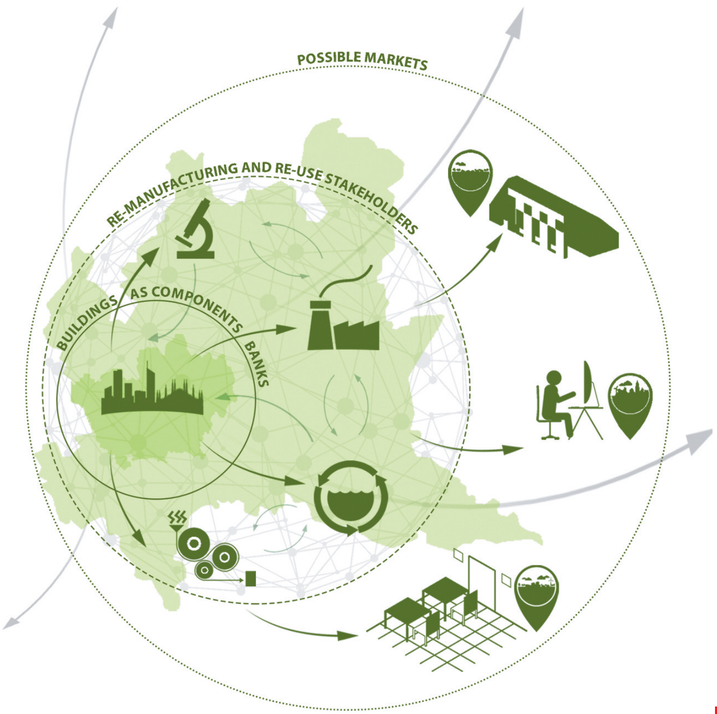
Re-manufacturing networks for tertiary architectures

Innovative organizational models towards circularity

edited by Cinzia Maria Luisa Talamo



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

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Part III – Insights

Introduction

This book deals with re-manufacturing, recondition, reuse and repurpose considered as winning strategies for boosting regenerative circular economy in the building sector.

The book presents many of the outcomes of the research "Re-NetTA (Re-manufacturing Networks for Tertiary Architectures). New organisational models and tools for re-manufacturing and re-using short life components coming from tertiary buildings renewal". The research was funded in Italy by Fondazione Cariplo for the period 2019-2021 and developed by a multidisciplinary group composed of all the authors present in this publication.

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

The building sector is a fundamental lever for the activation of circular economy. European Commission identifies the construction sector as a "Priority area" involved in specific challenges in the context of circular economy: according to the Eurostat statistical data in EU-28 the main field that produces waste is construction sector, contributing to 33.5% of the total waste generated by all economic activities and households in 2014. Besides, the construction sector is an important driver for circular economy as it provides, according to European Commission data, 18 million direct jobs and contributes to about 9% of the EU GDP. The application of new circular economy strategies can create new jobs, social benefit, energy and resource efficiency and a sustainable environment.

Currently, the circular strategy more promoted in the built environment is recycling. Most of European Projects (e.g. HISER PROJECT, Resource Efficient Use of Mixed Waste, DEMOCLES, ENCORT) and particularly Life Project investigate on recycling (inter-sectoral or within the construction sector) of construction and demolition waste and deal with specific recycling topics (e.g. LIFE-PSLOOP Polystyrene Loop; CDW recycling Innovative solution for the separation of construction and demolition waste). Often recycling implies the downcycling and requests complex and energy-consuming processes. On the contrary, if well-organized, re-manufacturing and reuse require very simple and low-impacting processes, reduce the generation of waste and maintain over time the value of the resources embodied in manufactured products – once they are removed from the buildings – by extending their useful life and their usability with the lowest possible consumption of other materials and energy and with the maximum containment of emissions in the environment.

In the perspective of circular economy, the focus of this book on tertiary buildings derives from some considerations:

- cities all over the world are characterized by high quantities of tertiary buildings with various destinations (public and private offices, accommodation facilities, retail, exhibition facilities, temporary shops, etc.);
- there is an increasing stock of unused, often obsolete, tertiary buildings, especially after the pandemic;
- tertiary buildings are more and more characterized by quick cycles of renewal and reconfiguration of interior spaces following a series of phenomena that determine a fast functional obsolescence and frequent reshaping such as: recent approaches that shift attention to the use of buildings in terms of service (such as hoteling, leasing, co-working, smart working and various declinations of sharing) determining a high degree of temporary use; shortening of leases; transformations in the Real Estate market; transformations in the models of commerce;
- this kind of buildings generate significant quantities of disused elements and systems that become waste if not reused or remanufactured. These products (in particular interiors, services, equipment and furnishings) have usually a high degree of residual performances and are characterized by being dry assembled (therefore easy to disassemble), composed of high-value raw materials, generally equipped with manufacturer technical datasheets (therefore easily traceable) and, besides, by having a high added value.

This book investigates the most promising strategies and organisational models to maintain over time the value of the environmental and economic resources integrated into manufactured products, once they have been removed from buildings. Some novel concepts for the construction sector should be introduced:

- the integrated "re-actions" (re-manufacturing, re-condition, re-purpose, reuse, repair) as strategies for keeping building products and their embodied materials in use for longer time with significant decrease of waste, energy and water use and emissions through the reduction of manufacturing activities;
- the building as "components bank". The building is no longer meant as the last destination of industrial products, but as a node within circular processes;
- "planned obsolescence" as a proactive strategy for addressing and optimizing the "re-actions";
- decommissioned building products meant not as waste but as "bought and sell" items available for purchase from catalogues or other sources;
- "reverse supply chains" that is the delivery of goods (decommissioned elements) from the owners to the reuse or remanufacture operators.

These new concepts are connected with various possible approaches, innovative for the construction sector:

- from product to service, i.e. overcoming the purchase of building elements towards "pay per use" approaches which assume the presence of an operator who supplies products for defined periods and uses and who withdraws them and re-introduces them into the use network, possibly after re-manufacturing, repair, etc.;
- "disown ownership", possibly with forms of peer to peer market, which assume the presence of networks that facilitate the sharing, renting or leasing and exchanging of products that can be remanufactured and repaired over time;
- lengthening of the life cycle of products through services, with low or zero consumption of materials and energy, based on the scheduled monitoring and updating (re-manufacturing, recondition, repair). These services may be integrated within FM (Facility Management) services related to space and maintenance management;
- assessing the reduction of impacts and the consumption of resources from the point of view of environmental (LCA), economic (LCC) and social (SLCA) sustainability in order to evaluate the effectiveness of circular economy strategies based on re-manufacturing and reuse processes.

By assuming these concepts and approaches the book introduces some challenges to the existing paradigms:

– from the design of products, meant as “black boxes”, to the design of systems that can be divided into items, identified for the different durations and for the possibility of being disassembled, remanufactured, traced and reused once isolated;
– from the sale of a product (the building element) to the supply of a service, enhancing the “extended producer responsibility” and “shared responsibility” along the supply chain through the introduction of new re-manufacturing operators;
– from the ownership of an asset to the delivery of a service (for example renting and leasing models).

Also thanks to the hints that emerged from the intense dialogues and many roundtables involving various categories of stakeholders, conducted during the *Re-NetTA* research, the book intends to identify and analyse the most important berries to the development of effective re-manufacturing practices and the possible strategies to overcome them.

The book is articulated into three parts and 15 chapters.

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

Chapter 1 deals with the relationships between circular economy and building sector, proposing tertiary architectures as promising testing ground for assessing circular strategies.

Chapter 2 introduces and discusses a hierarchy of the possible “re-actions” for circularity, each of one characterized by the return of a used product, trying to highlight the fundamentals and the basic conditions for propagating re-manufacturing, recondition, reuse and repurpose.

Chapter 3 provides an overview of the most existing consolidated practices of re-manufacturing within different industries and highlights possible strategies and approaches to transfer to the building sector.

Part II PROMISING MODELS outlines, according to a proposed framework (Ch. 4), a set of promising circular organizational models to facilitate re-manufacturing practices and their application to the different categories of the tertiary sector: exhibition, office and retail. This part also reports the results of active dialogues and round-tables with several categories of operators, adopting a stakeholder perspective. The chapters 5,6,7 describe each of the three models and share the same structure: the description of the organizational model, cases and views from the

perspective of some key stakeholders in the field-sectors, the enabling and hindering elements.

Chapter 4 proposes three promising circular organizational models and discusses some key features useful for deepening them: *rent contract as a support for re-manufacturing*; a*ll-inclusive solution to support re-manufacturing; alternative/secondary markets for re-manufactured products.*

Chapter 5 introduces the rent contract, focusing on value chain key factors that enable circular practices. Representative case studies for the tertiary sectors are discussed.

Chapter 6 presents the characteristics of an innovative organizational model proposed for the tertiary architecture based on the integration of all-inclusive services with the goal of promoting re-manufacturing practices. The investigation is developed considering the exhibition, office and retail sectors.

Chapter 7 The chapter presents the characteristics of an innovative organizational model aimed at promoting circular dynamics through the setting of a supply chain that identifies alternative/secondary markets as potential destinations for reused, re-manufactured and repurposed products.

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

Topic A “Design for Re-manufacturing” investigates the relevance of original product design in the specific context of re-manufacturing in tertiary architecture, with a focus on design strategies and guidelines.

Chapter 8 focuses on the topic of design for re-manufacturing (DfRem), presenting a set of guidelines that can facilitate product re-manufacturing processes toward more circular and sustainable organizational models in specific contexts, with particular attention on the tertiary sector.

Chapter 9 deepens the subject of design for re-manufacturing and circular processes applied to the field of textile architectures.

Topic B “Digital Transformation” explores the possibility to apply digital technologies to re-manufacturing practices, highlighting possible solutions to streamline current activities and to exploit the novel availability of real-time information and advanced data management capabilities offered by Information and Communication Technologies (ICTs).

Chapter 10 investigates how digital technologies can support the transition to circular economy of tertiary building through the digital simulation of the disassembly and remanufacturing stages.

Chapter 11 discusses how some barriers to the spreading of re-manufacturing practices may be handle more effectively by means of the Information and Communication Technologies (ICTs), especially Internet of Things (IoT), highlighting the key role of information platforms towards stakeholder collaboration and co-operation.

Topic C "Environmental Sustainability" focuses on the environmental benefit of re-manufacturing practices, emphasizing the application of life cycle tools to support the sustainability assessment of circular practices, encouraging the materials flow monitoring and information exchange among stakeholders.

Chapter 12 focuses on the assessment of the environmental sustainability of building products derived by re-manufacturing organizational models, in order to support eco-innovative approaches for the development of long-term value and green products. In this context, the material flows associated with re-manufacturing process are mapped and analyzed in depth, providing a framework for the application of LCA to re-manufacturing processes and re-manufactured products.

Chapter 13 deals with the traceability tools (e.g. materials passports, pre-demolition audit, etc.) useful to keep information related to building components in their entire life cycle (from material extraction to the disassembly after use and the end of life).

Topic D "Stakeholder Management, Regulations & Policies" deals with the definition of regulations supporting the relationships between the stakeholders and of approaches to the management of the re-manufacturing supply chain, providing also value chain insights to foster circular processes in the building industry.

Chapter 14 introduces the Sustainable Product-Service Systems (S.PSS) discussing to which extent they can enable value chain opportunities for re-manufacturing practices in the context of tertiary architectures and focusing on the application of product-service based models attached to re-manufacturing activities in the tertiary architectures context.

Chapter 15 aims to provide an overview of the main aspects on novelty introduced by reuse and remanufacturing practices assuming as a sample the Italian regulatory framework of the building sector, in particular focusing on aspects related to negotiation (sale, donation and leasing), safety, environmental and waste management.

4. Organizational models for reuse and re-manufacturing in the building sector

by *Nazly Atta, Anna Dalla Valle, Serena Giorgi, Luca Macrì, Sara Ratti, Salvatore Viscuso*

4.1 The need of new organizational models to implement reuse and re-manufacturing within building sector

The increasing need for sustainable processes within manufacturing and construction sectors to mitigate the negative impacts on the environment and meet the needs of future generations led in the past decades to the development of circular strategies. Among these virtuous practices, down-cycling and recycling have been the most investigated with proven benefits especially in the industrial fields (Özer, 2012; Parker *et al*., 2015). However, despite their undeniable value, these practices turn out to have higher environmental impacts than other end-of-life strategies (Özer, 2012; Parker *et al*., 2015; Paterson *et al*., 2017; Talamo *et al*., 2021). Hence, going beyond down-cycling towards more sustainable practices, in the last few years the interest focused on re-manufacturing, meant as a process whereby used products, having reached the end of their use-life or useful-life, are restored for starting a second lifecycle (Gutowski *et al*., 2011). In particular, re-manufacturing is generally intended as the process that restore used products to the "like-new" functional state, by renovating and/or replacing components with minimum consumption of materials and energy (Gunasekara *et al*., 2018; Bernat, 2019; Cheng *et al*., 2021). In this way, re-manufacturing acts as a strategy for closing the loop between disposal and supply chains, extending the service lifespan of products, preserving embedded resources and limiting environmental impacts (Gutowski *et al*., 2011). Moreover, the "like-new" feature of re-manufacturing implies that re-manufactured products usually have a warranty at least equal to the original one (Ijomah, 2008), ensuring quality products with high performance (Parker *et al*., 2015; Özer, 2012; Paterson *et al*., 2017). Also due to these reasons, today re-manufacturing represents

a well-established practice in several sectors (Benoy *et al*., 2014), such as Aerospace, Automotive, Electronics, Machinery, Marine, Rail (USITC, 2012; Parker *et al*., 2015; Butzer and Schötz, 2016; Gunasekara *et al*., 2018) with proven economic and environmental benefits, as shown in the previous chapter (see Chapter 3). Indeed, these industrial sectors show an intrinsic aptitude for re-manufacturing, since characterized by:

- durable products, usually made up of high-value components;
- stable technology-cycles of products, longer than their use-cycles;
- available regeneration technology to perform product re-manufacturing;
- propensity of products to be leased or delivered "as a service" rather than "as a hardware" (Yang *et al*., 2018).

Also due to these features, within these sectors re-manufacturing represents a practice implemented not only as a circular strategy to carry out at the end of the useful life of a product, but also during the product service life, when both the performance and the economic value of the product are still significantly high and, therefore, when reprocessing activities are able to deliver a high-quality re-manufactured product with limited efforts (Ardente *et al*., 2018; D'Adamo and Rosa, 2016). For these benefits, in the recent past, industrial companies have consolidated re-manufacturing practices within their businesses, gaining added value and competitive advantages (Cao *et al*., 2020; Sundin *et al*., 2020; Golinska-Dawson *et al*., 2021). Alongside industrial operators, also the EU recognizes the value of re-manufacturing as a promising approach to close product loops, reducing waste and emissions (Boorsma *et al*., 2019) in several production fields, with particular reference to the construction sector (European Commission, 2020). In fact, according to the European Commission (2020), "Construction and Buildings" is a field that urgently requires widespread and coordinated actions towards circularity and sustainability (European Commission, 2020). As stated by the EU, the application of re-manufacturing strategies to the construction sector represents a shared priority at European level which must directly engage all member states (COM 2015/ 614; European Commission, 2020). Indeed, in the last two decades the contribution of the construction sector to greenhouse gas emissions counted as approximately the 40% of the totality of emissions on the global scale (Yan *et al*., 2010). Moreover, according to Eurostat (2016), the construction sector in past years generated more than a third of the total amount of waste produced by the totality of economic activities and households (Eurostat, 2016). This is mainly due to the "take-make-dispose" models that characterize the construction sector. Indeed, the latter mostly adopts linear models, which start with the extraction of raw materials from the environment – then processed into construction materials – and end with their disposal at the building end-of-life (Benachio *et al*., 2020; Elisha, 2020). This linearity can be attributed to different causes, including the following two:

- materials and products are assembled on the construction site, mostly employing wet construction technologies, hence embedded in ways that cannot be disassembled or deconstructed at the end of the building life. Therefore, the end of this linear process can only be the demolition of the building and the transfer to landfill of its components and materials that become waste to be disposed of. In this last stage of the building process, materials and components cannot be recognizable as functional entities – thus distinguishable potential resources – since they were assembled for a one-time use only and not to be reuse/reworked (Benachio *et al*., 2020);
- generally the lifespan of buildings is very long, exceeding 60 years (CSHub@MIT, 2016) and, therefore, it is difficult to envision it as a closed cycle. This idea of "long and durable" life of buildings, on the one hand, often implies corrective approaches to the management of building elements, leaving them to perform their functions until they are no longer able and only then performing interventions (e.g. punctual repairs and replacements of parts) to correct the occurred anomalies and degradations, without any strategic planning of preventive maintenance services. On the other hand, it hinders the spreading of "design for disassembly" and "design for re-manufacturing" practices which could support a "lifecyle-oriented" design, opting for components and systems that will be more easily removable / repairable / reusable / re-workable during the life cycle of the building, as well as at the end of its useful life.

By intervening in the early stages of the building process with appropriate strategies aimed at extending the useful life of products, lengthening their first lifecycle and/or guaranteeing over time multiple reiterated lifecycles, the generation of construction waste could be limited (COM 2015/614; European Commission, 2020) overcoming this linear view of the building process.

To achieve these objectives, Re-NetTA (Re-manufacturing Networks for Tertiary Architectures) project proposes new circular approaches in the construction sector, following a gradual approach according to some procedural steps:

1. identify which of the fields of the building sector is the most promising and characterize the related offer of products to be (potentially) re-manufactured (Par. 4.2);
2. define the paradigm shifts that have allowed other sectors to make the leap towards circular processes (Par. 4.3);
3. outline the key features of the circular models already in use in other sectors, adjusting them to the specificity of the construction sector, also with the support of stakeholders (Par. 4.4);
4. on the basis of the defined key features, develop new circular organizational models for the construction sector (Par. 4.5), to be tested and validated in the fields defined in point 1, with the support of stakeholders (see Chapters 5, 6, 7).

The support of stakeholders is concretized through a series of roundtables and focus groups, organized by sector (exhibition, office, retail). The stakeholder sample involved 27 interviewed actors and, in particular, 16 companies contributed significantly – through an active involvement within workshops and roundtables – to the development and evaluation of the organizational models.

The majority of the stakeholders belong to the reference geographical area of Re-NetTA project, i.e. Lombardy region, and they have been identified according to two alternative selection criteria:

- representativeness of the sector, i.e. relevance of the actor within the sector on the basis of market shares and turnover;
- level of innovation, originality and maturity of practices (compared to the traditional scenario).

The sample includes for-profit companies, third sector actors (i.e. cooperatives) and trade associations. As emerges from the following list, the roundtables and focus groups are organized by sector and according to the principle of complementarity of the stakeholder roles to cover the whole supply chain. Consequently, the subjects involved for the tertiary subsectors include:

- exhibition: designers, outfitters, manufacturers and sellers;
- office: renters, outfitters, manufacturers, general contractors, trade associations, maintainers;
- retail: sellers, designers, manufacturers, general contractors, third sector stakeholders in reverse logistics and manufacturing operations.

4.2 Tertiary architectures as promising field for re-manufacturing

In the context of the construction sector, re-manufacturing represents a regenerative circular process aimed at maintaining overtime the intrinsic economic and environmental value of products even when they are removed from buildings. To this end, re-manufacturing aims to extend the useful life and usability of products generating the least possible consumptions and emissions (Talamo *et al.*, 2019) and reducing the production of scraps and waste from maintenance, renewal and demolition interventions. In light of this premise, among the different building sectors, the tertiary field (including exhibition, retail, office, hosting, etc.) seems to be one of the most favourable for the start up of re-manufacturing practices since it is characterized by:

– short renewal times and frequent reconfigurations of interior spaces (OMI, 2017) that determine the accelerated obsolescence of equipments/interior fittings. Moreover, the recent approaches that envision the use of buildings in terms of service (such as hoteling, space-sharing, co-working, smart working, etc.) imply a high degree of temporariness in product use patterns as well as the shortening of lease contracts;
– availability of significant quantities of disused components (e.g. interiors, equipments and furnishings) with high residual performance (Rose and Stegemann, 2018). These components, typically developed for tertiary buildings, are usually characterized by being composed of high-value raw materials, being dry assembled (therefore easily to disassemble) and having a high added value.

As a promising strategy characterized by processes that use less energy and materials than recycling, re-manufacturing has the potential to avoid the transformation of this kind of components into waste. Hence, presenting key outcomes of Re-NetTA project, the following paragraph introduces the main paradigm shifts towards circularity in the field of tertiary architectures and, starting by the definition of a set of key features able to describe circular models, it sets the stage for the proposal of new organizational models for building product life extension based on re-manufacturing.

4.3 Paradigm shifts towards circularity in the building sector

The analysis of re-manufacturing best practices from the different industrial sectors (see Chapter 3) leads to the identification of some recurring innovative approaches aimed at extending the useful life of products.

These approaches can promote the development of new organizational models within the tertiary architecture field, shaping new win-win relationships among stakeholders, laying the foundations for the development of virtuous circular practices.

In particular, the first approach follows the logic of the "disown ownership" (Dalla Valle *et al.*, 2021), implying a paradigm shift towards practices oriented to the offer of products "as a service" instead of the sale. According to this new approach, the ownership of products is retained by the provider and not transferred to the customer as in the case of sales. Hence, the customer is no longer the buyer of a physical good but it becomes the purchaser of a service. From being the "owner" of a product, the customer becomes the "user" of it, paying for the "availability to use" of the product itself. Consequently, also the payment method switches from a single-payment to new formulas based on pay-per-use, pay-per-period or pay-per-performance systems (Bocken *et al.*, 2018; Sousa-Zomer *et al.*, 2018).

The second approach refers to the concept of "servitization", namely the transition from the pure sale of a product to the sale of a "product plus service" solution that actually gives rise to a long-lasting relationship between customer and supplier, transforming the transaction into a system capable of selling together with the product also a set of value services integrated into the product itself. In this regard, it is important to highlight that services are not simply an addition to the sale of a product, but they become a central element of the offer itself, contributing to extend the product useful life and allowing the customer to always have a high-performing product (Della Mura, 2020). In this case, ordinary maintenance becomes part of the range of offered services, as part of the product useful-life extension strategies. Furthermore, in this regard, by tracing and keeping a history of the interventions undergone by the product, at the end of the service-life the re-manufacturer will be able to evaluate the residual performance and the re-manufacturing potential of the product.

The third approach is based on the concept of industrial symbiosis, identifying new business opportunities by exploiting cross- and intersectoral synergies following the logic of "waste-resource" (Talamo and Migliore, 2017). Industrial symbiosis gathers traditionally-separate industries in a collective and cooperative approach, aimed at gaining competitive advantage, that involves the exchange of materials and products between industries even belonging to different sectors. This approach is grounded on the concept of "network", hence on the collaboration between operators in order to exploit synergistic possibilities in a waste-resource perspective. Accordingly, the waste of one sector becomes a resource for another, creating long-term synergistic interconnections able to optimize the management of resources.

The fourth approach focuses on the product design, shifting the attention upstream of the process by proposing "design for re-manufacturing" strategies, aimed at facilitating the re-manufacturing process by product design so that disassembly, cleaning, reprocessing and reassembly activities are facilitated during the product lifespan. According to these strategies, in order to guarantee a greater propensity for reworking and high durability of the products, it is necessary to opt for design solutions oriented towards modularity, ease to dis/assembly and ease to find spare parts on the market.

4.4 Key features of circular processes

On the basis of the introduced paradigm shifts, an interpretative framework able to describe circular models (Tab. 4.1) is proposed. The framework consists of nine key features (described below), further articulated into multiple possible configurations. The key features are here intended as a set of key elements that characterize circular organizational models based on re-manufacturing practices. Following the business process, they are: original product design; product procurement; product collection; re-manufacturing actors; re-manufactured product design; product-service distribution; product ownership; revenue system; market destination and segment.

Tab. 4.1 - Key features of circular models based on re-manufacturing

Key features		Possible configurations	
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	Re-manufactured product design	E1	Product re-designed for re-manufacturing
		E2	Product not re-designed for re-manufacturing but with facilitating features
		E3	Product not re-designed for re-manufacturing
F	Product-service distribution	F1	With a partner intermediation
		F2	With a dealer intermediation
		F3	Performed autonomously by re-manufacturers
G	Product ownership	G1	Ownership is transferred to the customer
		G2	Ownership is retained by the provider
		G3	Ownership is transferred to the customer with provider's extended responsibilities
H	Revenue system	H1	Traditional single payment
		H2	Deposit-based single payment (with surcharge)
		H3	Performance payment (e.g. Pay-per-use/-period, etc.)
I	Market destination and segment	I1	Same market destination and segment of the original product
		I2	Same market destination of the original product but different market segment
		I3	Different market destination from original product

Tab. 4.1 - continued

Source: Adapted from Dalla Valle *et al.*, 2021

In particular, the aim of the proposed framework is twofold (Dalla Valle *et al.*, 2021). On one side, already-existing organizational models can be represented and described as combinations of the proposed key features; while on the other side, the proposed framework opens up opportunities for outlining innovative circular models based on re-manufacturing, starting from novel combinations of the proposed key features configurations (Tab. 4.1).

The proposed key features – and related configurations – are below described in detail following the business flow, from product design to time-to-market.

A. *Original Product Design*

This key element refers to the design features of the original product and its propensity to receive rework and partial replacements over time. In this stage, as highlighted in Chapter 3, one of the main strategy for circularity is represented by "Design for Re-manufacturing" (DfRem) (Prendeville and Bocken, 2017; Hazir and Sundin, 2020). Following this strategy, the re-manufacturing interventions performed at the end of the first product use-cycle are favored thanks to upstream choices related to the development and design of the original product (e.g. dis/assemblability, modularity, spare pat availability, etc.) (Yang *et al.*, 2015, Hatcher and Ijomah, 2011, Abuzied *et al.*, 2020). Focusing on the Original Product Design, Tab. 4.2 describes the three different options of the key feature configuration.

Tab. 4.2 - Original Product Design – possible configurations

A. Original product design		
A1	Product designed for re-manufacturing	Products are intentionally and specifically designed according to criteria and characteristics that are able to facilitate the future product re-manufacturing after the first use cycle (e.g. facilitated disassembly, interchangeable components, modular structures, durable materials, etc.).
A2	Product not designed for re-manufacturing but with facilitating features	Re-manufacturing is facilitated by some component features that – although not intentionally designed for re-manufacturing – are able to facilitate some steps of the re-manufacturing process (e.g. standard dimensions, availability of spare parts on the market, dry assembly, etc.).
A3	Product not designed for re-manufacturing	Original products not intentionally designed to be re-manufactured and they do not own design features that are able to facilitate re-manufacturing interventions.

B. *Product Procurement*

This feature focuses on the strategies to secure the procurement of physical cores to be re-manufactured. The strategies to procure products to be re-manufactured (Tab. 4.3) are mainly based on the "reverse supply chain" logic as key trigger of circular business models, promoting contractual mechanisms between re-manufacturer and product-holder oriented to grant or promote the return of cores after use.

Tab. 4.3 - Product Procurement – possible configurations

B. Product procurement		
B1	Surcharge-based mechanism	At the sale the customer pays a surcharge that will be fully paid back at the return of the sold product at the end of its use.
B2	Buy-back mechanism	The customer receives an economic incentive for the return of the used product at the end of its utilization.
B3	Direct-order mechanism	The re-manufacturing operation is activated by a direct order for a substitution of the used product with a re-manufactured one that guarantees the same or an upgraded performance compared to the old one.
B4	Service contract mechanism	The customer pays for a product&service solutions, including re-manufacturing activities, setting the stage for the return of cores, thus easing the circular practice.
B5	Leasing-based contracts	By maintaining the product ownership in provider hands, a leasing scheme obliges the return of the product from the customer, thus enabling circular offerings.

C. *Product Collection*

The key feature focuses on the actors and modalities of the physical collection of materials/products to be re-manufactured. Compared to a linear model, the management of the retrieval of post-use product represents an additional activity to implement, that can either trigger or undermine the feasibility and the economic sustainability of a circular business opportunity (Prendeville and Bocken, 2017). Tab. 4.4 clustered the possible product-retrieval configurations in three macro-categories, based on the level of responsibility of the re-manufacturer within the logistics management of cores to be re-manufactured.

Tab. 4.4 - Product Collection – possible configurations

C. Product collection		
C1	Enabled by "collectors" activity	The post-use products are retrieved by "collectors", namely logistics operators acting as reference points for picking and stocking specific post-use goods, thus easing the possibility for re-manufacturing firms to get the cores.
C2	Performed autonomously by re-manufacturer	Where the market proximity and the logistics infrastructure are present, the re-manufacturer can manage autonomously the physical retrieval of cores.
C3	Hybrid solutions	The core collection is jointly managed by the re-manufacturer and the dealers, i.e. intermediate points between production and end-market, representing collection points for customers that return post-use products and for re-manufacturers that obtain the cores for re-manufacturing processes.

D. *Re-manufacturing actors*

It refers to the types and roles of the actors that perform re-manufacturing on products, studied based on the relationship with the original equipment manufacturers (Östlin *et al.*, 2008; Duberg *et al.*, 2020). These roles are defined in Tab. 4.5 according to three types of re-manufacturer.

Tab. 4.5 - Re-manufacturing actors – possible configurations

D. Re-manufacturing actors		
D1	Original Equipment Re-manufacturer	Original Equipment Re-manufacturer (OER) is represented by a firm responsible for re-manufacturing its own manufactured product, exploiting potential manufacturing processes, existing market share and resource synergies.
D2	Contracted Re-manufacturer	Contracted re-manufacturer is represented by a firm responsible for re-manufacturing activity and bound by contract with the original equipment manufacturer.
D3	Independent Re-manufacturer	In this case the independent re-manufacturer is a firm with little or no contact with the original equipment manufacturer. Factors like proximity to the market and resources and skills linked to re-manufacturing processes are strategic for contracted and independent re-manufacturing businesses.

E. *Re-manufactured product design*

This key feature refers to the implementation of the strategy of Design for Re-manufacturing (DfRem) within the re-work interventions on post-use products (Tab. 4.6). Regardless of the original design, new design solutions for the re-manufactured products can be introduced in order to positively affect their successive performances.

Tab. 4.6 - Re-manufactured product design – possible configurations

E. Re-manufactured product design		
E1	Product re-designed for re-manufacturing	Specific design choices are implemented within the re-manufacturing process in order to facilitate future re-manufacturing interventions.
E2	Product not re-designed for re-manufacturing but with facilitating features	The re-manufacturing process introduces new features to the product that are not directly facilitating successive re-manufacturing practices but that are able to ease some steps of the process.
E3	Product not re-designed for re-manufacturing	The interventions carried out through the re-manufacturing process are not aimed at introducing features to ease future re-interventions, but simply to restore the product performance according to market requirements and opportunities.

F. *Product-service distribution*

This key feature focuses on the structure of the network aimed at distributing re-manufactured products and services on the market. The way in which products and/or services are delivered to the customers represents a key aspect that characterizes downstream choices to reach the final market. Tab. 4.7 proposes different product distribution configurations.

Tab. 4.7 - Product-service distribution – possible configurations

F. Product-service distribution		
F1	With a partner intermediation	The re-manufacturer works in direct relationship with an external partner that not only supports the delivery of re-manufactured products to the final market but it also collaborates with the re-manufacturer to offer product-related services to customers throughout the whole product use-cycle.
F2	With a dealer intermediation	The re-manufacturer relies on a commercial third-party, acting as an intermediation for the delivery of re-manufactured products to the final market. This solution is used in case of lack of final market proximity.
F3	Performed autonomously by re-manufacturers	The re-manufacturer can directly access to the final market through an internalized distribution system. Hence, the re-manufacturer manages the delivery of re-manufactured products and related use-cycle services with its own capabilities.

G. *Product ownership*

This feature deals with the "right of property" on the re-manufactured products after they have been delivered to the customer. Surveying the sample of best practices (see Chapter 3), it emerges the presence of multiple transaction types that determine different rights of ownership over the re-manufactured product. From the different alternatives of product ownership transfer (Tab. 4.8), diverse levels of responsibility of the providers over the product delivery emerge.

Tab. 4.8 – Product ownership – possible configurations

G. Product ownership		
G1	Ownership is transferred to the customer	The ownership is completely transferred from the manufacturer/provider to the customer, through a traditional sale offer.
G2	Ownership is retained by the provider	The ownership – and usually lifecycle responsibilities – is retained by the manufacturer/provider, which interest appeared to shift from the quantity of sold products toward the extension of their lifespan.
G3	Ownership is transferred to the customer with provider's extended responsibilities	Hybrid configuration represented by the extension of manufacturer/provider responsibilities, although the product ownership is transferred to customers, e.g. extended warranties or after-sale included services.

H. *Revenue system*

This concept refers to the contract relationship between the customer and the provider and to the related modality of payment for the purchase of re-manufactured products. In addition to the traditional single payment, Tab. 4.9 highlights innovative payment systems oriented towards circular business models.

Tab. 4.9 – Revenue system – possible configurations

H. Revenue system		
H1	Traditional single payment	Simple sale transition based on a single payment for the purchase of a product.
H2	Deposit-based single payment (with surcharge)	Within a sale transition based on a single payment, a percentage is considered as a deposit, that is refunded if the customer bring back the product after the use.
H3	Performance payment (e.g. Pay-per-use, Pay-per-period, etc.)	Payment modalities that do not necessarily imply a sale transition and that could be deferred in time. They are quantified on the basis of the performance accessed by the customer (e.g. pay-per-use, pay-per-time, pay-per-period).

I. *Market destination and segment*

This feature refers to the market destination of the re-manufactured product and its customer typologies, defined in relation to original product. The market destination explains the market targeted by the re-manufacturer, while the market segment represents the category of customers of

the re-manufactured product. As highlighted in Tab. 4.10, the assessment of the market of the re-manufactured product is affected by both product-specific and market-specific factors.

Tab. 4.10 - Market destination and segment – possible configurations

I. Market destination and segment		
I1	Same market destination and segment of the original product	The market destination of the re-manufactured product is the same as the original one when both products have the same function, and thus they are demanded by the same market. The specific market segment targeted by the re-manufacturer is the same as the original product if not significant differences in terms of product value are perceived by the market, and thus the same client of original product is willing to accept the re-manufactured product as well. These two options, if combined, describe the first identified cluster.
I2	Same market destination of the original product but different market segment	The re-manufactured product is perceived differently from the original product customers (e.g. same function but lower performance), and so it is targeted to a different market segment.
I3	Different market destination from original product	The re-manufactured product is repurposed (i.e. different function than the original product) to target a new market, not competing with the original product.

4.5 New organizational models for the building sector

On the bases of the above-introduced key features, the present paragraph aims to propose three circular organizational models for the construction sector. The three proposed models – understood as a set of interconnected strategic and operational solutions (Osterwalder and Pigneur, 2010) – are based on re-manufacturing and reuse practices in order to promote circularity within the construction sector and, in particular, in the field of tertiary architectures. Based on the paradigm shifts defined in Par. 4.3 and by means of the key features identified in Par. 4.4, the three proposed circular models are:

1. *Rent contract as a support for re-manufacturing*;
2. *All-inclusive solution to support re-manufacturing*;
3. *Alternative/secondary markets for re-manufactured products.*

In particular, these models have been – firstly – outlined starting from combinations of the key features on the basis of the best practices on-going in the construction sector but especially in other industrial sectors where re-manufacturing appears more mature and structured (Benoy *et al.*, 2014). Secondly, they have been developed through the active involvement of the main stakeholder categories (e.g. investors and clients, manufacturers, construction companies, installers, facility managers) of the tertiary architecture field by means of roundtable sessions and focus groups.

4.5.1 Rent contract as a support for re-manufacturing

The first model "Rent contract as a support for re-manufacturing" proposes the rent contract as a strategy for promoting re-manufacturing practices to lengthen product life-spans. Rented products with end-of-use residual performance are re-manufactured in order to start a subsequent new use-cycle, overcoming the "single use" approach towards a "multiple-use" one (Fig. 4.1).

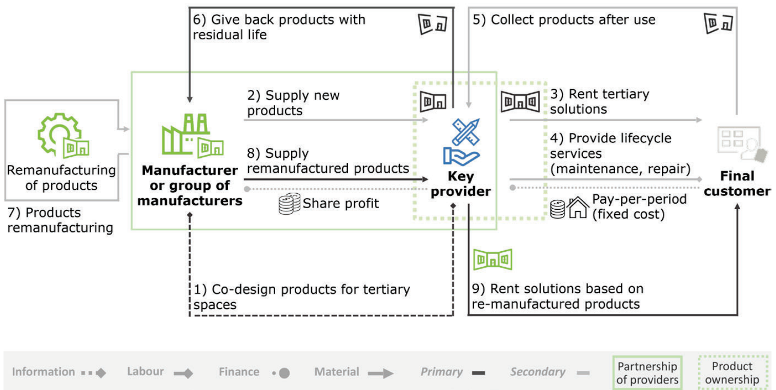

Fig. 4.1 – Rent contract as a support for re-manufacturing – organizational model (Dalla Valle et al., 2021)

Following this approach, the original manufacturer co-design the products in collaboration with an external party – the provider – who is in charge of offering them for rent to customers (Tab. 4.11). Moreover, the provider has

also the responsibility of collecting the used products at the end of the rent contracts in order to return them to the original manufacturer, who carries out the re-manufacturing activity. Thus, used products are brought back to the original performance in order to be offered again for rent by the provider to new customers, activating in this way a circular value chain.

Tab. 4.11 - OM1 key features

Key features of OM1 " Rent contract as a support for re-manufacturing"					
Key features		**Possible configurations**		**OM1**	
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	
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	**Re-manufactured product design**	**E1**	**Product re-designed for re-manufacturing**	
		E2	Product not re-designed for re-manufacturing but with facilitating features	
		E3	Product not re-designed for re-manufacturing	
F	**Product-service distribution**	**F1**	**With a partner intermediation**	
		F2	With a dealer intermediation	
		F3	Performed autonomously by re-manufacturers	
G	**Product ownership**	G1	Ownership is transferred to the customer	
		G2	**Ownership is retained by the provider**	
		G3	Ownership is transferred to the customer with provider's extended responsibilities	

Tab. 4.11 - continued

Key features of OM1 " Rent contract as a support for re-manufacturing"				
Key features		**Possible configurations**		**OM1**
H	**Revenue system**	**H1**	**Traditional single payment**	■
		H2	Deposit-based single payment (with surcharge)	
		H3	Performance payment (Pay-per-use, Pay-per-period)	
I	**Market destination and segment**	**I1**	**Same market destination and segment of the original product**	■
		I2	Same market destination of the original product but different market segment	
		I3	Different market destination from original product	

The offer of products for rent, without any transfer of ownership to the customers, is aimed at sensitizing both manufacturers and providers towards the co-design and manufacturing of products characterized by high durability and maintainability, facilitating multiple reiterative product use-cycles before reaching the end-of-life (i.e. not sufficient residual performance for recovery). Retaining the resources embedded into products and guaranteeing multiple use-cycles, this model may lead to both environmental and economic benefits over time.

4.5.2 All-inclusive solution to support re-manufacturing

The second organizational model "All-inclusive solution to support re-manufacturing" involves the sale of the product together with a set of life-extension services performed during the product use phase (Fig. 4.2). Hence, the customer pays for the product and the related services aimed at extending its useful life, including for instance: cleaning, repair, maintenance, replacement and re-manufacturing.

As shown in Fig. 4.2, this model is based on the close partnership between the provider (product supplier) and the re-manufacturer (service supplier). The provider supplies the product to the customer, while the re-manufacturer provides overtime the services connected to the product. This win-win partnership brings benefits to both parties. Indeed, on one side the provider, in order to offer all-inclusive solutions on the market, needs the support of a re-manufacturer with technical know-how and operational

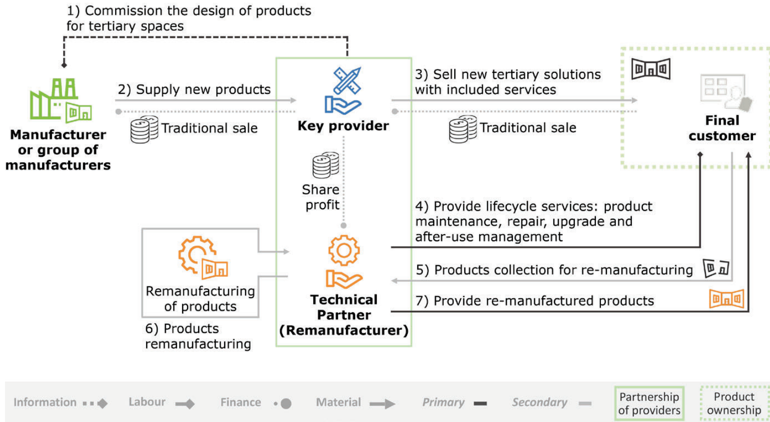

Fig. 4.2 - All-inclusive solution to support re-manufacturing – organizational model (Dalla Valle et al., 2021)

skills in the field of repair, maintenance and re-manufacturing. On the other side the re-manufacturer, in order to intercept a greater share of customers, exploits the partnership with the provider, taking advantage from its marketing connections and product commercializing activities performed for promoting the all-inclusive solutions (Tab. 4.12).

Tab. 4.12 - OM2 key features

Key features of OM2 "All-inclusive solution to support re-manufacturing"				
Key features		**Possible configurations**		**OM2**
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	
B	**Product procurement**	B1	Surcharge-based mechanism	
		B2	Buy-back mechanism	
		B3	Direct- order mechanism	
		B4	**Service contract mechanism**	■
		B5	Leasing mechanism	

Tab. 4.12 -continued

Key features of OM2 "All-inclusive solution to support re-manufacturing"				
Key features		**Possible configurations**		**OM2**
C	**Product collection**	C1	Enabled by "collectors" activity	
		C2	Performed autonomously by re-manufacturer	
		C3	**Hybrid solutions**	
D	**Re-manufac-turing actors**	D1	Original Equipment Re-manufacturer	
		D2	**Contracted Re-manufacturer**	
		D3	Independent Re-manufacturer	
E	**Re-manufactured product design**	**E1**	**Product re-designed for re-manufacturing**	
		E2	Product not re-designed for re-manufacturing but with facilitating features	
		E3	Product not re-designed for re-manufacturing	
F	**Product-service distribution**	**F1**	**With a partner intermediation**	
		F2	With a dealer intermediation	
		F3	Performed autonomously by re-manufacturers	
G	**Product ownership**	G1	Ownership is transferred to the customer	
		G2	**Ownership is retained by the provider**	
		G3	Ownership is transferred to the customer with provider's extended responsibilities	
H	**Revenue system**	H1	Traditional single payment	
		H2	Deposit-based single payment (with surcharge)	
		H3	**Performance payment (Pay-per-use, Pay-per-period)**	
I	**Market destination and segment**	**I1**	**Same market destination and segment of the original product**	
		I2	Same market destination of the original product but different market segment	
		I3	Different market destination from original product	

With regard to Tab. 4.12, it is important to stress how the present model differs from the first one in terms of product life-extension strategy. Indeed, the first model aims to guarantee multiple subsequent reiterative use-cycles of the same product even by different customers. Differently, this model has the goal of extending as much as possible

the first product use-cycle by promoting long-term relationship with the same customer. This latter approach (the so-called "loyalty strategy") aims at matching the duration of use with the useful life of the product (thus minimizing the waste of residual performance), favouring the creation of win-win long-term commercial relationships between the provider plus the re-manufacturer (supply side) and the customer (demand side).

4.5.3 Alternative/secondary markets for re-manufactured products

The third proposed organizational model is based on: (i) product-reuse for the subsequent sell on secondary markets with respect to the original one (primary market), as well as on (ii) the strategy of repurposing, involving the change of the original function of the post-use product for its subsequent placing in a different market (Fig. 4.3). This model promotes reuse and repurposing as strategies towards industrial symbiosis by preventing waste generation through the reuse or refunctionalization of post-use products of a market into reworked product (or potential resources) for sale (or production) processes within another segment of the same market or within a different market.

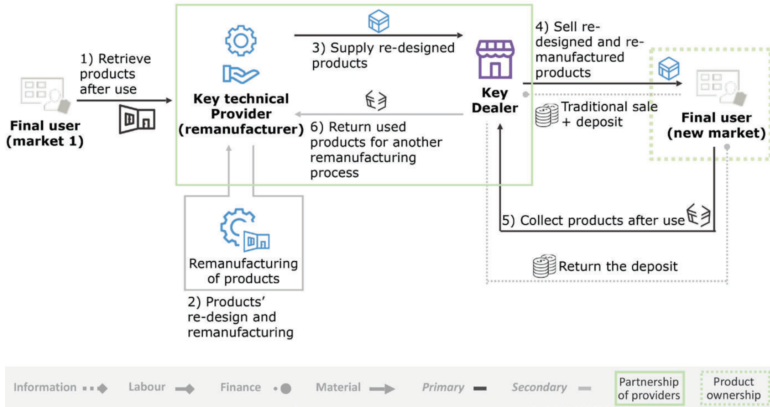

Fig. 4.3 - Alternative/secondary markets for re-manufactured products – organizational model (Dalla Valle et al., 2021)

According to this model, the recovery of post-use products is carried out by an independent re-manufacturer, who performs the required operational interventions (Tab. 4.13). In partnership with the re-manufacturer, the dealer is the market intermediary who deals with the distribution of re-manufactured products to end customers with a sale that includes a deposit. This deposit-based payment system is useful in order to incentivize the end user to return the products after use, guaranteeing the circularity of the model. The dealer then returns to the re-manufacturer the post-use products collected from the clients (after returning the related deposits). The re-manufacturer, closing the circle, carries out the reworking activities on the products for the starting of a new use-cycle.

Tab. 4.13 - OM3 key features

Key features of OM3 "Alternative/secondary markets for re-manufactured products"				
Key features		**Possible configurations**		**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**	
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	**Re-manufactured product design**	**E1**	**Product re-designed for re-manufacturing**	
		E2	Product not re-designed for re-manufacturing but with facilitating features	
		E3	Product not re-designed for re-manufacturing	

Tab. 4.13 -continued

Key features of OM3 "Alternative/secondary markets for re-manufactured products"				
Key features		**Possible configurations**		**OM3**
F	**Product-service distribution**	F1	With a partner intermediation	
		F2	**With a dealer intermediation**	
		F3	Performed autonomously by re-manufacturers	
G	**Product ownership**	**G1**	**Ownership is transferred to the customer**	
		G2	Ownership is retained by the provider	
		G3	Ownership is transferred to the customer with provider's extended responsibilities	
H	**Revenue system**	H1	Traditional single payment	
		H2	**Deposit-based single payment (with surcharge)**	
		H3	Performance payment (Pay-per-use, Pay-per-period)	
I	**Market destination and segment**	I1	Same market destination and segment of the original product	
		I2	**Same market destination of the original product but different market segment**	
		I3	**Different market destination from original product**	

The innovative nature of this model implies a strong commitment by the involved stakeholders, both on the supply and demand side. Indeed, on the supply side, collaboration and coordination efforts are required to the re-manufacturer and the dealer in order to effectively handle the logistic activities and to assess market opportunities for promising product re-design and repurpose. On the demand side, an effort of foresight on the issue of circularity is required to the clients, accepting both the deposit-based payment system and the reconverted and regenerated products.

Concluding, the introduced key features of innovative circular approaches and the three innovative organizational models based on re-manufacturing represent a contribution towards the development of networks of heterogeneous operators (e.g. clients, designers, providers, manufacturer, artisans, dealer, third sector, etc.) able to identify and exploit new synergies needed in order to establish the market conditions required for the activation of circular practices based on re-manufacturing within the construction field. In the next Chapters (5, 6 and 7), the proposed organizational models are explored and discussed with respect to three main fields of the tertiary sector, namely: exhibition, office and retail.

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

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

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

The text is articulated into three sections.

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

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

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

FrancoAngeli
La passione per le conoscenze