leading to lasting business partnerships. This fosters customer loyalty and enables virtuous circular practices such as using products multiple times and activating reverse supply chains between customers and outfitters or partnered re-manufacturers. As a result, it promotes sustainable business practices and benefits both parties involved.

– Product ownership and closed-loop supply chain. In sectors such as exhibitions, where the provider usually keeps the ownership of the product, a closed supply chain can enable greater control over the flow of materials and products. This level of control can be advantageous for implementing circular practices.

– Market dynamics and trends. After the pandemic, office building designs are being revised, leading to a rethinking of the entire office workspace. This presents an opportunity to start circularity practices, pursue flexibility in using multifunctional spaces, and 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 a percentage of products with contents of recycled materials or reused/re-manufactured systems and equipment; on the other side, requiring solutions and products designed for disassembly and re-manufacturing following critical indicators of circularity.

– Repurposing strategies. Stakeholders of the retail sector are already implementing repurposing strategies as part of their corporate social responsibility practices. The goal of these projects is to create new markets for products with low residual economic value, gain relevance in large-scale organizations prioritizing sustainability-related activities, and have sufficient resources to allocate to such initiatives.

Nevertheless, barriers must still be addressed and overcome, presenting essential challenges for future research and innovation outlined 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 the efficiency and cost-effectiveness of circular practices, while excessive 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. Usually, manufacturers prioritize cost-effectiveness, which can limit the exploration of alternative, more circular solutions.

– Tight timetables. In the exhibition sector, limited time frames often prevent proper disassembly and recovery of products, which hinders circular activities relying on accurate demounting.

– Material flow volume. Material flows coming from maintenance, restoration, and demounting processes may be insufficient to justify new industrial processes, and it is challenging to predict quantities and product types in a medium-long time.

– Economic disadvantage. Re-manufactured products must demonstrate economic advantages over new ones, as they may obtain market acceptance if they are competitive in quality or price. At present, it is difficult to predict the costs of re-manufacturing owing to uncertain and case-by-case conditions.

To conclude, among numerous factors, the economic and environmental aspects are highlighted as significant drivers for adopting circular practices. The feedback from stakeholders emphasizes the importance of retaining the economic value and the material resources in recovered products, which can stimulate the adoption of circular supply chains. In parallel, new regulations may be needed to address aspects such as ownership, responsibilities, and certification of re-manufactured products, as happens in setting the technical feasibilities that control the Design for Disassembly[67]. Furthermore, to support the shift toward reuse and re-manufacturing, traceability systems are called to be implemented and integrated into the construction chain to acquire detailed knowledge of the original characteristics and subsequent process operations of the product during the life cycle.

DECLARATIONS

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Investigation, data analysis and interpretation, draft preparation: Viscuso S, Atta N, Dalla Valle A, Giorgi S
Supervision: Talamo C, Lavagna M

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Conflicts of interest

All authors declared that there are no conflicts of interest.

Ethical approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

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