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TESI DI LAUREA

"Product-service systems and circular business models: a theoretical and empirical contribution"

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INTRODUCTION

The circular economy (CE) is described by the practitioners and academia as the main tool to promote sustainability and to respond to the global need for a more sustainable economy (Reim et al. 2021). Additionally, it can have significant advantages from the standpoint of social sustainability (Stahel 2010; Pieroni et al. 2019). The goal of the circular economy is to create a resource-effective and efficient economic structure that is better suited to respecting the limits of the planet (Ghisellini et al. 2016). To put CE ideas into practice, social, industrial, and consuming systems will need to change the way they are built to rely on renewable energy and material sources and to decrease waste production by purposefully narrowing, slowing, and closing the flow of materials and resources (Bocken et al. 2016; Pieroni et al. 2019).

The implementation of circular economy may be done at three distinct levels, micro, meso, and macro (Bressanelli et al. 2019; Geng et al. 2008). At the micro level is analyzed the transformation achieved by the single company towards CE. The meso level shifts the focus from the single company to the collaboration of companies inside an industry, for achieving the eco-industrial parks (Geng et al. 2008). At the macro level the emphasis is on the initiatives taken by the cities, regions, or nations to promote the adoption of the CE paradigm (Murray et al. 2017).

To adopt a circular economy paradigm inside a company, this should base its value creation on utilizing economic value retained in products after use (Evans et al. 2017). But, in order to obtain real change, it is fundamental that CE is adopted at all the aforementioned three levels. The deployment of CBMs is, however, impacted by a variety of issues, including the diversity of client categories, product attributes, distribution networks, and marketing tactics (Reim et al. 2019).

Product-Service Systems (PSS), and in general servitized business models are frequently mentioned as one of the possible facilitators for setting up new business models for the circular economy, encouraging product life-extension and product take-back (Tukker et al. 2015; Bocken et al. 2017; Lewandowski 2016). One of the most famous examples of a servitized value proposition is the “Power-by-the-Hour” project proposed by Rolls-Royce. In this proposal, airline manufacturers pay for a variable fee based on the availability of the engines, without having to pay a purchase price. The focus of the value proposal (for Rolls-Royce) must be on providing effective engine maintenance. In doing so, they deployed sensors on the engines to monitor them and to continuously collect data in real time, in order to elaborate them through specific IoT technologies and execute preventive and predictive maintenance.

The literature has highlighted the advantages that businesses may gain from PSSs, including improved customer relationships, increased barriers to entry for rivals, and the creation of new income sources (Baines et al. 2013; Spring et al. 2017). However, their adoption by companies is still restricted due to the challenges in designing and implementing these types of offers (Rosa et al. 2019a). In fact, servitization requires profound changes in the business model of companies, in particular the way in which they interact with their key partners and customers, and the variation to their value proposition (Adrodegari et al. 2017).

Despite the challenges of servitized business models and product-service systems, they can have a great impact on the company competitiveness and in particular on its ecological footprint.

The purpose of this thesis project is to understand if the implementation of services and their integration with products in the business models increases the environmental performance of the companies. Furthermore, given the high potential benefits of servitization but the low degree of adoption of these business models by companies, it is also interesting to analyze what are the barriers and the difficulties that companies encounter when they intend to transform their business model into a more circular and servitized one.

For these purposes, I initially carried out a systematic literature review in order to fully understand PSSs, the circular economy, and their interaction in circular business models. Then, for understanding the challenges connected to adopting a circular economy strategy and the implementation of a business model based on services. Finally, to get a deeper analysis of the topics, I combined the literature review with case-based research of four Italian companies. The companies analyzed have adopted a servitized business model with the main purpose of decreasing their environmental impact and that of their customers. In particular all these companies adopted an end-of-life (EOL) management service for their clients, that is a servitized strategy that reduces the wastes and drives companies to adopt a circular economy. Ricoh Italia has been selected as a benchmark in the servitized business model and their approach to sustainability and circular economy. Then Montecolino S.p.a. and Aquafil Group have been selected as two companies that adopted a servitized business model based on EOL management operating in a very active sector with regard to the circular economy. Finally, Astelav was chosen because of the idea behind their business model. It is, in fact, a service provider company which as a value proposition collects used appliances and renews or refurbishes them and extends the life of the products through the maintenance and sale of spare parts.

The thesis is separated into two main sections, and it is structured as follows: Section 1 establishes the study's context by reviewing the literature, in the disciplines of product-service

systems, circular economy and servitized circular business models. Section 1 is further divided into subsections, where are deeply analyzed all the main topics covered in all the papers studied during the literature review. Section 2 presents the case studies and the methodology in which they were conducted and then analyzed. Moreover, this section presents the results of the studies and the discussion.

1. Product-Service Systems and Circular Business Models: the theoretical background

1.1 Systematic literature review: method

For the elaboration of this thesis, I firstly developed a qualitative study by analyzing the literature, and to deeply understand its underlying themes. Initially I was interested in clarifying the concept of circular economy and servitization, and then to understand how servitization, in particular the concept of Product-Service System (PSS), can lead to the development and implementation of Circular Business Models (CBM).

In the first step of the analysis the search string used was "Circular*" and "Servitization" in Scopus (that is the largest database of abstracts and citations), limited to the subject area of "Business, Management and Accounting", "Economics, Econometrics and Finance" and "Multidisciplinary". Considering the fact that authors might use different terms in their keywords, or in their abstract for analyzing the same topic (i.e., servitization or product-service systems), I used another search string in order to find all the papers with a correlation between circularity and servitization. This additional search string was "Circular*" and "Servitization" or "Circular*" and "PSS", limited to the "Business, Management and Accounting" subject area. In the research I included all the articles containing one of the defined words of the two search strings which could be mentioned either in the title, or in the keywords or in the abstract of the papers, and I excluded all the articles that were not published in English language. The year of publication was not used as a restriction, even though given the topicality of the subject, the oldest article found was published in 2015. By applying the inclusion and selection criteria in the Scopus search engine, 74 papers emerged from the research.

In the second step, from reading the title and the abstract of the articles, I excluded those that were not relevant for the thesis purposes. After excluding duplicates, 56 potential papers were selected, and they were considered to be potentially useful. I organized them into a table in an Excel file, where I reported the authors, the title, the abstract, the year of publication, the Scopus link, the source title, and the authors' keywords.

In the next step of the analysis, I read the introduction, the method, and the conclusion of the 56 potential articles, then 39 articles emerged interesting to be analyzed further. Through the in-depth analysis of those papers and to overcome possible limitations of the database search, other 25 articles have emerged by cross-referencing as interesting and useful to analyze further.

Finally, in the last stage I made a summary, highlighting the main topics, of the 64 remaining papers, and I grouped them by proximity of the results obtained in the conclusions, and the main topics covered in the papers. In fact, all the papers I read contained analyses of six main topics, which I then categorized into six groups that reached related conclusions.

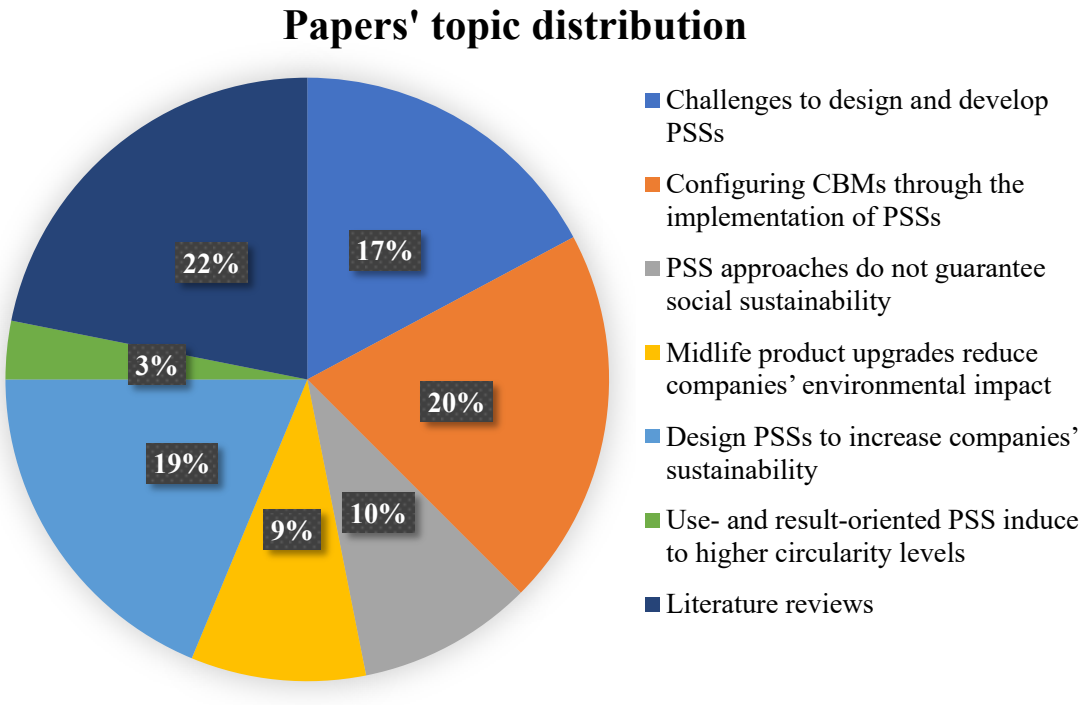

Figure 1.1.1 *Distribution of the analyzed papers and their main topics.*

Clusters	Number of papers	%
Challenges to design and develop PSSs	11	17%
Configuring CBMs through the implementation of PSSs	13	20%
PSS approaches do not guarantee social sustainability	6	9%
Midlife product upgrades reduce companies' environmental impact	6	9%
Design PSSs to increase companies' sustainability	12	19%
Use- and result-oriented PSS induce to higher circularity levels	2	3%
Literature reviews	14	22%
Total	**64**	**100%**

Table 1.1.1 *Clusters' labels and papers' distribution.*

In addition, I included one additional group of articles that I labeled as "Literature reviews," which clustered all the papers that contained analyses of the literature that had been published up to that moment. The distribution of each paper into each cluster is depicted in Figure 1.1.1 and in Table 1.1.1.

The first cluster of conclusions describes the challenges and barriers that companies meet when they want to design and develop product service systems. Indeed, firms may face some challenges in the implementation of servitization practices such as customers' resistance to changing the way they purchase and use products, or the high investments required to modify the business model. The second cluster leads to the conclusion that servitization approaches, and PSSs are one of the main tools to achieve a more efficient use of resources, increase sustainability and achieve a circular business model. The third cluster of conclusions leads to the fact that even though PSSs are one of the main instruments to obtain a circular economy, they do not automatically lead to an increase in sustainability. Indeed, companies may be

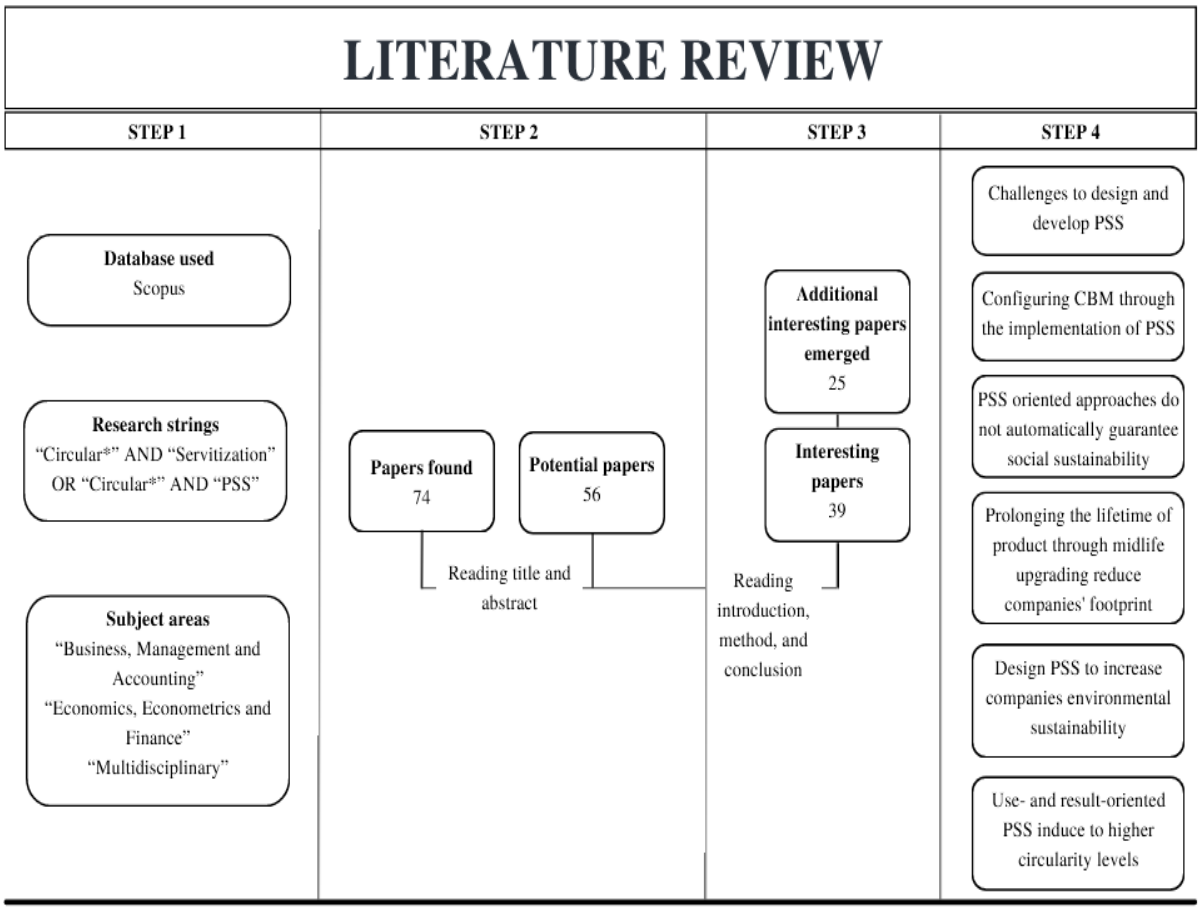

Figure 1.1.2 *Stages of the systematic literature review (elaboration based on Kolling et al. 2022).*

interested in implementing PSSs only to pursue profit purposes, instead of being interested in reducing the environmental impact (Mont 2002; Ellen MacArthur Foundation 2013b). Thus, to

be sure of introducing more sustainable practices in their operations, companies must want to achieve a reduction in their waste production and know how to implement PSSs and evaluate their impact on companies' sustainability.

The fourth cluster leads to establishing that prolonging the lifetime of products through middle of life upgrading induce an increase in sustainability. In fact, especially in PSS-based business models, the manufacturers retain the ownership of the assets, and for this reason they are incentivized to extend the life of these goods, reducing the use of resources to make new products. The fifth cluster describes how companies should generally design PSSs with the aim of achieving a circular economy. Finally, the sixth cluster of papers leads to the conclusion that use- and result-oriented PSS induce higher circularity levels. Hence, the fact that often companies retain the ownership of the product in these two types of PSS increase their incentives to maintain the goods at the higher level possible, and this usually reduces companies' footprint.

All the clusters and their relative topics are further analyzed below in some of the next sections.

1.2 Product-Service Systems: an overview

Product-service system (PSS) is a business model, often specifically designed to reduce the company's environmental impact, while it fulfills customers' needs (Kolling et al. 2022). The term PSS was firstly introduced by Goedkoop et al. (1999), who defined it as "a system of products, services, networks of players and supporting infrastructures that continuously strive to be competitive, to satisfy customer needs and to have lower environmental impacts than traditional business models". Tukker et al. (2006) later defined PSS as "a mix of tangible products and intangible services designed and combined so that they are jointly capable of fulfilling final customer needs". They identified two foundations on which PSSs are based (Rexfelt et al. 2009, p. 675):

- "The final functionality or satisfaction that the user wants to realize as a starting point of business development, instead of the product fulfilling this functionality".
- "Providing such functionality while reducing impact on the environment".

Therefore, the final goal of designing PSSs is to produce solutions rather than tangible goods while reducing the company's footprint, and it involves the design of a system that includes both physical items and services, fully integrated with each other to meet all the customers' requirements. For this reason, the main challenge of PSSs is to develop a system solution since products and services taken on their own does not reduce companies' footprint. They have to be completely integrated into a system, that helps to switch from an approach of producing,

consuming, and disposing, to a system in which products and services (and the supporting infrastructures) provide a high value to customers, fulfilling their needs, and at the same time reduces the environmental impact (Mont 2002).

Maxwell et al. (2003) listed a comprehensive set of criteria (depicted in figure 1.2.1) to highlight PSS's ability to empower companies to address all the three sustainability dimensions simultaneously (environmental, social, and economic).

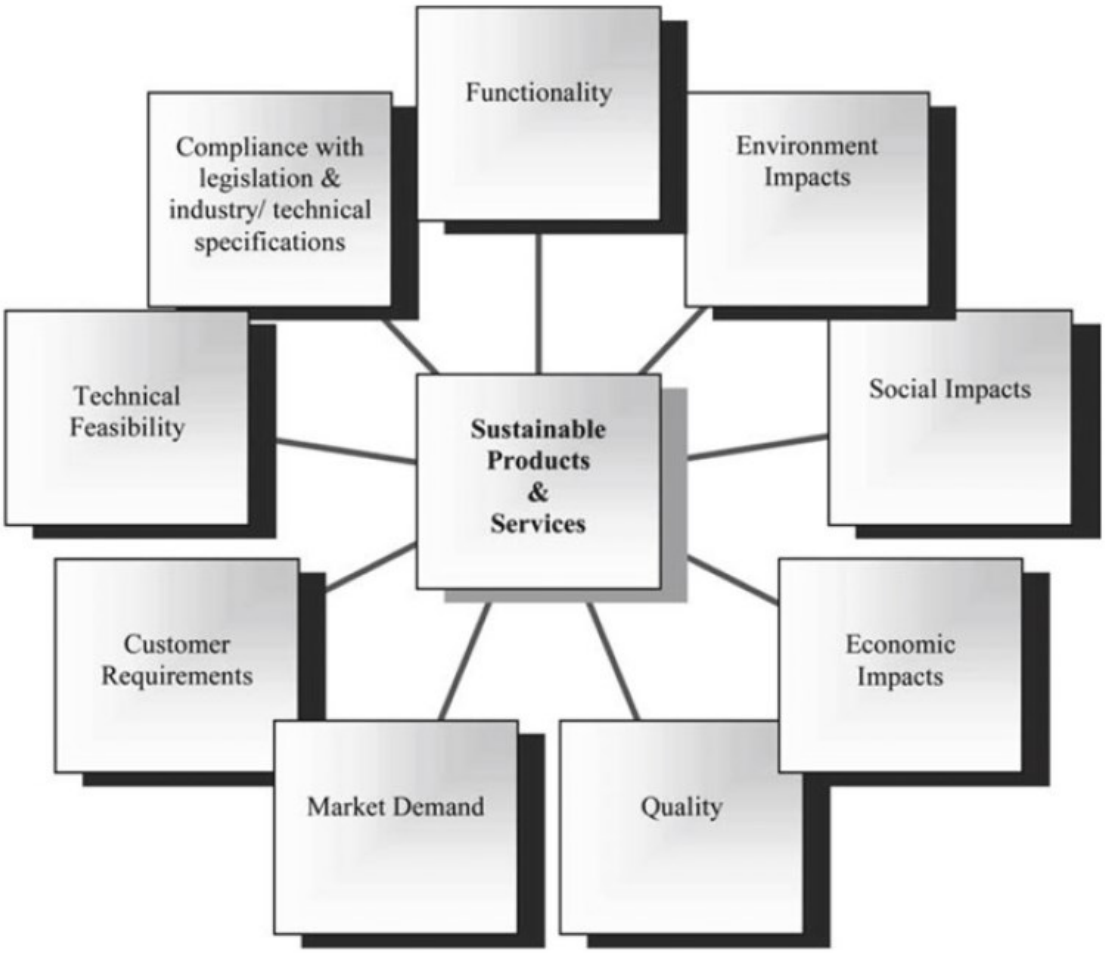

Figure 1.2.1 *PSS's criteria that optimize sustainability (Maxwell et al. 2003).*

Three different types of product-service systems are usually described in the literature (Tukker 2004) (Figure 1.2.2):

- *Product-oriented PSS:* The focus is on selling products to customers with additional services. In this PSS type, there are two possible service configurations (Annarelli et al. 2019):
    a. Product-related service, in which the offered services are strictly related to the usage phase of the product, such as spare parts provision or preventive maintenance.

b. Advice and consultancy services, such as advice on logistic optimization, education and training on the use of products or financial services.

- *Use-oriented PSS:* The business model is oriented to sell the product function, and it is no more focused on the product. The ownership of the product is no more transferred to the customer, but it remains in the hand of the PSS provider. This PSS type can be differentiated in:
  a. Product lease, where the customer pays a fee for continuous access to a determined product over an agreed period of time, obtaining an exclusive (individual and unlimited) use of the product.
  b. Product renting or sharing, in which the goods can be sequentially rented and used by a lot of clients.
  c. Product pooling, where it is allowed that different customers can simultaneously use the product.
- *Result-oriented PSS:* The business model is oriented toward selling a result that a product can give to the customer. The same result can be obtained by various products. Services in this PSS type can be distinguished in:
  a. Activity management and/or activity outsourcing, where the contractual agreement between the PSS provider and the client regards the outsourcing of an activity.
  b. Pay per service unit, which is very similar to use-oriented services but, in this case, the client pays for elementary units of output provided.

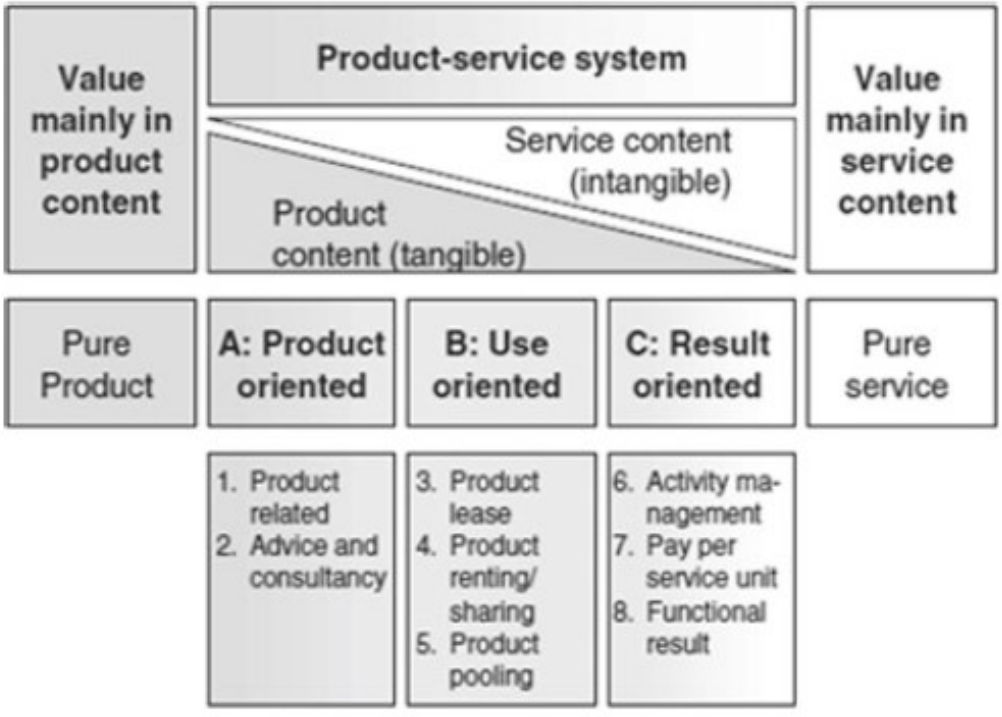

Figure 1.2.2 *Product-service systems classification (Tukker 2004).*

c. Functional result can be considered the most extreme example of servitization/PSS. In this case, the customer and the service provider agree on the result that has to be delivered, and it usually has no significant constraints on how to deliver the result.

Lay et al. (2009) used five key elements to describe and help to understand PSS (Figure 1.2.3):

- *Ownership of the product*, which should be carefully managed by companies, especially because it can give the possibility to recycle, refurbish or remanufacture the products, but at the same time can have a great economic impact, for example in the total amount of assets in the balance sheet. It can be divided into:
  a. Ownership during use, that can be maintained by the manufacturer (or by the intermediate who sold the product) or transferred to the customer.
  b. Ownership after use, that can be maintained by the service provider or returned to the manufacturer for the reuse or remanufacture of the components.
- *Personnel*: once companies decide to provide the service, they should divide their human resources into two categories, one focused on the manufacturing, and the other focused on maintenance and service supply.

Characteristic Features		Options			
Ownership	during phase of use	Equipment producer	Leasing bank	Operating joint venture	Customer
	after phase of use	Equipment producer	Leasing bank	Operating joint venture	Customer
Personnel	Manufacturing	Equipment producer	Operating joint venture	Customer	
	Maintenance	Equipment producer	Operating joint venture	Customer	
Location of operation		Equipment producer's establishment	Establishment "fence to fence" to the customer	Customer's establishment	
Single / multiple customer operation		In parallel operation for multiple customers	Operation for a single customer		
Payment model		pay per unit	pay for availability	fixed rate	pay for equipment

Figure 1.2.3 *Morphological box with the key elements to understand product-service systems (Lay et al. 2009).*

- *The location of operations* can be usually at the producer's establishment, or at the customer's establishments. This model also considers a third way, where the supplier establishes a "fence-to-fence supply park" in order to strictly collaborate with its customers.
- *The number of customers served simultaneously*, which depends on the PSS solution, and it can vary from one customer served at a time to multiple customers served in parallel. This characteristic is strongly dependent upon the amount of product and service components involved in the offering, and for this reason, companies are limited from this point of view.
- *Payment model* is the last characteristic analyzed in this model. The payment can be made in the traditional way for the purchase of the good, or it can be a flexible payment, like, for instance, the payment for the actual utilization (pay for availability).

A business strategy based on a product-service system creates a value proposition centered on the needs of the final customers, instead of focusing on the product (Baines et al. 2007). This permits companies to fully engage in the design of a need fulfillment system that radically decreases the environmental impacts and increases the social benefits (Mont 2002). An example brought by Baines et al. (2007) helps to understand this dynamic (Figure 1.2.4). In this example is shown the "servitized transformation" of the traditional purchase of a photocopier. In the traditional business model, the manufacturer sells the photocopying machine to the customer, and it may add some basic service components, such as all the activities related to the installation or to ensure its functioning. The user pays a price, and the ownership is transferred to the customer, who in turn becomes responsible for the usage, maintenance, replenishment of the consumable parts, and at the end of the product lifetime for managing the disposal of the machine. At this point, the transaction is over. In the case of the transition to a PSS based offer, the ownership remains in the hand of the producer, who in this case, is responsible for managing the equipment and all the related consumables. Moreover, the manufacturer is responsible for monitoring the performance of the machine and to provide the services related to maintaining the right operation conditions. Furthermore, the machine provider is usually in charge of the activities related to the disposal of the product, and so related to the reverse logistics. The consumer does not pay the purchase price, but pays for the usage of the equipment, thus in this specific example, based on the number of printed copies. Maintaining the responsibility (and ownership) of the asset allows the manufacturer to better exploit their technical know-how, and it allows increasing the quality and efficiency of the maintenance service (usually preventive maintenance), reducing the machines' downtimes, and increasing their lifetime. This leads to

an increase in the complexity of the company processes, but it also gives the possibility of recycling (refurbishing, remanufacturing) the products.

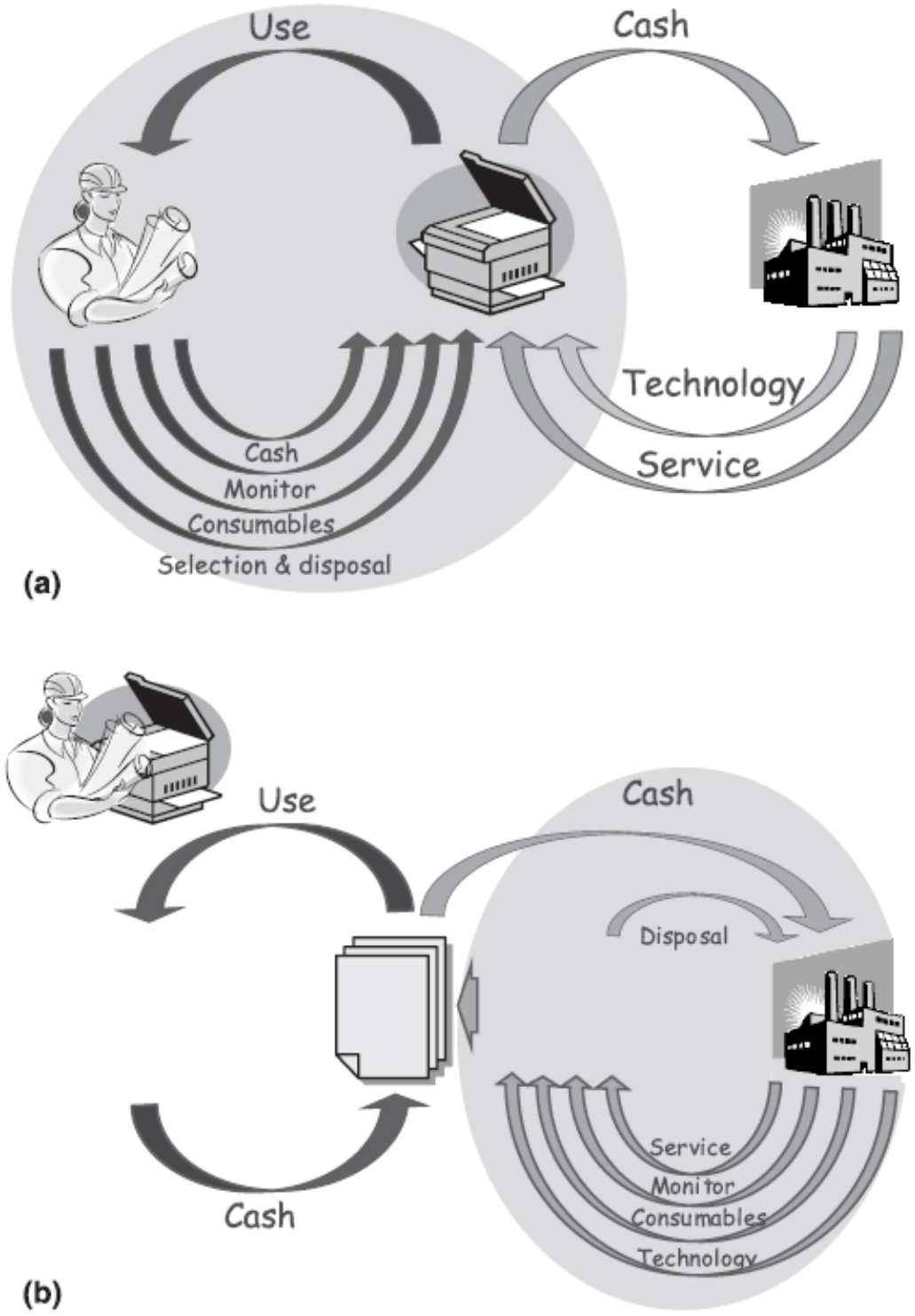

Figure 1.2.4 *Change of focus in the transition to a product-service system-based offer. In (a) the traditional purchase of a photocopier, in (b) the PSS offer of the photocopier (Baines et al. 2007).*

Kristensen et al. (2019) described product-service systems as a three-step enlargement of the value propositions, that moves the focus from the product (i.e., traditional transactional business model focused on product price, design, and sale) to the service (i.e., the addiction of a set of services to an existing product), and finally to the system (i.e., creating value through the combination of products and services, including a sustainable and shared value perspective) (Figure 1.2.5). This process leads to a great potential to shift from a focus on materiality (i.e., product) towards non-materiality (i.e., system). The shift from materiality to non-materiality leads to a switch from non-social to social, as the focus changes from products and user's satisfaction to solving societal challenges (i.e., sustainability), which includes multiple stakeholder relations.

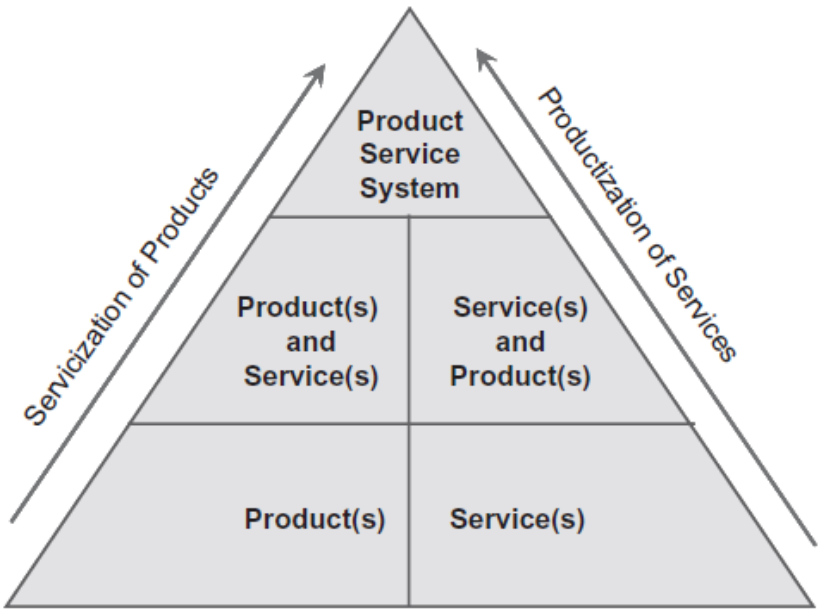

Figure 1.2.5 *Three step evolution of the product-service system concept (Baines et al. 2007).*

Providing services separately in terms of contracts from selling the related products, which is often done in many sectors, is in terms of environmental sustainability and economically a waste (Sakao 2022). This is because in a traditional contractual relationship, the product seller is not economically incentivized to prolong the lifetime of the products. Indeed, PSSs help to shift from a business model based on the ownership of the product, to a use and/or performance model, and thus prolonging its life cycle (Fischer et al. 2022). In a PSS, both service providers and service customers are actually concerned with the performance of goods and materials of higher quality (Tukker 2015; Reim et al. 2015; Stahel 2016).

In order to implement PSSs effectively, companies should focus their efforts on a proper design of the products, keeping in mind to have a life cycle perspective (Geum et al. 2011). In fact, when companies decide to offer PSSs, they should design them to maximize the product life

cycle, and the focus should be to increase the ease of repair and maintenance of the products. This can be easily achieved through the modularization and standardization of all the product components and spare parts (Adrodegari et al. 2020). Indeed, longevity and modularity enable PSS models to slow, narrow, close, and regenerate the flow of materials (Bocken et al., 2016), and thus leading companies to achieve a circular economy. Regarding modularity, Kreye et al. (2019) in their work found that to implement servitization strategies, especially in a BtoC context, there are two prerequisites that should be respected: internal collaboration (within the PSSs manufacturer), and product characteristics. In particular, for what concerns product characteristics, the focus might be on the complexity of products and its management through modular product design. Indeed, they stated that modularity opens up options that permit quick and efficient servitization on-site, by separating or replacing a module and repairing it at another location. Moreover, in their work, they highlighted the importance of a stable and coordinated network of relationships, which involves all the choices regarding the partner selection, training, relationship governance, and joint marketing to consumers to enable shaping BtoC servitization. In fact, to design PSSs, firms need a system approach, which requires close integration and collaboration of all the actors within the life cycle of the PSS (Mont 2002). Finally, they underlined the significance of a strong institutional setting. Specifically, consumer wishes, and regulatory frameworks affect the potential requirements for product operation and maintenance by indirectly influencing the economic environment even as public buyers (e.g., hospitals).

1.2.1 Product-service systems' implementation advantages

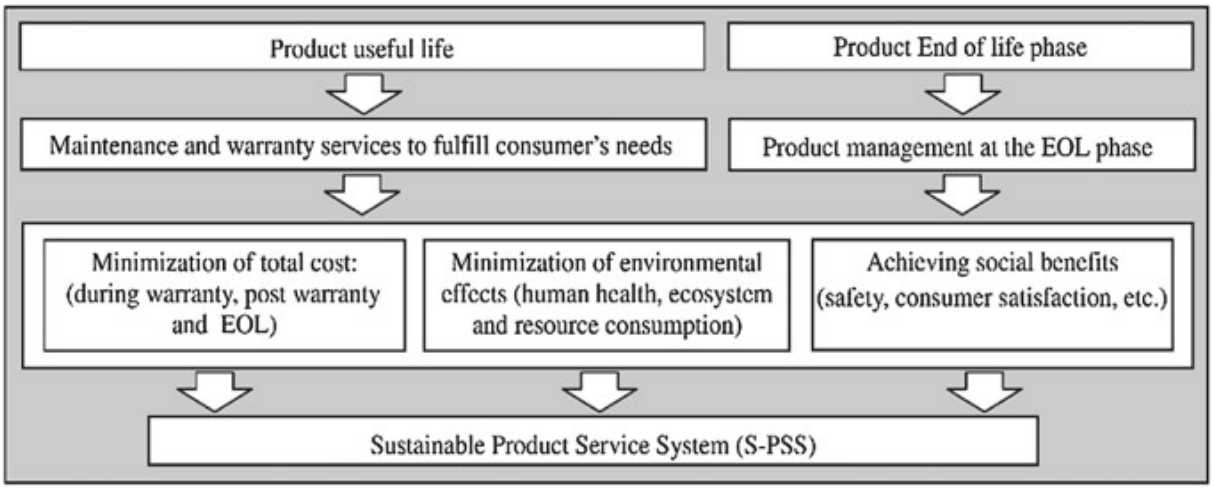

Figure 1.2.1.1 *Sustainability of product-service systems (Shokoyar et al. 2014).*

Integrating products and services is considered essential when developing more sustainable solutions, in fact, offering product-service systems can improve the circularity of businesses

(Pieroni et al. 2019) and it is therefore seen as a means to realize a circular economy (Kjaer et al. 2018; Grahn 2022). Hence, firstly, PSSs may have a great impact on the sustainability of companies' operations. Secondly, PSSs have economic benefits and may increase the competitive advantage over competitors. In fact, Baines et al. (2007, p. 6) stated that the main economic benefits of PSSs derive from the opportunity to differentiate: "PSS is claimed to provide strategic market opportunities and an alternative to standardization and mass production. The fundamental benefit is an improvement in total value for customers through increasing service elements". The market value for users, provider costs, capital requirements, and the capacity to sustain value in the future may all be tied to PSS's economic and strategic potential, providing the first significant sign of its strategic relevance (Tukker 2004).

The competitive advantage developed by a company is influenced (and influences) by the competitive context in which it operates, and it is characterized by firm specific resources (physical, human, etc.) that are rare, difficult to imitate and use, and hard to substitute (Barney 1991). Consequently, Annarelli et al. (2020) found out three distinctive sources of PSS's competitive advantage:

- The type of PSS, that is the business model value proposition based on customer behavior, and thus directed to that specific market segment.
- The PSS's core resources, that are the most important factors, such as competences and organizational processes, on which the value proposition is based.
- The level of protection from replication, that is, the ability of the company (the PSS's uniqueness) to protect itself from the threat of replication and imitation.

Sakao (2022) demonstrated the resource efficiency achieved by a Swedish manufacturing firm through the comparison of a typical product offering with a product-service system offering. The results showed that the costs and the environmental impact in the PSS offering were reduced by 18% and 45%, respectively. The benefits of the PSS come mainly from the savings in production, thanks to activities like take-back (reverse logistics) and refurbishing.

The advantages of developing a servitization strategy can be achieved by manufacturing companies but also by service companies (Mont 2002). In fact, manufacturing companies by adding service to their products can improve their relationships and commitment to their clients, raise their aptitude for innovation, and increase the value offered to their customers. Instead, service companies, by adding a product to their service offer, they may diversify the services, and protect their market share by proposing something different from their competitors.

PSS carries a variety of drivers for the companies and their business models, bringing a non-negligible value derived from diverse product-service combinations, and they cover both the

economic and the environmental dimensions of sustainability. These drivers might be valuable for both manufacturers and service companies that are looking to adopt a servitization strategy for (Annarelli et al. 2019):

- Building and keeping strong relationships with clients,
- Increasing the engagement of suppliers,
- Achieving advances in legislation because of the adoption of solution that reduce the environmental impact,
- Reducing the production of waste, and in general environmental costs,
- Increase the current offer,
- Increase the efficiency of companies' assets,
- Enhancing the competitive advantage, through the search of a Unique Selling Proposition (USP),
- Protecting and/or increasing the market share,
- Discouraging new entrants to join the market,
- Increase the flexibility of the offer (i.e., renting, leasing),
- Availability of different offer models,
- New possibilities thanks to the adoption of remanufacturing/recycling/reusing approaches.

Servitization requires integrated relationships, with benefits and costs for both provider and user (Kreye et al. 2021). Especially in a BtoB environment, providers will receive higher profit margins with more stable and long-term predictable cash flows (Wise et al. 1999) and increasing competitiveness through buyer lock-in (Schmenner 2009). Instead, buyers stand to cut the operational costs of equipment by outsourcing maintenance activities and focusing on their core activities (Wise et al. 1999), along with optimized buyer operations through providers' technical expertise (Kastalli et al. 2013). In a BtoC context, consumer motivation to accept servitization may result from increased life expectancy of engineered products, hence a reduced environmental impact. Moreover, the growing social interest in sustainability issues leads customers to increase their interest in practices that reduce waste, such as PSSs.

Numerous papers have been published discussing how PSSs can induce to a more sustainable economy, although generally it has been argued that the results-oriented PSS type is the best in terms of resource-efficiency (Tukker 2015). Grahn (2022) in his study analyzed how result-oriented PSS contributes to increase resource efficiency by creating more value with less

environmentally damaging resource consumption, through the initiation of several resource efficiency enablers:

- It increases focus on creating only the value that is desired, and thus it reduces resource consumption for activities that are not generating value.
- The remuneration for creating value, and not for delivering just a product, drives a broadening of the supplier view regarding the best combination of resources and effort that can be used as tools to create value.
- The incentives for innovative resource-efficient solutions increase.
- When a supplier does not get remunerated for the supplied product but only for the result that the consumers expected and the value that is created for them, the resource-efficiency incentive is transferred from the customer to the value creator.

Hence, all the benefits deriving from the adoption of a business model with a value proposition based on a product-service system can be summarized in the following table (Annarelli et al. 2019):

Customer benefits	**Companies benefits**	**Environmental benefits**
- Higher value delivered. - The degree of service flexibility - The degree of personalization offered - Higher quality level - Improved satisfaction of needs - Offering of new functionalities, thanks to combinations of products and services	- Creation of new market opportunities - Disclosure of new sources of competitive advantage - Availability of detailed information on the usage of products and their performance - Higher margins provided by service replacement of products - Stronger relationships with customers, bringing to a higher	- Reduction in consumption of inputs - Reduction in the production of wastes and by-products - Public pressure on environmental issues - Increase in service supply - Chance for new job creation and development

- No concerns linked to monitoring product status - No concerns for end-of-life disposal	level of customer retention and trust - Disclosure of new innovation potential, thanks to the service elements in the offering - Chances for the reuse/remanufacture of products and components.

Table 1.2.1.1 *Summary of product-service system implementation benefits (based on Annarelli et al. 2019).*

1.2.2 Product-service systems' implementation challenges

PSSs are described as the main tool for the transition to a more sustainable business, and thus to achieve a circular economy, but there could be some challenges and barriers that companies might face during their design and implementation.

Mont (2002) in his study stated that to develop and implement PSSs, firms may incur in some difficulties, mainly caused by the necessity to involve several stakeholders (customers, suppliers, service producers) to design the system of products and services. Moreover, once the PSS is done, a social system and/or infrastructure is needed that would accept or support the suggested product-service scenario. Indeed, it is not obvious that customers will adopt a system in which they may not be the owners of the product. Moreover, companies could be afraid of changing the system (i.e., from short term to long term profit) and the source of their profits. In general, it is not easy for companies to shift to PSSs, because they have to change their corporate culture and approach to the market through resource and time investments.

Additionally, companies may incur in the so-called "servitization paradox" (Gebauer et al. 2005; Neely 2008), which contends that businesses who implement servitization may see increases in sales but not in profits. Indeed, studies have shown that firms perform better when they add a larger proportion of service offerings to their manufacturing product offering, rather than adding services only in a very incremental way (Fang et al. 2008), but this may increase costs. More specifically, adding services to the offer often leads to an increase in fixed costs,

which, together with the poor scalability of servitization, can induce to an erosion of the profits, making the application of this business model ineffective. However, thanks to technological advancement, the servitization process can be done gradually together with the value chain (Coreynen et al. 2018), and thus being able to collaborate with partners, or to interface with customers through digital tools, leading to a rise in the efficiency of production and customer services. In general, however, "to develop advanced services, and have profits, companies need to renew their delivery system in depth, making it capable of managing the new costs and risks that a PSS offer implies, which requires significant resources" (Annarelli et al. 2019, p. 24).

It is important also to consider all the factors that may influence the consumer acceptance of the offers based on PSS, because companies must take into consideration the role played by final clients, since very often customers are actively involved in servitization processes. That is one of the reasons why there has also been an increase in focus on contracts in relation to servitization and PSS. Furthermore, an important factor in determining the effectiveness of a PSS is consumer acceptance or resistance to change. For this reason, the analysis of customers' requirements is a crucial step of the whole servitization process, and which determines its success. At this regard, Rexfelt et al. (2009) analyzed and listed all the factors that may influence customer product-service system acceptance:

- Financial reasons (i.e., expensive products that are rarely used are more likely to be offered as a successful PSS).
- Perceived relative advantages compared to alternatives.
- Perception of fixed and variable costs, insight in total life-cycle costs.
- Uncertainties regarding risks, costs, and responsibility.
- Communication between supplier and consumer.
- Relationship between the supplier and consumer (i.e., defining the new roles and obligations).
- Transaction costs in terms of both time and money. PSS must be easily available wherever and whenever needed.
- Quality of the PSS (i.e., organization, reliability, and convenience).
- Reputation and image of the service provider.
- Habits as an obstacle to acceptance.
- Ownership of goods is important to consumers and hinders the acceptance of PSS.
- Environmental attitudes may be of relatively little importance compared to other factors.

However, as pointed out by Meijkamp (2000), not only there are a lot of different types of consumers with different needs, but there are also a lot of product and service combinations. This complexity is also discussed in a study of Hirschl et al. (2003, p. 877) who point out the

importance of use regimes, “a set of technological, economic, and social elements such as infrastructure, attitudes and values, institutional arrangements, price relations, and symbolic meanings of products that determine consumer behavior”. Moreover, the social and cultural context in which product-service systems are provided is an important driver to determine consumer acceptance (Rexfelt et al. 2009). For example, society's regulatory and normative institutions can make it harder for consumers to purchase PSSs solutions (Mont 2004).

In the literature have been described different PSS implementation barriers in different business contexts. For example, small and medium enterprises (SME) may face some challenges compared to large enterprises due to their dimension. In fact, SMEs usually have greater difficulty accessing financial resources (but also to human resources) than large companies. Given the importance of long-term relationships and a deep network of partnership to effectively implement PSS, SMEs may find it challenging because of limited external contacts and/or customer support (Dey et al. 2020). In addition, they may lack managerial skills and enterprise culture to be able to switch to a service-based business model (Neely 2008).

Internal challenges	**External challenges**
Time constraints	Position in the value chain
Current business model	Customer interests in PSS solutions
Financial resources	Handling of reversed logistics
Organizational structure and internal processes	
Dedicated employees for service development	
Competence	

Table 1.2.2.1 *Major challenges for SMEs when designing product-service systems (Akesson et al. 2022).*

Regarding this, Akesson et al. (2022) have found nine challenges (listed in Table 1.2.2.1) that SMEs experience when designing PSS. They grouped these implementation difficulties into six internal challenges and three external challenges.
The internal challenges are:

- Time constraints, because of the tendency to prioritize daily tasks.
- Current business model, both in terms of customer’s resistance regarding the change in ownership and firm’s resistance to change business model.
- The limited financial resources.

- The organizational structure and internal processes, such as a service department or a dedicated development process.
- The lack of dedicated employees for service development.
- Limited competences for designing PSSs.

The external challenges are:

- The position in the value chain, in the sense of being a contract manufacturer and not being the owner of the product, thus having little control of the product after being delivered to their customers.
- The customer's interests in product-service system solutions (customer's demand in service solutions may be low), and given the high dependency on their clients, it would be difficult to change the companies' business model.
- Reverse logistic management, it is unclear what customers and companies need to do when it comes to returning the goods. It is also difficult to organize an efficient reverse logistic.

In another business context, Tunn et al. (2021) analyzed and clustered into four categories all the implementation barriers specifically for use-oriented PSS. First, touchpoints related barriers, such as contamination issues given by the fact that the product may have already been used by others. This issue is more relevant with PSSs that have a short duration of use (i.e., the time during which a consumer obtains exclusive access to the product), because the touchpoints are frequent. Second, barriers related to the use phase, such as doubts on the quality of the products. On the contrary, this issue emerges particularly in long-term use PSSs, because the duration of use is high. Third, issues related to the concept of use-oriented PSS, for example the lack of ownership. This usually depends on the product placed in the PSS. In fact, a consumer is more inclined to adopt use-oriented PSSs for products like personal computers than for clothes or shoes. Fourth and last, some barriers relate to the touchpoints and the use, because some consumers do not trust other clients, or they are afraid that PSS providers could limit their access to the products, or generally to have a good experience during their usage.

Kuhl et al. (2022) explored from different perspectives all the barriers (and enablers) to shift to a servitization strategy and obtain a circular economy by exploiting PSSs. They developed a multi-level perspective taking into account three analytical levels: the micro-level (business model level), meso-level (sociotechnical level) and the macro-level (societal level), and through case studies, they described for each level all the challenges, but also the enablers, to implement PSSs. At the macro-level there could be cultural factors that help PSSs development, because

of the rising societal interest in sustainability and in particular in circularity, but also the growing acceptance of business models based on subscriptions. Instead, the cultural barriers mainly regard the desire to always purchase the latest product, therefore are lost the circularity principles such as maintenance to increase product lifetime, or product regeneration, and thus it is lost the right sense of urgency to act to solve the sustainability problem. Moreover, companies focus to maximize shareholder value, limiting all the investments that may be risky. Then there are political enablers, such as the presence of incentives to innovate, and regulations that induce companies to adopt circular practices. At the same time, the lack of incentives, subsidy policies, and in general the absence of adequate support constitute a barrier for the transition to a CE. In fact, for example, the lack of quality standards on refurbished products limits customers' willingness to buy those products.

At the meso-level, the market enablers are the presence of high resource and input prices, and their scarcity, that drive companies to increase the effort to extend the resource loop. On the contrary, the speed of technological (and fashion) changes limits the possibility to close and narrow the resource loops, due to the speed at which products become obsolete. Moreover, customers may not accept refurbished and remanufactured products. Then, there are the supply chain enablers, such as the geographical proximity of the partners which facilitates the collaboration and reduces the costs, and the existence of some collaboration platforms to help industry actors by receiving advisors and support. At the same time, the difficulty of predicting customer demand for products that may have multiple life cycles, the lack of information sharing and collaboration between supply chain actors, the lack of suitable secondary raw materials for the recycling, and lack of suitable partners inhibit the company's possibility of implementing circular practices.

Finally, at the micro-level, the organizational enablers regard the high awareness of the company to environmental issues, and a strategy and/or a culture aimed at achieving CE. The organizational barriers concern the internal prevalence of a linear mind set with a too young circular orientation. Moreover, the increasing complexity of the processes and their management, the risk of cannibalization between refurbished and new products inhibits the willingness to implement PSS and reverse supply chain. In addition, the company may face financial barriers related to the increase of the complexity of the cost structure and financial risks. Moreover, the company may have technologies and knowledge that may act as enablers, such as the distinctive ability to design products for circularity.

Multi-level perspective	Enablers	Barriers
Macro-level (societal level)		
Cultural	- Rising societal interest in sustainability	- Focus on maximizing shareholder value - Lacking sense of urgency
Political	- Directing targets and regulations	- Lack of political incentives - Lack of clarity over waste, by-product, and resource status -Lacking quality standards
Meso-level (sociotechnical level)		
Market	- High prices and price volatility of resource inputs - Resource scarcity of key input materials	- Speed of fashion and technological changes - Lack of customer acceptance
Supply chain	- Geographical proximity of supply chain partners - Availability of collaboration platforms	- Difficulty of predicting customer demand for products with multiple life cycle - Lack of willingness to collaborate - Lack of availability of suitable secondary raw materials - Lack of suitable partners
Micro-level (firm level)		
Organizational	- Environmental awareness within the company - Integration of CE into company strategy - Long-term orientation of management	- Hesitant company culture - More complex management and planning process - Risk of product sales cannibalization - Organizational linear lock-in - Lack of communication, silo thinking, and unclear roles and responsibilities - Incentive structure supports existing linear business model

Financial		- Increased complexity, cost and financial risks of circular models - High up-front capital expenditures and investment costs - Lack of resources (i.e., money, time)
Technology and Knowledge	- Ability to design products for circularity - Ability to use digital capabilities and tools	- Lack of CE knowledge in identifying and assessing business model innovation opportunities - Lack of access to digital technologies - Low or variable quality and quantity of returned products - Unsuitable product design, due to high complexity in materials and number of components - Technological trade-off between product quality and circularity - Insufficient training and availability of skilled personnel

Table 1.2.2.2 *Enablers and barriers to obtain a circular economy by exploiting PSSs from different perspectives (Kuhl et al. 2022).*

1.2.3 Product-service systems timing

The timing (i.e., the "when") to address service design parameters in detail is an important PSS design decision, but it can be difficult for a PSS designer to define it. The opportunity of partly postponing service design is often not optimally seized in practice by manufacturers. Namely, too many, or too few decisions are made for the service design at the end of product design. An example is assigning excessive resources, such as reserving service technicians and shipped spare parts fixed to the service, whereas not clearly planning for an overhaul (Sakao 2022). Thus, one potential solution for the management in PSS design implementation is to designate a PSS facilitator, in order to coordinate the integration activities within the company. For what concerns the timing, Pigosso et al. (2015) identified seventeen best practices for PSS design and development, highlighting the importance of each best practice in a specific stage of the PSS development process. It emerged that the early stages are the most important, in fact as can

be seen in the Table 1.2.3.1 the product strategic planning (PSP) (i.e., the definition of the business strategic plan, analysis of the portfolio of products), informational design (IDE) (i.e., revise and update the product's scope; detail the product life cycle and define the main customers/users), and concept design (CDE) (i.e., model the product functions and define its architecture) phases encompass 13 out of the 17 identified practices. Moreover, product launch (PLA) (i.e., develop distribution process; develop customer support services; develop technical assistance processes; promote launch and marketing; launch the product; manage the product launch) and product accompanying and monitoring (PMA) (i.e., evaluate customers' satisfaction; monitor the product performance) seems to play a crucial role in ensuring the business success of the developed PSS.

Best practices for PSS development	**Development phase**
Develop a business model that can support the transition towards PSS	Product Strategic Planning
Create networks that foster innovation and promote customer resource integration	Concept Design
Define PSS offerings and value propositions to be provided to customers and stakeholders	Informational Design
Add service elements to the portfolio of offerings	Product Strategic Planning
Understand customer value creation processes to develop suited and specific value propositions	Informational Design
Co-create value together with the customers by developing service- and customer-oriented offerings	Informational Design
Identify available offerings in the market	Informational Design
Understand the life cycle of the offerings	Informational Design
Map and visualize the actual activities of the users of the company's offerings	Informational Design
Focus on value-driven communication of offerings – clearly communicate the value associated with the PSS offer	Product Launch

Increase the extent of interactions with customers through the PSS offerings	Product Accompanying and Monitoring
Collect PSS data through increased interaction with customers	Product Accompanying and Monitoring
Align physical product characteristics with service offer characteristics and vice-versa	Concept Design
Identify preferable product properties to increase the value of the PSS business model	Concept Design
Define the level of customization of the PSS offering according to the business model	Concept Design
Assess strengths and weaknesses of the current product portfolio and markets	Product Strategic Planning
Identify the market value of the PSS compared to the competing product in terms of tangible and intangible value	Product Launch

Table 1.2.3.1 *Classification of the best practices for PSS and the related development phase (Pigosso et al. 2015).*

1.2.4 Product-service systems do not guarantee social sustainability

PSS is focused on delivering a combination of products and services that are able to fulfill the customer's needs, and at the same time it has a great potential to increase sustainability. For example, Martin et al. (2021) analyzed "Tools for you" service by Husqvarna and the results showed that the rental service could lead to improve environmental performances, because compared to traditional product purchasing, renting a good has the potential to make the best use of the designed service throughout the lifetime of the products.

However, implementing PSS solutions does not guarantee resource reduction or absolute resource decoupling (Pigosso et al. 2015; Annarelli et al. 2016). For example, product leasing does not lead automatically to more sustainable businesses (Agrawal et al. 2012), because it could drive to replace products more frequently. Also, in the case of sharing systems such as car-sharing, people usually have easier access to products, which will ultimately increase consumption rather than avoiding it.

For this reason, Kjaer et al. (2018) developed a two-step framework (Figure 1.2.4.1) that helps to understand firstly, how PSS leads to a CE strategy (e.g., when a PSS should be qualified as

a CE strategy), and secondly, how a CE strategy leads to an absolute resource decoupling (i.e., to obtain a reduction in the amount of resources used to generate economic growth while decreasing environmental deterioration and ecological scarcity).

In the first step, it is described that PSS enablers of resource reduction link PSS to CE strategies through two intermediaries: the PSS strategies (the business actions) and the resource reduction aims.

In this paper were identified five PSS strategies:

- Operational support, the PSS provider supports the product operation (i.e., performance monitoring).
- Product maintenance, the PSS provider maintains the product during use (i.e., predictive maintenance, repair, upgrade).
- Product sharing, the PSS provider, combines retained ownership (i.e., product rental) with sharing of resources among users.
- Take-back/EoL (End-of-Life) management, the PSS provider is in charge of EoL management and decides how products are reused, remanufactured, refurbished, recycled, etc.
- Optimized result, the PSS provider delivers a functional result, and the offering is dematerialized.

A PSS might incorporate one or more PSS strategies (e.g., when combining product sharing and different EoL strategies in a rental scheme), and thereby also combine more than one PSS enabler. These PSS enablers of resource reduction are:

- Operational efficiency, it is particularly relevant for product categories that are resource intensive during the use stage.
- Product longevity, which potentially minimizes resource consumption.
- Intensified product usage, that is enabled through product sharing.
- Product system substitutions, for example, when PSSs shift the way in which customers fulfill their needs, leading to a more sustainable consumption.

From these PSS enablers are derived three resource reduction aims that are: the reduction of the consumption of resources during product use, the reduction of the necessity to produce new products, and the displacement of more resource intensive systems with the intention to obtain a net resource reduction.

The second step of the framework ultimately leads to an absolute resource decoupling, thus, to define if a PSS strategy leads definitely to a reduction in resource consumption, through three subsequent requirements: first, ensure net resource reduction, which depends on the reduction of the use of resources and the additional resources needed for changing the strategy and

offering the PSS; second, avoid burden shifting between life cycle stages, because optimizing one life cycle stage might increase resource consumption in other life cycle stages; third, mitigate rebound effects that occur when a product is offered at a lower price, which is often the case with shared, reused, or recycled products. In fact, consumers will spend the saved money on alternative goods, which increases the consumption (e.g., when a more fuel-efficient car incentivizes users to drive more) (Scheepens et al. 2016). However, rebound effects are very difficult to mitigate because they often occur as a result of mechanisms that come from outside the direct control of the PSS provider.

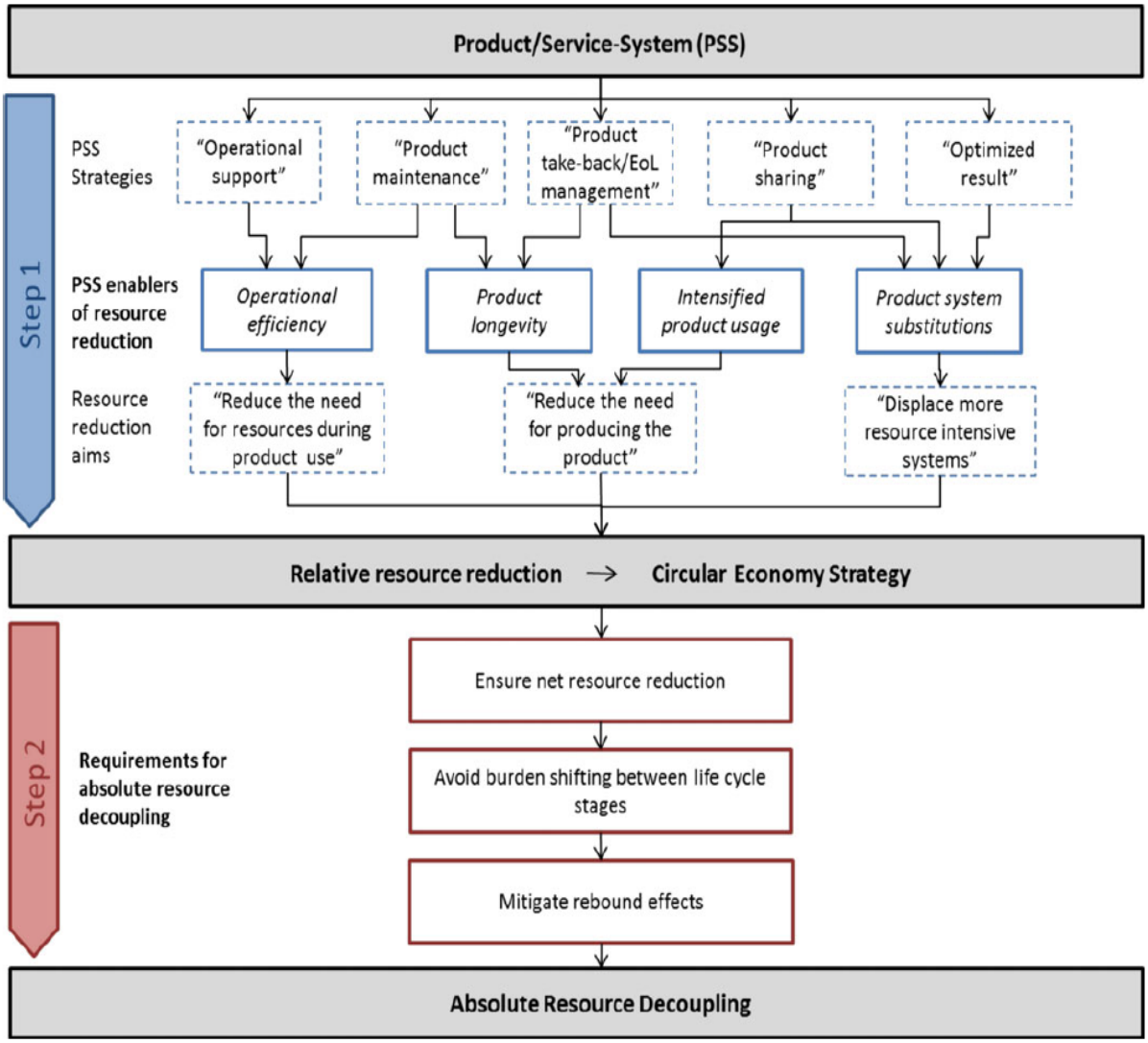

Figure 1.2.4.1 *The two-step framework developed by Kjaer et al. (2018) that leads from product-service system to circular economy strategy, to finally achieve absolute resource decoupling.*

Pieroni et al. (2019) in their work demonstrate that often to obtain an effective resource decoupling, companies have to face a trade-off (represented by the dotted arrows in Figure 1.2.4.2) between some choices. In fact, to mitigate for example the rebound effect, companies

might deal with a reduction of revenues due to a lower customer consumption. Environmental rebound effects can be mitigated by changes in the pricing strategy. It could be argued that the application of higher prices to avoid rebound effects could lead to difficulties for the companies in managing competition strategies. Nevertheless, the additional perceived value enabled by the CE-offerings (i.e., PSS), the changing customer preferences, and the rising demand for sustainable solutions could successfully compensate for this problem.

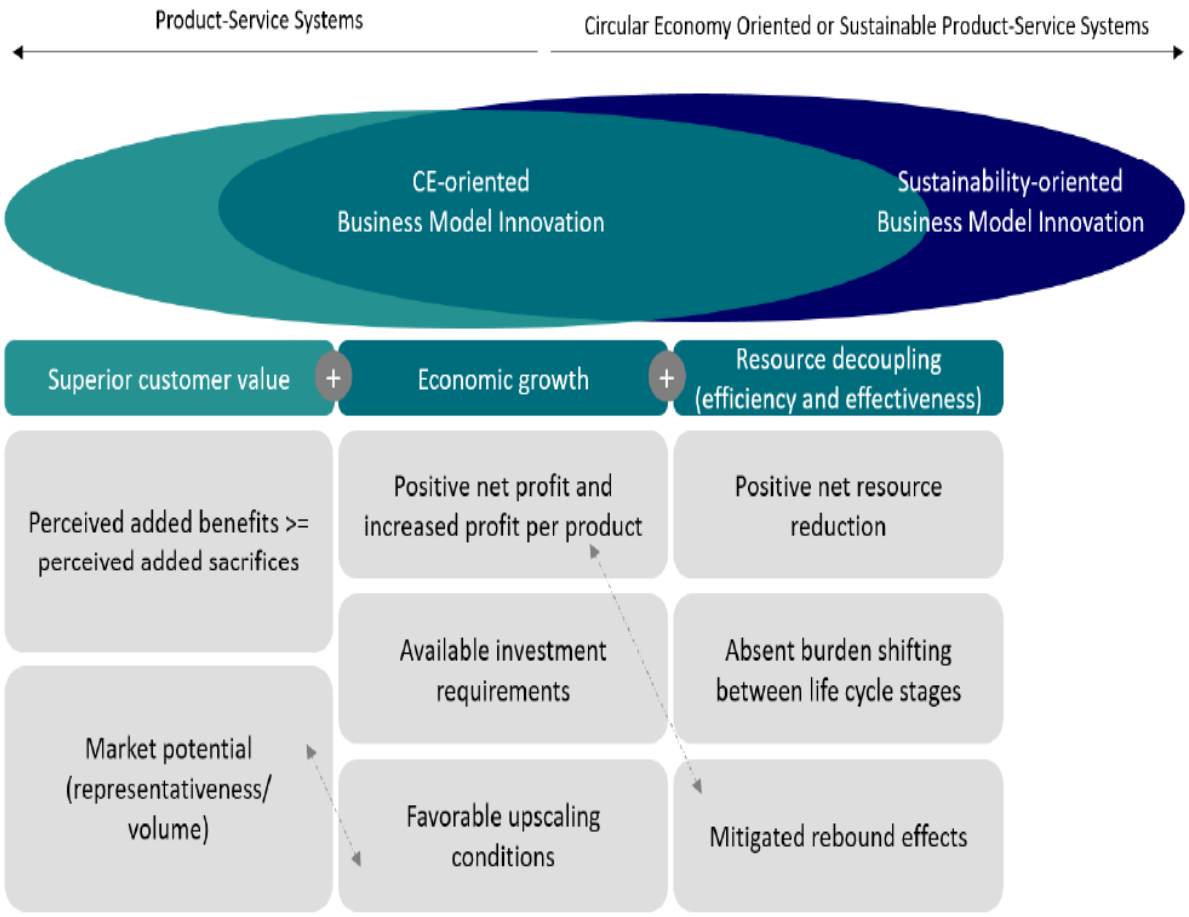

Figure 1.2.4.2 *Conditions for creating circular business models based on product-service systems (Pieroni et al. 2019).*

As mentioned above, one of the main strategies that can be implemented with PSS is the management of the end-of-life of the product, thus, it appears plausible that service providers know exactly when goods will become obsolete, and when to withdraw them from the consumers. Anyway, a service is usually offered to meet the needs of stakeholders at the time of the purchase, during use or at disposal. Hence, whether products, components, and materials continue to flow, depends on the response of the stakeholders to obsolescence. Moreover, even though resources are owned centrally by service providers, there is a risk that resources continue

to flow linearly (Zeeuw van der Laan et al. 2020) and the result will not lead to a more sustainable solution. For example, in use- and result-oriented PSSs, resource owners are often tempted to sell pre-obsolete resources to avoid disposal or repair costs.

In fact, producing closed-loop resource flows does not emerge as the primary reason to adopt PSSs (Ellen MacArthur Foundation 2013b). More likely, manufacturers are driven by the commercial and financial benefits (gaining a competitive advantage by offering added value; exploring market trends; anticipating legislative threat; and gaining feedback and customer insights on products) (Mont 2002; Ellen MacArthur Foundation 2013b; Pigosso et al. 2015).

However, PSS remains one of the main tools to achieve CE, and it is seen as a feasible and promising environmental strategy, with the potential of enabling a more sustainable society through the provision of environmentally efficient solutions, but to obtain a real increase in companies' environmental performances, PSS sustainability has to be evaluated (Figure 1.2.4.3). In fact in a servitization context, the service provider is incentivized to use and maintain the products efficiently and at the highest possible usage level, and this potentially leads to environmental benefits, like a reduction in materials and energy consumption especially during production and use phase; the extension of the manufacturer's responsibility for the product in the use and end-of-life phases (i.e., refurbishing activities); the development of more durable and use-intensive products; increase quality end-stock and less down-cycling; collection of end-of-life products, with increased re-use (i.e., regeneration); easier upgrading to more eco-efficient technologies (Pigosso et al. 2015).

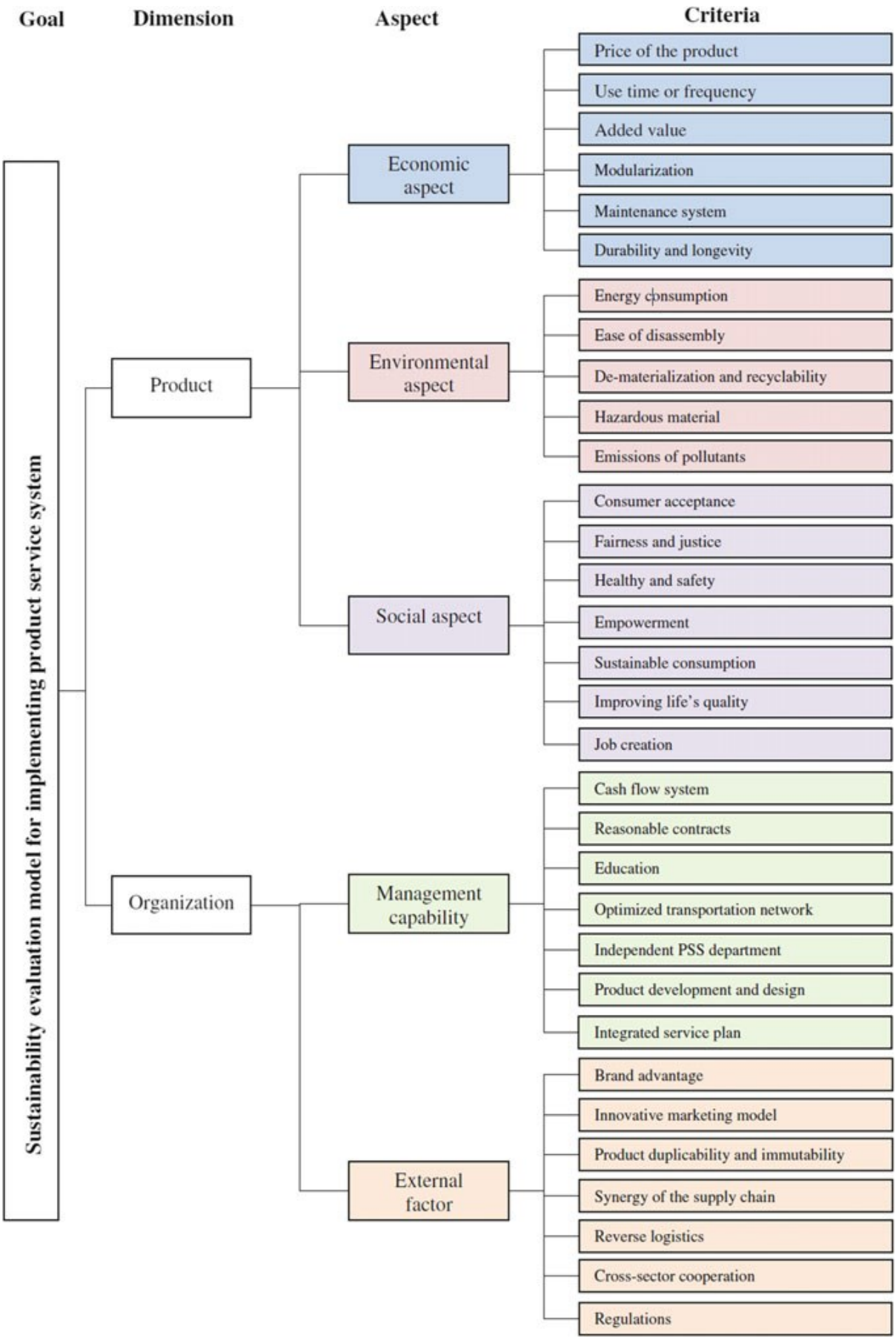

Figure 1.2.4.3 *Conditions for creating circular business models based on product-service systems (Pieroni et al. 2019).*

1.3 An introduction to circularity and Circular Business Models

1.3.1 Circular Economy

The circular economy (CE) has emerged as the main concept in the vast majority of industries to face and solve resource scarcity and environmental concerns. In fact, it offers a way to close the loops of material flow throughout the economy by encouraging the application of the 3Rs principle: reduce, reuse, and recycle (Ying et al. 2012; Parida et al. 2019). The first of the three Rs, reduction, is perfectly described by Huppes et al. (2005, p. 1) as "creating value while decreasing environmental impact". The second R, reuse, implies the importance of a proper product design, in order to be able to future cycle of disassembly, reassembly, and reuse. However, this principle can be applied only if customers are willing to buy goods that are already used or remanufactured (Geisendorf et al. 2018). The third R, recycle, refers to "any recovery operation by which waste materials are reprocessed into products, materials or substances, whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations" (European Union, 2008, p. 8).

One of the most common definitions of circular economy is offered by Ellen MacArthur Foundation (2016): "A circular economy is one that is restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles". According to the Ellen MacArthur Foundation (2012), a transition towards CE involves four fundamental building blocks (Bressanelli et al. 2019): first, several circular product design strategies (product life extension (Mont 2008) or material selection (Bakket et al. 2014)) have to be pursued in order to maintain products (materials and components) at their highest value and utility for as long as possible. Second, servitized business models (leasing, sharing, pay-per-use), especially result-oriented, foster take-back activities, because in these models the manufacturers retain product ownership. Third, the integration of reverse logistics into supply chains might induce a reduction of waste and may help companies to make profits by recovering and subsequently remanufacturing (recycling, refurbishing) used products (Kazemi et al. 2018). Whenever possible, it should be preferable to give a hierarchy between these activities. In fact, as shown in Figure 1.3.1.1, the inner circles allow more value to be kept intact (Kalverkamp et al. 2017). Fourthly, several enablers and favorable conditions might encourage the transition to a circular economy. Those conditions can be the collaboration between a network of partners (Elia et al. 2017), the development of digital technologies (Bressanelli et al. 2018), raising consumer

awareness of sharing, regulating, financing and creating a market for secondary products (Saidani et al. 2018).

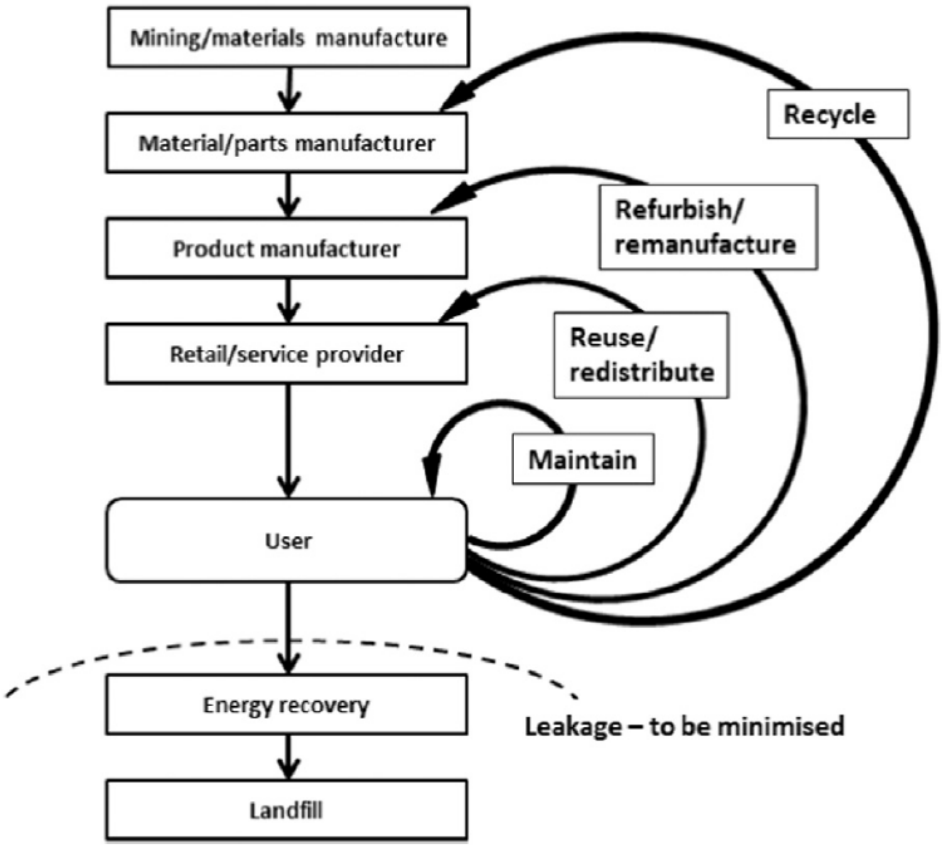

Figure 1.3.1.1 *Circular economy (Spring et al. 2017).*

The basic idea of a circular economy is that the economic and environmental value of materials and resources used in the manufacturing process and product components is maintained at the highest level for as long as possible. Circular economy pushes all the stakeholders of an economy to reduce the environmental impact of their action and to support a more environmentally friendly resource usage (Planing 2015). This can be done either by prolonging product life through maintenance and/or upgrading goods, or by reusing and recycling product components (den Hollander et al. 2017; Saavedra et al. 2018). “While great strides have been made in improving resource efficiency, any system based on consumption, rather than on the restorative use of resources, entails significant losses along the value chain” (Ellen MacArthur Foundation 2015b). The aim of the CE is to replace the classical concept of end-of-life, where the consumer after the use throws the product, with the new concept of regenerating the good and putting it back into the value chain, thanks to an advanced design of materials, products, and the introduction of new business models (Michelini et al. 2017). The circular economy

eliminates waste by designing processes that form cycles of assembly, use, disassembly and reuse (Spring et al. 2017).

As depicted in Figure 1.3.1.1, circular economy can be represented by four loops (Salonitis and Stavropoulos 2013; Ellen MacArthur Foundation 2013a), that represent the four key principles of circular economy, and starting from the inner cycle are (Urbinati et al. 2017, p. 488): product-life extension through maintenance, that is "products are designed to be durable and to have a long lifetime, thus reducing consumption. Such products are by definition high quality, so businesses often need to change their business model in order to offset the increase in product cost, for example by leasing instead of selling products or generating revenue by selling additional services". Redistribution/reuse, i.e., "The most sustainable product is often one we already own. Reusing a product preserves all the added value within that product". Refurbish/remanufacturing, which is defined as "a series of manufacturing steps acting on an end-of-life part or product in order to return it to like-new or better performance, with warranty to match". Finally, recycling, which is "the most common Circular Economy process through which used materials are treated so as to make them suitable for reuse".

The current socio-economic system is based on a linear economy, in which companies make goods and consumers use them and get rid of them. The linear model is usually typical in value chains, where in every stage is added value to the product (Spring et al. 2017), while the final stage is a "value sink" (Normann 2001). Indeed, traditional economy models expect that companies elaborate and transform materials into products using energy, sell those final products to their customers, and at the end throw them away when they are no more useful or are no longer working (Su et al. 2013). This linear production model results in an unnecessary waste of resources in a variety of ways: production chain and end-of-life waste, excessive energy use, and ecosystem erosion. With these signs of resource depletion, the demand for a new economic model is becoming stronger (Ellen MacArthur Foundation 2014).

1.3.1.1 Circular economy's advantages

Rosa et al. (2019a) grouped all the benefits of adopting CE for business in three macro categories: economic benefits, environmental benefits, and social benefits (Table 1.3.1.1.1). The economic benefits of adopting a CE strategy include the chance to reduce the overall costs (but also the improvement of sales and profit margins thanks to a better management of the cost structure), starting from the purchase of raw materials and to the transportation of products, but also from the customers' point of view. In fact, the latter will face lower energy or maintenance costs. Moreover, there is a reduction in business risks through operational risk management, through a service relationship with customers (i.e., product-service). There is the possibility of

opening new revenue streams, by the management of internal resources. In addition, CE can reduce the product and or the process complexity by decreasing the number of components that are needed in the production processes. In this way, modularity and/or standardization of products could also be enhanced, facilitating future maintenance intervention. Finally, the economic benefits of the adoption of CE in companies' businesses include an increased capacity to innovate and improve the competitive advantage over competitors.

By adopting a circular economy in their business strategy, companies achieve also environmental benefits, that include the compliance with environmental regulations, the reduction of environmental impacts, by adopting closed loop resource flows or renewable energy sources, the improvement of resource efficiency (in products, productions, or logistic), and the improvement of the whole supply chain sustainability.

Furthermore, CE induces social benefits such as the improvement of health and safety in workplaces, the development of innovative skills and knowledge related to sustainability, increasing customer retention, the possibility of reaching new markets and new countries by understanding different market needs for efficiency. In addition, it enhances the firm reputation and brand value, because nowadays, sustainability becomes an essential and distinctive element of good corporate reputation, and it is usually used for marketing purposes to increase customer loyalty and retention. Hence, it can be worthwhile for companies to innovate the value proposition in order to include circular strategies like, for example, product life extension through upgradability (Nubholz 2017).

Economic benefits	**Environmental benefits**	**Social benefits**
Reducing overall costs	Complying with environmental regulations	Enhancing reputation and brand value
Reducing business risks	Reducing environmental impacts	Reaching new markets and countries
Opening new revenue streams	Improving resource efficiency	Improving health and safety in workplaces
Reducing product/process complexity	Improving supply chain sustainability	Developing innovative skills and knowledge
Improving competitive advantage.		

Table 1.3.1.1.1 *Benefits of adopting a circular economy in companies' businesses (Rosa et al. 2019).*

1.3.1.2 Circular economy's challenges

To implement a circular economy, companies may face some challenges. Linder et al. (2017) analyzed these challenges: firstly, the willingness of their customers to change their consumption habits (which are further examined in the next section). Then, to undertake this change companies require technological expertise and knowledge of how their product can be, for example, remanufactured, or restored to the original conditions. In addition, the challenges that derive from the return flow logistic, such as the predictability and reliability of the return flow (Östlin et al. 2009). Then, the technological and design restrictions of products can be a limit to the adoption of a circular economy, since not every product is suitable for remanufacturing. Also, the potential problem of cannibalizing the sale of new products. Another potential issue is not being able to respond to fashion changes (Mont et al. 2006). Moreover, if the ownership remains in the hand of the manufacturer, and the good are rented out (rather than sold to customers), a financial risk may be transferred from the customer to the producer (Mont et al. 2006; Besch, 2005). In addition, also the operational risk of the firm increases because the manufacturer firm has to perform some of the activities that usually are done by the clients (Kuo et al. 2010). Moreover, there can be some barriers related to the lack of support from related policy, laws, and regulations. Finally, there might be considerable challenges related to the creation of the required network of key partners, such as retailers or service partners, as the introduction of a circular business model may be not compatible with their business models (Mont et al. 2006).

Bressanelli et al. (2019), through the analysis of the literature, identified 24 challenges to adopt a circular economy perspective, and they classified them into seven categories that are briefly explained below and depicted in Table 1.3.1.2.1.

First, when companies decide to adopt servitized business models, they may face some *economic and financial viability* challenges, and these challenges refer in particular to those business models in which the function is sold instead of the product itself. In this category can be grouped three different challenges:

- Time mismatch between revenue and cost streams. Since providers are no longer selling the product ownership, but they instead sell a result, the revenue streams are postponed over time, reducing the economic and financial viability that can be used to implement CE practices.

- Financial risk. This risk is transferred from the user to the provider, because the latter is financially exposed due to the possibility that the customers decide to early terminate the contract.
- Operational risk. This risk is also transferred to the providers, because they are often responsible for the operational costs of the solution offered, such as all the maintenance activities.

The second category is related to all the *market and competition* challenges, and it includes three different challenges:

- Cannibalization. Companies may be afraid to implement circular practices because they think that remanufactured products reduce primary sales.
- Know-how access and Intellectual Property (IP). Activities such as remanufacturing carried out by third parties (independent of the manufacturer) might induce a loss of control of the IP of the manufacturer's products.
- Brand image. If those activities conducted by a third party are not performed properly, they may negatively impact on the manufacturer brand image.

The third category regard all the challenges related to the *characteristics of the products*:

- Fashion changes. Since products in a circular economy prospective are designed to last over time, they are often unable to face fashion changes.
- Product complexity. The more complex the products, the more difficult it is to recover and recycle them.
- Product (mass) customization. This leads to customized products, increasing the complexity of disassembly and recycling.

The fourth category regard the *standards and regulation* challenges:

- Taxation and incentives are not aligned with the adoption of the CE paradigm.
- Measures, metrics, indicators. The existing economic indicators were built based on the traditional linear economy.
- Lack of standards regarding CE processes and activities.

The fifth category of circular economy adoption challenges concerns the *supply chain management*:

- Return flows uncertainty. Uncertainty about the quantity, quality, time, and place of the returns of end of use products reduces the incentives of implementing circular economies activities.
- Transportation and infrastructure. CE increases the transportation activities and costs if the products have to be sent back to the manufacturer.

- Availability of suitable supply chain partners. Finding the right partners may be a difficult task for companies who want to implement circularity.
- Coordination and information sharing. It could be difficult due to geographical distance or because companies may be reluctant to share some information with other supply chain partners.
- Product traceability may be inefficient due to inadequate support systems.
- Cultural issues (linear mind-set). Internal resistance to changes, with a linear mind-set ("Linear lock-in").

The sixth category is about challenges related to the *technology*:

- Eco-efficiency of technological processes. Renovation processes may be much more expensive (in terms of raw materials) compared to linear production and may cause losses or cross-contamination of materials.
- Product technology improvement. Products that are designed to last over time may not be able to continuously improve themselves from a technological point of view.
- Data privacy and security. Concerns about privacy and data security when companies have to collect used products inhibits these types of activities.

The seventh and final category of challenges regards the *users' behaviors*:

- Ownership value. Particularly in a BtoC context, customers may not be inclined to not own the goods they are using.
- Careless behavior in product usage. Since customers are no longer the owners of the products, they may adopt behaviors that reduce the life of the products.
- Users' willingness to pay. The purchase price is often one of the main factors that influence the customers' choice. During the acquisition process, users often only consider product price as one of the main factors influencing their choice. Circular products may be sold at higher prices compared to the traditional one, given their quality and upgradability. At the same time, customers may not be interested in buying secondhand products, since they may have a perception of lower quality or reliability.

Category	**Challenges**
Economic and financial viability	- Time mismatch between revenue and cost streams - Financial risk - Operational risk
Market and competition	- Cannibalization

	- IP and know-how access - Brand Image
Product characteristics	- Fashion change - Product complexity - Product (mass) Customization
Standards and regulation	- Taxation and incentives - Measures, metrics, indicators - Lack of standards
Supply chain management	- Return flows uncertainty - Transportation and infrastructure - Availability of suitable supply chain partners - Coordination and information sharing - Product traceability - Cultural issues (linear mind-set)
Technology	- Eco-efficiency of technological processes - Product technology improvement - Data privacy and security
Users' behavior	- Ownership value - Careless behavior in product usage - Users' willingness to pay

Table 1.3.1.2.1 *Circular economy implementation challenges clustered into seven categories (Bressanelli et al. 2019).*

In the same study, they proposed some levers that companies should adopt to overcome the circular economy implementation challenges. First, adopting modularity in product design helps to overcome all the challenges arising from product complexity and product customization (Mont 2008). This also enhances product upgradability, in such a way coping also with the challenges related to fashion change and technological evolution (Kumar et al. 2008). Furthermore, implementing an "access over ownership revenue model" permits companies to monetize design-to-last and all the maintenance activities, contrasting the cannibalization challenge (Sundin et al. 2005). The financial and operational risks can be overcome by the right contractual agreements, and at the same time providing all the services necessary to generate value also for the users in order to contrast the ownership value and willingness to pay challenges (Neely 2008; Sundin et al. 2005). In order to reduce the return

flows uncertainties, companies may forward and backward integrate supply chain activities. Alternatively, if the company is able to develop relationships and partnerships with the other supply chain actors, they can also mitigate the challenges related to intellectual property information sharing (Whalen et al. 2018). Product complexity and customization challenges may be overcome by the development of the right skills and technical competences (Lewandowski 2016). The implementation of digital technologies permits companies to mitigate the challenges related to careless customers' behaviors, and it also increases the coordination with suppliers and customers enhancing product traceability (Bressanelli et al. 2018). Finally, appropriate government incentives, communication, and awareness generation (i.e., eco-labelling and certifications) of circular economy for both companies and users overcome the cultural and willingness to pay challenges (Densley et al. 2017; Lieder et al. 2018).

1.3.1.3 Customers' willingness to adopt circular consumption

In addition to a company's ability and willingness to adopt circular business models, it is important to consider the willingness of customers to adopt circular consumption. In fact, not all consumers want to buy regenerated products or to change their consumption habits. In this regard, Pearce (2009) found six groups of customers that are suitable for remanufacturing (Linder et al. 2017). It is important to specify that they are not completely separated groups, and that some remanufactured products may be more suitable for a certain group. These customers groups are composed of customers who:

- Need to retain a product for their activities,
- Want to avoid reapproving a product,
- Are price sensitive, or they do not make extensive use of the product,
- Are interested in using a discontinued product,
- Want to extend the life of product already used,
- Are interested in environmental sustainability.

In another interesting study, Hazen et al. (2017) analyzed the drivers that prompt customers to adopt a circular consumption. They analyzed, from a circular economy perspective, the Push, Pull, and Mooring theory, which suggests that people migrate to different areas (in this case from a linear to a circular consumption model) because they are pushed and/or pulled by macro-level factors. In addition, micro-level mooring factors are useful to enhance the effects of the push and pull factors.

Push refers to those macro-level factors that are typically negative, and usually lead people to change their existing location (such as high electricity or fuel prices) (Stimson et al. 1998; Moon 1995). For the economic context, are those factors that might motivate customers to change product or service purchased, such as high prices or bad product quality. In fact, given the fact that often remanufactured (or refurbished) products have a lower price, this induces customers

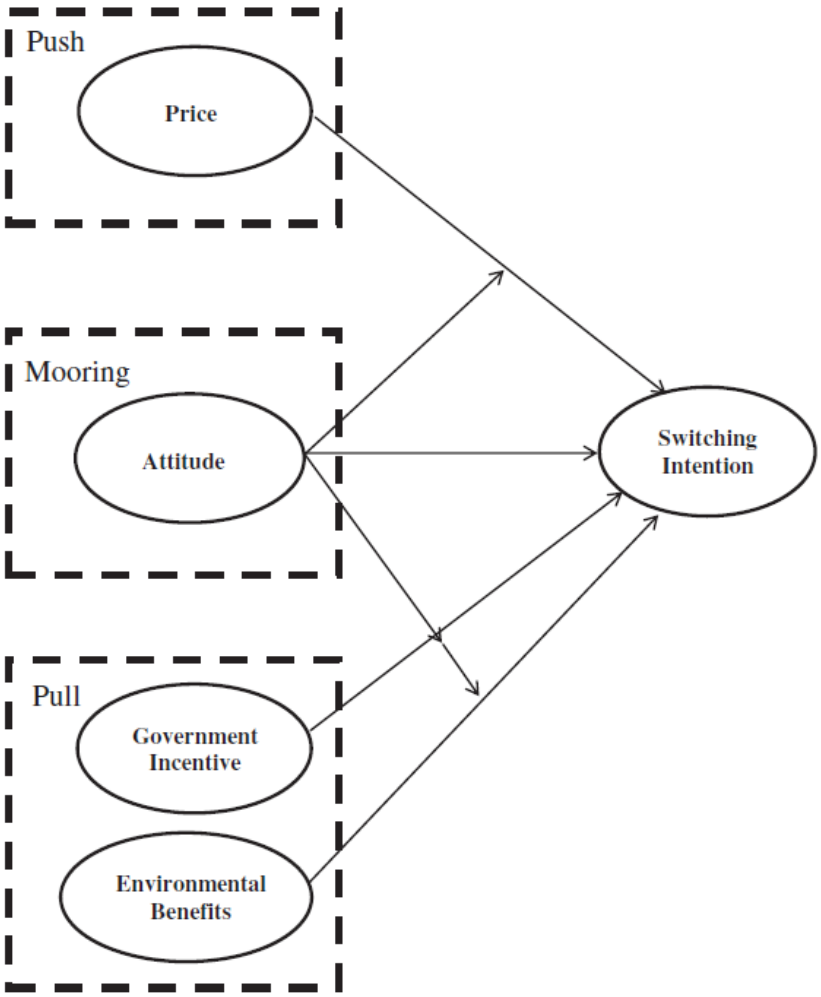

Figure1.3.1.3.1 *Push-Pull-Mooring model to understand the drivers that leads consumers and companies to switch to a circular economy model (Hazen et al. 2017).*

to buy those products instead of buying new ones (incrementing circular economy level in a supply chain).

Pull refers to those macro-level factors that are generally considered as positive and attract people to more appealing locations (Moon 1995; Dorigo et al. 1983). In the economic context, pull factors might be government incentives, in the form of regulations or tax benefits, or superior product performances. In fact, governments usually promote more sustainable activities such as remanufacturing (Stern 2000). Moreover, also the environmental benefits of

purchasing and using remanufactured products has a positive effect on the willingness of customers to change their consumption habits (Teles et al. 2015; Grimmer et al. 2014).
Mooring refers to micro-level factors that intervene (by moderating push and pull factors) in people's intention to migrate to another location and are personal, social, and cultural factors, such as their attitude toward something (Longino 1992; Moon 1995). Then, in the context of a circular economy, the attitude of customers to switch their habits plays an important role in determining their willingness to take this step towards sustainability.

1.3.2 Companies adoption of the circular economy: Circular Business Models

One of the main circular economy definitions is given by the Ellen MacArthur Foundation (2012): "system restorative and regenerative by design, which aims to maintain products, components, and materials at their highest utility and value". Following this definition (and the definitions given in the precedent sections), companies who want to adopt a business model based on the circular economy paradigm should change their value proposition following three CE value drivers (Bressanelli et al. 2018) (Table 1.3.2.1). Firstly, the company should present a solution that maximizes the use of its resources and goods, seeking resource efficiency. Secondly, the company has to design products in order to extend their lifetime. Thirdly, the company should aim to close the loop of resources, that means to improve the reuse, remanufacturing, and as a last option, recycling. These CE value drivers, if appropriately designed and implemented, might increase companies' economic and environmental benefits.

Servitized BM type	**Circular Economy Value Drivers**			**Main drawback with respect to CE adoption**
	Increase Resource Efficiency	*Extend Lifespan*	*Close the Loop*	
Product-oriented		+: After-sales services such as repair, extended warranties, maintenance contracts		This BM type incentives companies to maximize product sales, alongside the negative environmental impact of more products that probably will become waste

Use-oriented	+: Product sharing among users	+: Extra-Services such as extended warranties, predictive maintenance, repair +: Design-to-last products +: Upgrade –: Quicker wear and tear due to less careful usage by customers	+: Take-back agreement +: Design for closing the loop	This BM type could bring a less careful usage by the customers base, leading to a quicker wear and tear
Result-oriented	+: Product sharing among users	+: Extra-Services such as extended warranties, predictive maintenance, repair +: Design-to-last products +: Upgrade	+: Take-back agreement +: Design for closing the loop	It may be difficult to measure results in terms of product/system performance and reach an agreement between customer and supplier
Key: "+" means a positive effect of the BM type on the CE value driver, while "–" means a negative effect.				

Table 1.3.2.1 *Product-service system types and their relationship with circular economy value drivers (Bressanelli et al. 2018).*

For helping companies to transform their business model in circular business model, Bocken et al. (2016) developed three fundamental strategies toward the cycling of resources:

1. Slowing resource loops: By designing long-life items and extending the life of the product (i.e., service loops to extend the life of a product), the period of use of the products is extended or intensified.
2. Closing resource loops: Thanks to recycling, the loop between post-use and production is closed, which leads to a circular stream of resources.

3. Narrowing resource flows, with the intention of reducing the used resources per product.

To close the resource loop, companies can design their products following these strategies: designing for a technological cycle (the aim is to develop products in such a way that the materials can be easily recycled into new materials for the production of new products), designing consumption products for the biological cycle (in such a way products' components can be safely re-introduced into the natural system), or by designing for disassembly and reassembly (products and parts can be separated and reassembled easily) (Ellen MacArthur Foundation 2016). Circular business model strategies for closing resource loops are essentially two: extending resource value (e.g., collection and management of resources that would have been classified as waste, and turn them into value), industrial symbiosis, which concerns with using residual outputs from one process as feedstock for another process, and it usually benefits from geographical proximity of businesses.

Companies and product designers can achieve a slowing of the resource loop by extending the utilization period of the products, which can be done through designing long life products thanks to a proper selection of materials, or through the design for product life extension, that can be facilitated through maintenance and repair; upgrading and upgradability; standardization and modularization; and, in common with closing the resource loop, dis- and reassembly. It is fundamental to design circular products in the early stages because, once the product will be marketed, only small design changes will be possible.

The circular business model strategies for slowing resource loops are four: extending product value (e.g., exploiting the residual value of products), classic long-life model (e.g., delivering durable products with the possibility to repair them), encourage sufficiency (e.g., induce customers to a non-consumerist approach through principles such as durability, upgradability, service, warranties, and repairability), access and performance models (e.g., provide to users all the necessary to satisfy their requirements, products and services, but without the necessity to own the products).

"Narrowing loops" approach differs from the other two strategies, because it has no impact on how quickly items move within the flow of materials, and it does not involve any service loops (e.g., repair). To implement circular economy principles, society, industry, and consumer systems will have to change their fundamentals, using renewable energy, recyclable materials, and reducing waste generation by intentionally narrowing, slowing, and closing material and energy flows.

Business Model Strategies	Definition
Access and performance model	Providing the capability or services to satisfy user needs without needing to own physical products
Extending product value	Exploiting residual value of products (from manufacture, to consumers, and then back to manufacturing) or collection of products between distinct business entities
Classic long-life model	Business models focused on delivering long-product life, supported by design for durability and repair for instance
Encourage sufficiency	Solutions that actively seek to reduce end-user consumption through principles such as durability, upgradability, service, warranties, and repairability and a non-consumerist approach to marketing and sales (e.g., no sales commissions)
Extending resource value	Exploiting the residual value of resources: collection and sourcing of otherwise "wasted" materials or resources to turn these into new forms of value
Industrial Symbiosis	A process-oriented solution, concerned with using residual outputs from one process as feedstock for another process, which benefits from geographical proximity of businesses

Table 1.3.2.2 *Business model strategies to slow and close resource loops (Bocken et al. 2016).*

Stahel (1994) further developed the concept of closing the resource loop, and he distinguishes two fundamentally different types of loops within a closed loop system in a circular economy: firstly, the reuse of goods that is the extension of the period of life of the goods through the design of long-life products, repair, reconditioning, and technical upgrading, that leads to a slowdown of the flow of materials. Secondly, the recycling of materials which is the collection of waste materials, their subsequent processing and transformation into new products or components; anyway, recycling does not affect how quickly materials or goods flow through the economy.

The transition to CE requires not only changes in product design, but also radical changes in their commercialization and consumption. Circular economic models and circular business

models are central to the circular economy (Lewandowski 2016) and are a precondition for its dissemination in the industry (Franco 2019). For this reason, the transition from traditional business models to business models oriented to circularity and servitization is not easy, and often it is done through steps, from a low level of offered services to a fully integrated product-service system (Figure 1.3.2.1). Kristensen et al. (2019) highlighted three maturity levels in the process of implementing circular business models, each with its own specificities. Maturity level 1 is largely concerned with circularity awareness, where it is important to show actual savings and results to all the stakeholders, in order to convince them about the benefits and importance of switching to circularity. Maturity level 2 can be seen as circularity progression, it involves moving from the "customer operation optimization business model to responsibility-sharing service agreements". Finally, maturity level 3 can be described as circularity advancement, and it is achieved when companies move beyond responsibility-sharing service agreements to product-looping business models, and they achieve full circularity. It concerns the development of the necessary skills to manage product ownership over its lifetime, hence could be very useful to develop a strong monitoring system to keep track of the product through its entire lifespan.

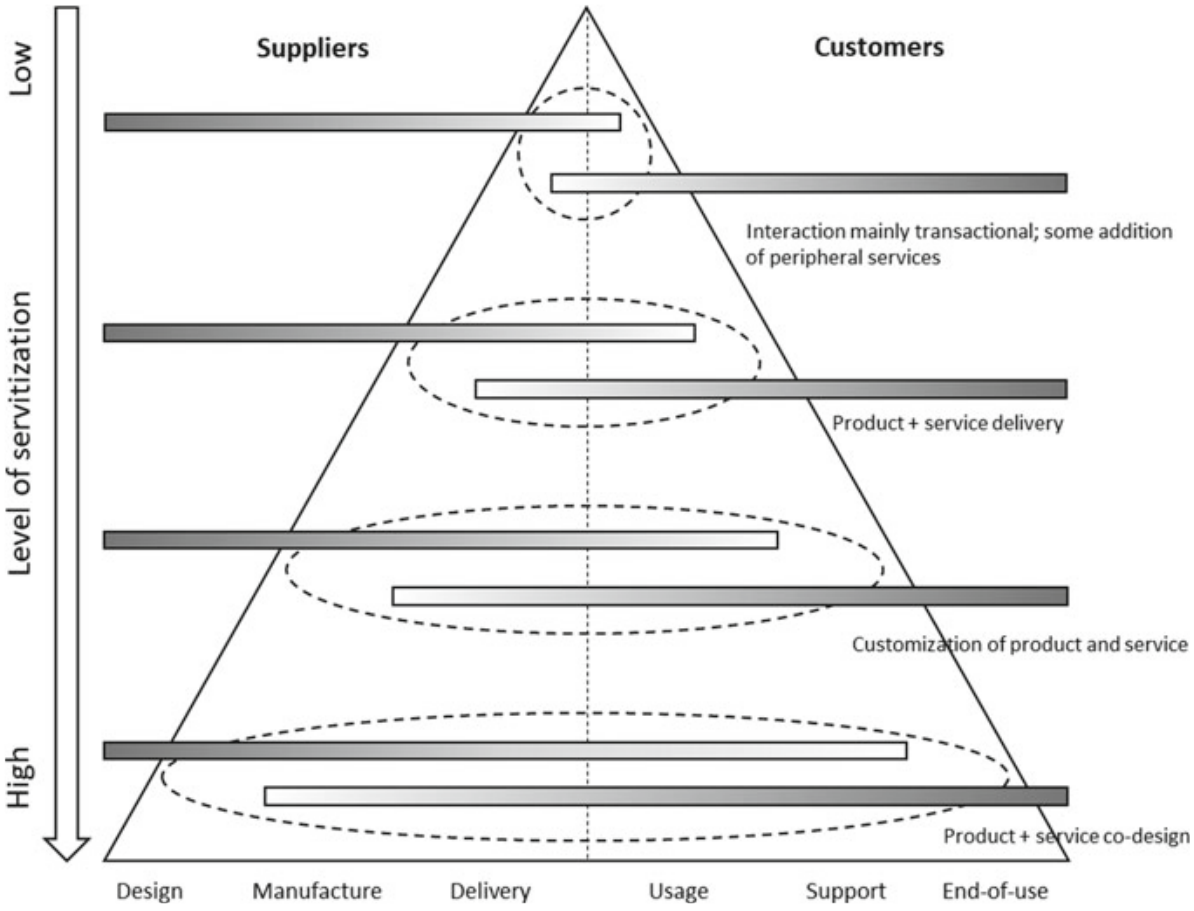

Figure 1.3.2.1 *Levels of servitization of the business model and a simplification of the related strategies (Martinez et al. 2010).*

Since it is not that easy to develop and implement successfully circular business models, often companies adopt mimicry to stimulate business model transformation (Frishammar et al. 2019). Indeed, it might appear paradoxical, but the key driver of the transition to a CBM, which would presuppose a certain level of innovation, is business model imitation. Many companies benchmark or study examples of circular, sustainable, or other innovative business models in firms from their own or other industries (i.e., Michelin's strategy to charge their clients for kilometers traveled thanks to sensors installed inside the tires), and then try to replicate those businesses to successfully gain a competitive advantage. A circular business model transformation can be tricky because it often requires changes to two or more of the key business model dimensions of the business model canvas (e.g., value proposition, key partners, revenue stream, and customer segments). For example, changes in the value proposition must be aligned with the preferences of customer segments, and new types of revenue streams will involve changes in the cost structure (Frishammar et al. 2019). Moreover, many firms often end up operating in multiple business models (PSS and conventional product sales in parallel), which require them to manage a portfolio of business models rather than just a single model (Sabatier et al. 2010).

1.3.3 Configuring Circular Business Models through PSS implementation

Circular business models (CBM) represent a crucial point in the transition to a more resource efficient productive approach and to obtain a circular economy. According to Frishammar et al. (2019, p. 8), "a circular business model is one in which a focal company, together with partners, uses innovation to create, capture, and deliver value to improve resource efficiency by extending the lifespan of products and parts, thereby realizing environmental, social, and economic benefits."

Given the high usage of resources, the manufacturing industry has a great potential to achieve huge benefits of switching to a circular culture and adopt CBMs operations (Ludeke-Freund et al. 2019). However, industry-wide implementation of CBMs is challenging, and it requires companies to consider tactical configuration and skill development to face environmental conditions in diverse markets (Reim et al. 2021). Indeed, there are a variety of different business models and there is not the right CBM for every firm. Because of the large diversity of businesses, the design, and realization of circular business models mainly depends on the willingness and readiness of the organization to change their mindset, their culture (Lewandowski 2016; Reim et al. 2019; Kuhl et al. 2022), and to develop new capabilities useful to successfully face and manage all the difficulties that a company may incur on when implementing CBMs (Lüdeke-Freund et al. 2019). For example, there is often a deep difference

in customers' perceptions of a value proposition when buying a product versus buying a function or result (Frishammar et al. 2019), such as in product-service systems, hence the requirement of skills is different. Similarly, there may be significant changes to the companies' mechanisms of capturing value, such as when revenues from sales of materials-intensive products are replaced with monthly earnings from providing product availability, obtained through servitization. This requires fundamental changes in business logic and often involves collaboration with both old and new players in the firm's ecosystem (Storbacka et al. 2013). All the elements of a business model based on a product-service system offer are depicted in Figure 1.3.3.1.

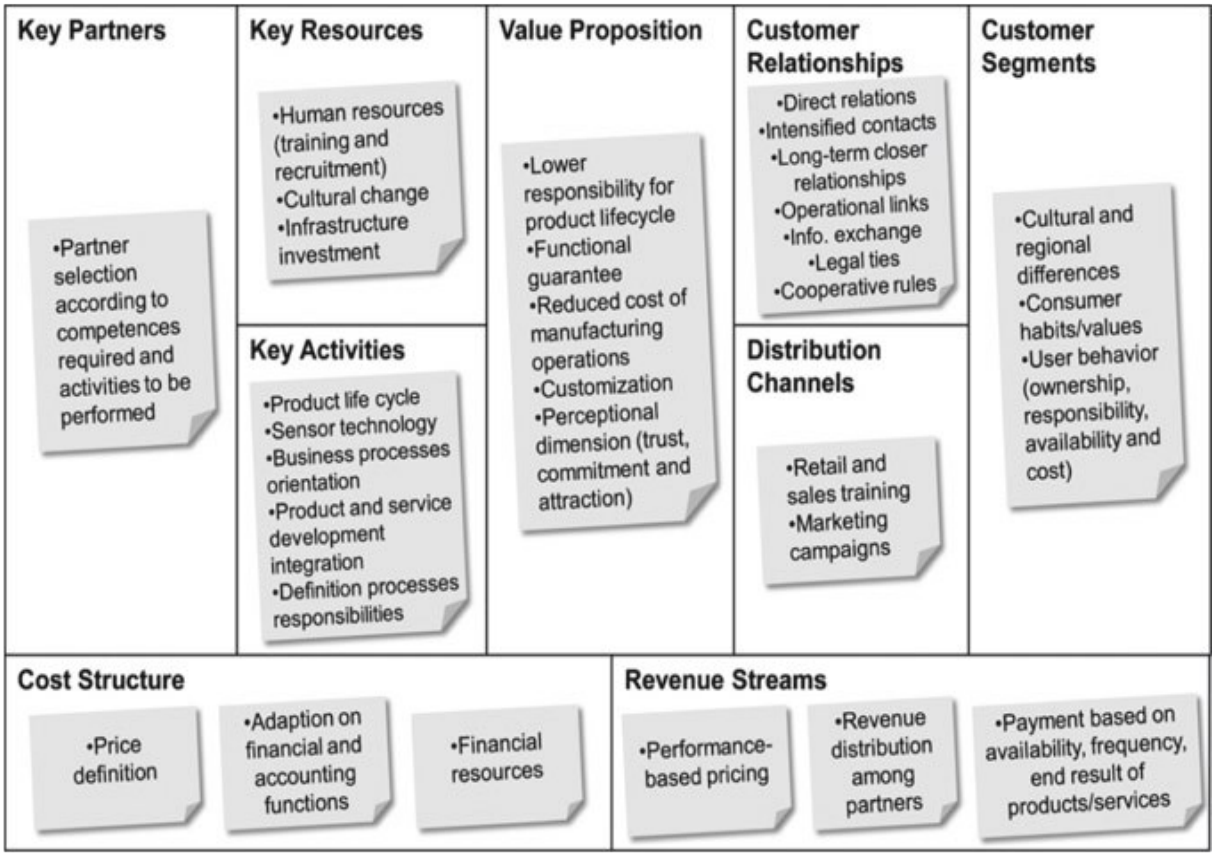

Figure 1.3.3.1 *Business model Canvas of a circular business model based on a product-service system (Barquet et al. 2013).*

With the introduction of a number of components that may significantly alter the offers, PSS significantly adds novelty to "conventional" business models. In fact, Annarelli et al. (2019) highlighted six key elements that characterize a PSS-based business model:

- Value creation
    a. *Design of the offering*. A crucial success element for assuring the creation of successful business models for servitization is redesigning the offering by taking into consideration notions of reuse, collaborative consumption, and redistribution.

It is developed using a modular method and gets increasingly articulated as a bundle of numerous elements that are combined with one another (products and services).

b. *Value co-creation*. Unlike the traditional product-focused model, in the case of adoption of PSS the services generate most of the value proposed to the clients. This value is mostly generated by the interaction between the two parts.

c. *Functional integration with partners*. To increase the competitive advantage, often the companies collaborate with value chain partners (suppliers, external service providers). In particular, it is fundamental to collaborate and collect all the information that comes from the front-office, positioned further down the value chain and in close contact with customers. The front-office unit is essential, because in addition to supplying information, by combining the modules created by the upstream units, it takes part in the design process and creates the systems of products and services that best meet the demands of the consumers. Moreover, given the high complexity of PSSs offers, many companies decide to specialize in their core activities and outsource the remaining processes to third-party companies. This induces the introduction of several new entrants in the value with a strong integration highlighted by a flurry of information and resource exchange.

- Value delivery

a. *Degree of servitization*. According to Martinez et al. (2010), there are four parameters that may be used to assess the degree of servitization and, consequently, the magnitude of the transformation's impact. First of all, the value basis of activities refers to the value provided to customers, which is seen as the key factor in ensuring their retention and ongoing relationship: with high servitization level, long-term relationships maximize the value perceived by customers.

Criteria	**High servitization**	**Low servitization**
Value basis of activities	Relationship based	Transactional based
Primary role of assets	Asset utilization	Asset ownership
Offering type	Total service integration	Physical product plus extra services
Production strategy	Mass customization	Mass production

Table 1.3.3.1 *Criteria to assess the company's servitization levels (Martinez et al. 2010).*

Secondly, the primary role of assets, because a servitized business model has a high focus on asset utilization rather than its ownership. Third, the offering type is related to the three types of PSS. A low level of servitization simply implies an addition of

services to the offer, instead a high degree of servitization implies a full integration of product and services. The last element, production strategy, is characterized by a mass production in low servitized BMs, and by mass customization in high servitized BMs.

b. *Pre- and post-sale value communication*. This is the company's area that faces the strongest change in a PSS transformation process. Given the fact that PSS offers are largely based on co-creation with customers, it becomes necessary to establish profound relationships with them. For this reason, the human resources involved in this process may need to develop more skills than before. They should strengthen their technical knowledge on the services provided by the company, as well as increase their knowledge of the company business and customer's operations. Moreover, they have to be able to communicate adequately the value provided by the new offer in the pre- and after-sale. In fact, given the intangibility of the services, it may be difficult to make the customers aware of the real value delivered, thus understanding how to create appropriate quantifiable criteria is essential.

- Value capture

  a. *Short-term and long-term commitments and retention of customers*. The last characteristic of a PSS based business model, as already emphasized by the crucial component of value co-creation, relates to the function of customers in the total PSS offering. This, as detailed in the next section, has a great impact on the contracts that regulate the relationships between the two parties (i.e., the distribution of the risks and responsibilities). Moreover, in the after-sale process the service must be provided for a long time (sometimes for the entire life of the products), implying a deep change in the value chain and in the company's business model.

It can be useful to also analyze the Linder et al. (2017, p. 183) definition of circular business models: "a business model in which the conceptual logic for value creation is based on utilizing economic value retained in products after use in the production of new offerings. Thus, a circular business model implies a return flow to the producer from users, though there can be intermediaries between the two parties". This definition leads to the fact that companies change the logic of their offer and can expect changes in the ownership of assets. In fact, the retention of the ownership of the goods facilitates the return flow of the used products to the manufacturer (Östlin et al. 2008; Sundin et al. 2005).

Lewandowski (2016) uses six business actions that facilitate the implementation of the principles of the circular economy in companies' businesses and are represented by the

ReSOLVE framework (Ellen MacArthur Foundation 2015b). The ReSOLVE framework is composed by regenerate, share, optimize, loop, virtualize, and exchange (Rosa et al. 2019b). *Regenerate* describes the transition to renewable energy and materials. *Share* actions aim to maximize the utilization of products by sharing them among users, but it is also meant to increase the product life through maintenance, repair, and the design of products to last over time. *Optimize* actions' goal is to increase the efficiency of a product, also reducing the waste during the production process, and it is usually done through automation, remote sensing, and the collection and analysis of production data. *Loop* actions aim to keep components and materials within closed loops, prioritizing the inner cycles (Figure 1.3.1.1) over the outer ones (e.g., reuse and recovery come before recycling) (Yang et al. 2018). *Virtualize* actions seek to fulfil customer's needs virtually instead of physically. *Exchange* actions relate to the substitution of old materials with advanced nonrenewable materials and/or through the application of new technologies (Reim et al. 2021).

Many of these business actions can be achieved through the implementation of product-service systems. Therefore, it should be important to deeply understand how PSSs can be effectively integrated in the companies' businesses and thus to ease the transition to a sustainable economy.

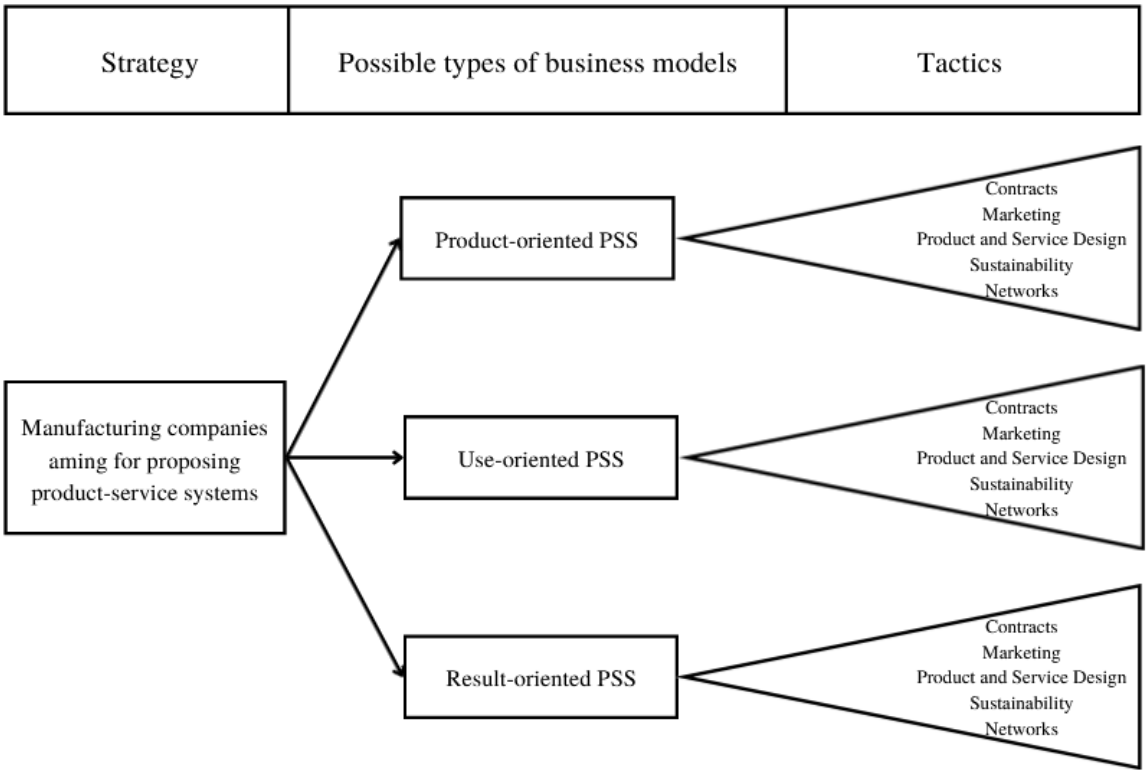

Figure 1.3.3.2 *Relationships among strategy, business models, and tactics for the development of product-service systems (Reim et al. 2015).*

To this regard, Reim et al. (2015) identified five tactics that might be considered in product-

service systems implementation and that are relevant to an effective circular business model execution (depicted in Figure 1.3.3.2). The first of the five tactic areas, *contracts*, addresses how rights and liabilities are distributed among the parties involved, that are significantly much more complex than selling a traditional product (this PSS aspect is further explored below). The second of the five identified tactics, *marketing*, describes how CBMs providers interact, communicate, and use customers and market insights to implement their business models (i.e., long-term relationships with customers). In fact, marketing activities differ significantly from traditional product-oriented to service-oriented marketing.

The third tactical area, *networks*, describes how CBMs providers use their network of relationships with all the stakeholders to ensure an effective implementation. However, the alignment of incentives within a group of ecosystem actors is often complex. For example, service partners may act opportunistically by selling service contracts without taking full responsibility for service maintenance costs, which must then be borne by the original equipment manufacturer (Frishammar et al. 2019).

The fourth area, *product and service design*, describes how providers design their products and integrate them with services to meet the diverse needs of customers.

The final tactical area is *sustainability*, because the implementation of PSS and CBM strategies does not automatically lead to circularity. Indeed, companies could be driven only by economic benefits and lead to higher consumption of resources.

In order to achieve real change in companies' business models and to move to more advanced levels of the circularity of the business model, numerous capabilities need to be developed. In fact, moving to the next maturity level (starting from the most basic level of circular production for moving to a circular service with a well-developed PSS) (Kristensen et al. 2019) is particularly challenging when the number of services increases, because the entire organization has to collaborate, and all the functions must be coordinated.

Reim et al. (2021) grouped those necessary capabilities into three macro categories: solution configuration, orchestration, and digitalization capabilities. Solution configuration capabilities are necessary to combine products and services (and digital components) to obtain circular benefits.

Orchestration capabilities describe the ability of managing and collaborating with the network of existing and new partners to achieve organizational goals. Examples of orchestration activities are nurturing (i.e., providing additional incentives), negotiating (i.e., resolving conflicts and tensions), and standardizing (i.e., seeking formal certification) to ensure an alignment of actors' interest, and to reduce the likelihood possible opportunistic behaviors

inside an ecosystem of partners network (Frishammar et al. 2019). Ecosystem leaders orchestrate all the business activities to create a common vision, with shared goals, to align the interest of the stakeholders involved. Parida et al. (2019) define orchestration as “a set of deliberate, purposeful actions by a core firm” (enforcing the rules of the game and ensuring that other partners adhere to the rules). For them, the role of ecosystem orchestrator or leader is critical for the implementation of circular economy principles, because the leader creates a shared vision of the values that should be nurtured.

Digitalization capabilities define how companies utilize data and analytics, collected from the PSS (and from other tools), to develop increased product life-cycle knowledge. Data can be used for example for preventive maintenance, to inform customers on how they are using the product to increase the efficiency, but also to understand customers’ consumption habits.

In fact, the Internet of Things (IoT), 3D printing, Big Data and related analytics, virtual and augmented reality, etc., are examples of digital technologies that form the core of the fourth industrial revolution and have been labeled as "disruptive" (Bressanelli et al. 2018). These technologies allow companies to implement BMs based on servitization and facilitate the transition to a CE. For example, the application of IoT into products allows manufacturers to have products always connected and keep track of how they are used and therefore give advice to customers to increase their useful life. Moreover, they can collect useful data that may also help in the activity related to end-of-life management. This enhances also the upgradability of the product components, contrasting the obsolescence of the products.

The higher the level of circularity, the higher the level of capabilities required to succeed and to keep a competitive advantage while developing circular business models.

Parida et al. (2019) developed, through the analysis of case studies, a two-stage process to achieve financial, social, and environmental benefits, and mainly to obtain an ecosystem transformation toward a circular economy (Figure 1.3.3.3). The starting point is the ecosystem readiness assessment, for understanding the orchestration and transformation processes that manufacturing companies and their ecosystem partners must undertake to move toward a circular economy paradigm. The readiness can be assessed through the analysis of:

- External trend assessment, that consists of analyzing trends that may directly or indirectly affect the business potential of the ecosystem, such as market trends.
- Business model assessment, with the goal of shifting from resource-intensive product-centric business models, toward service-centric business models such as pay-per-use models or outcome-based contracts.

- Ecosystem partner assessment (i.e., stakeholders), aiming at having a deep knowledge of their ecosystem partners' roles and responsibilities. Stakeholders are very important in a CBM transition process.

Afterward, to ensure real change, companies need diverse ecosystem orchestration mechanisms:

- Standardization mechanism, by developing both informal, where manufacturing companies create dominant standards that are largely accepted by the industry (even though not legally binding), and formal that implies large-scale acceptance from all the partners within the ecosystem, also those that are not strictly related to the company.
- Nurturing mechanism refers to how orchestrators should support the ecosystem to enable rapid innovation, which in turn supports a thriving business environment. It is done through initial investments and by showing the path to ecosystem partner companies to achieve circular business models, lead them to develop new routines and processes, and to open toward sharing core knowledge and information.
- Negotiation mechanism, by aligning actions across multiple ecosystem partners (old and new) and by setting the rules of the game, based on give-and-take relationships, reducing conflicts through relational interdependence between selected ecosystem partners, inclusion of new partners based on risk and benefit analysis.

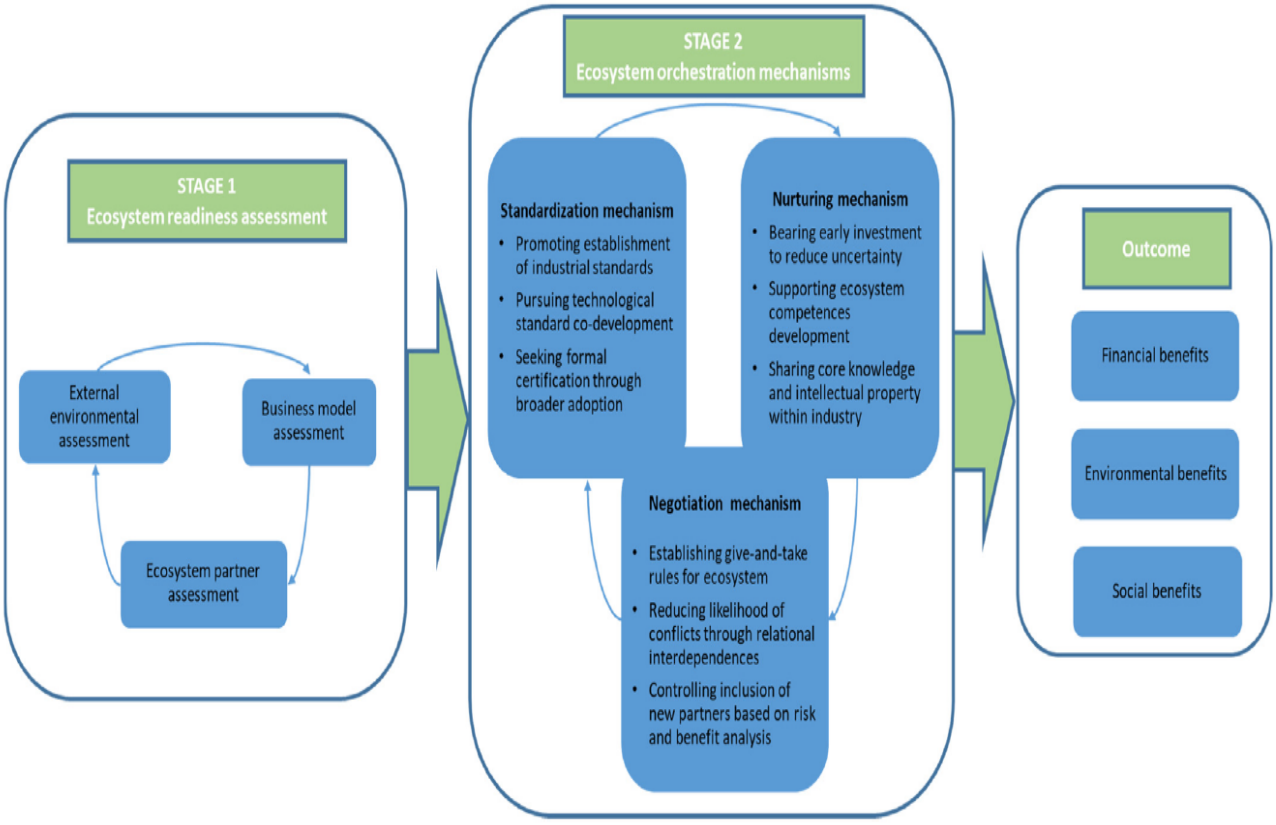

Figure 1.3.3.3 *Two-stage process model developed by Parida et al. (2019).*

McAloone et al. (2018) deeply investigated and developed a framework that helps to understand how to effectively develop PSSs in a CBM perspective. The framework includes four fundamental PSS dimensions (key elements that should be considered when designing a PSS) and four PSS design stages (steps from conceptualization to implementation) (Figure 1.3.3.4). The PSS dimensions are:

- Value proposition, that is the starting point for conceptualizing a PSS, with the aim of maximizing the value creation for the key stakeholders.
- Offering life cycle, because usually in a PSS-based business, the producing company assumes greater responsibility for the product, and it leads to the need of developing new competencies (e.g., customer support, maintenance/upgrade services). Thus, it can be useful to map and design the solutions for the entire life cycle of the product.
- User activity cycle, that is a conceptual map of the key stakeholders' needs, and the sequence of how to satisfy them. For circularity purposes the phase after the purchase is the most important, as it is the phase in which strategies like remanufacturing, reuse, recycling, etc. traditionally take place.
- Ecosystem (actor network), that is the understanding, mapping, and actual integrated designing of relationships among relevant stakeholders, which is important for ensuring an enhanced sustainability performance of the value chain.

After understanding the most important PSSs dimensions, companies can proceed to design the PSS, following an iterative process. In fact, generally the designing and development of PSSs moves through steps that McAloone et al. identified as analysis, definition, conceptualization, and evaluation.

- The analysis phase focuses on the comprehension of the impact of products and services in relation to the value that they provide, before attempting to change and improve existing systems. Usually, CE requires additional data related to customer behavior, digital technology, and cultural aspects.
- The definition phase should result in a precise PSS description, sufficiently detailed to fulfill the needs of the customer and a basic specification for the emerging PSS, including goals that can be obtained for the final PSS design, like the achievement of circularity or the increase of sustainability performances.
- The conceptualization step should result in a precise description where all relevant dimensions should be sufficiently described, and unknown risks investigated (i.e., legislative barriers, consumer behavior change). It involves the development of

prototypes, in order to test out the various ways in which the identified customer needs can be satisfied.

- The evaluation is the last step, and at this point a PSS solution should have been implemented, thus it is necessary to understand if the company is able to fulfill the customer's requirements, and possibly adjust the offer adequately.

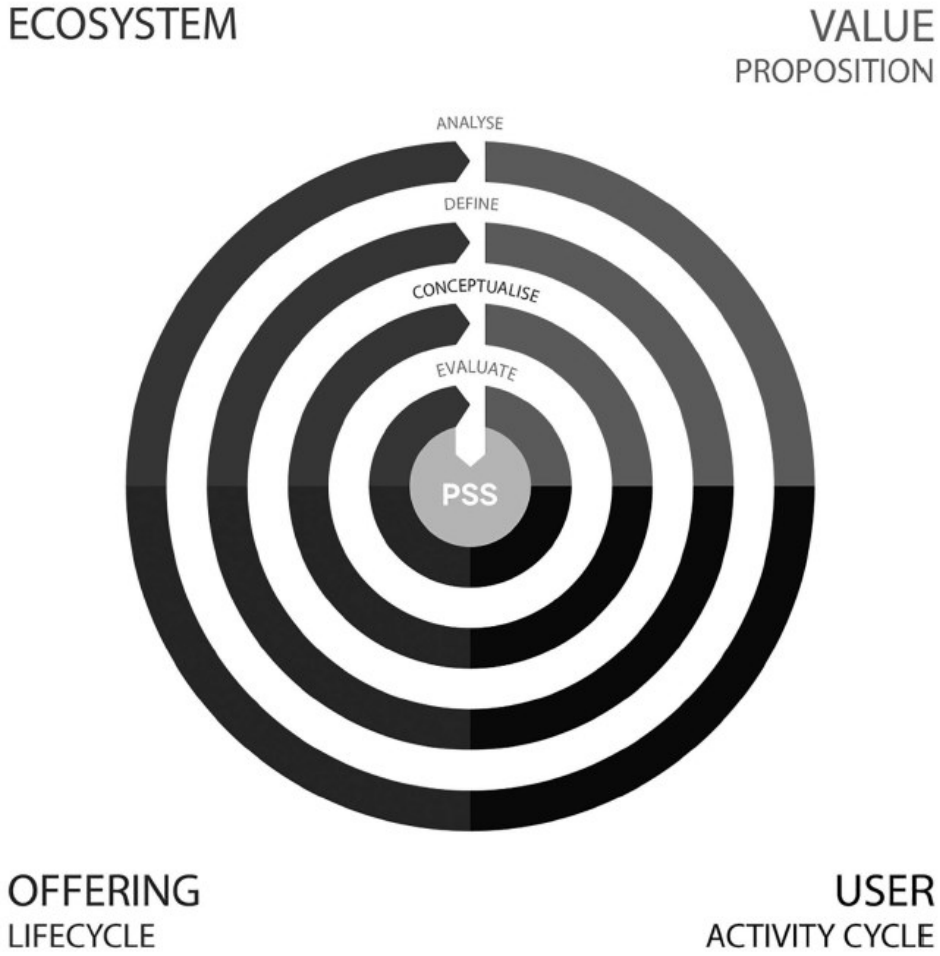

Figure 1.3.3.4 *McAloone et al. (2018) framework to implement PSSs.*

1.3.3.1 Contracts' characteristics in servitized business models

In a typical (linear) business model, after the purchase, all the responsibilities switch from the seller to the buyer. But, in a scenario where the seller does not sell only the product, but provides an integrated system of product and service, and therefore, he or she is providing an ongoing service (especially in use- and result-oriented PSS). The consequence is that also the contract must be changed, especially because the allocation of risks and securities between the service provider and users have to be redefined (Fischer et al. 2022). In particular, in the new contractual forms of PSS the role of financial risks and the responsibilities toward the product must be emphasized, in order to ensure user acceptance of product-service systems models

(Cherry et al. 2018). In fact, the acceptance and adoption of PSSs largely depends on how the consumers perceive them (Rexfelt et al. 2009). This is because consumers may be not interested in PSS phenomena per se, but they are likely to care more about the practical consequences that those PSS has on their consumer experience. Therefore, one of the main drivers on which PSSs adoption depends is the uncertainty of the quality or the reliability of these types of offers. For this reason, PSS contracts must reduce the uncertainty of servitized business models, in order to build a win-win situation for both customers and service providers. Moreover, consumer law has a role to play in informing consumers of models that are truly sustainable in order to make informed choices. In fact, as mentioned above, companies may engage in servitization not only for sustainability purposes, but primarily to generate increased margins (as the margin on service may be higher), to create a competitive advantage (product-service bundles are in general harder to imitate than pure products), and because of the possibility to "lock-in" consumers (Hojnik 2016; Mak et al. 2020).

Fischer et al. (2022) wrote that contracts design in a CBM process for PSS tends to focus on defining ownership of and access to joint materials, resources and modules, of the product, rather than focusing only on transactional aspects. Contracts should be designed to address the "tensions" of servitization, longevity and modularity, and to provide the enabling legal conditions for the implementation of a PSS model.

Hence, in a contractual agreement involving PSSs, there are three key aspects that should be carefully considered (Annarelli et al. 2019), and that might change according to the type of PSS (Table 1.3.3.1.1):

- Responsibility and terms of the agreement. They concern how the responsibilities are allocated among the contract's parties and what specifics are required to make rights charges clear from a purely legal standpoint. In product-oriented PSS, the ownership of the product is in the hands of the consumer, thus the provider has only to provide the additional services. Instead, in use-oriented PSS, the ownership of the product remains in the hand of the producer, hence, all the agreements regarding for example availability, price, or responsibilities over the product must be reported in the contract (Richter et al. 2010). The producer's responsibilities over the product reaches the maximum level on result-oriented PSS.
- Complexity and formalization. Usually contracts in product-oriented PSS are more formalized and standardized, given the standardization of the offer solutions, instead in result-oriented PSS there is the lowest level of contract standardization. Moreover, in result-oriented PSS the level of complexity is very high, given the fact that the responsibility is completely in the hand of the producer. Finally, when the customer-

provider relationship grows, the contract becomes more complex, leading to the need to enter into multiple parallel contracts (Azarenko et al. 2009).

- Level of risk. In product-oriented contexts, risks are typically associated with scenarios in which additional resources are required to fulfill the requirements of the contract, forcing the provider to reevaluate its business practices. All the risks associated with opportunistic customers' behaviors can be mitigated by adding the right terms of the contract (Azarenko et al. 2009). Instead, the risks of incorrect customers' behavior rise in use-oriented models because the ownership is not transferred to the customer, making it necessary to agree on the decision rights (Reim et al. 2015). In result-oriented contexts, the risks are all associated with the achievement of the promised results and the responsibilities lie with the service provider.

PSS category	**Liability and terms of the agreement**	**Formalization and complexity**	**Risk component**
Product-oriented	- Charges for services - Agreement on tasks, payments, and information management	- High formalization - Low complexity	- Low risk - Adverse behavior
Use-oriented	- Charges concerning availability - Definition of the level of availability and monitoring activities	- Average formalization - Average complexity	- Average risk - Adverse behavior
Result-oriented	- Charges concerning performance	- Low formalization - High complexity	- High risk - More freedom for provider

Table 1.3.3.1.1 *Summary of the contractual characteristics in business models based on product-service systems (Annarelli et al. 2019).*

1.3.3.2 Product ownership preservation enhances sustainability

As mentioned, offering PSSs, or in other words following a servitization strategy, helps the company's transition toward a CE, as it increments the sustainability performance of traditional product systems, due to its potential to extend product lifetime and decoupling value from the delivery of physical products, in such a way obtaining resource efficiency. Hence, the traditional ways of product consumption and utilization are replaced by the possibility of meeting customers' requirements through the delivery of increasingly dematerialized services, which often imply a change in the ownership structure (Mont 2002), that leads to a change in the companies' business model.

When producers maintain the full responsibility (property) of the products' life cycle, they are incentivized to optimize use of energy, to recycle materials wherever is possible, to increase the durability and extend the useful life of goods. Renting products may also imply that a product is more intensively used, with further potential for a reduction in the use of resources (Tukker 2004). Manufacturers have better insights (often derived from the collection of customer information) into what products that could be possible to invest in, in order to improve them and make them more (resource) efficient. This increases the incentive for customers not to make long-term investments in the ownership of products, but instead, focus on the payment for satisfying their needs, and letting producers choose, implement, and use the product that is most resource-efficient at that moment to fulfill their needs (Grahn 2022). This drives business models from generally investing in products to pay for obtaining a result (i.e., servitization).

The ownership of the product is one of the key elements of the PSS, particularly in use- and result-oriented, that mostly leads to a CE. Indeed, when companies retain the ownership of products, and have a strong control over the life cycle, leads them to create more value for the customer (Yang et al. 2018). The company therefore has the incentive to increase the sustainability of the products used by the clients. Hence, use-oriented and result-oriented PSS are more suitable for incrementing the circularity of the business model due to the fact that the ownership is in the hand of the manufacturer (Yang et al. 2018). Moreover, retaining the property of the product means that at the end-of-life phase of the product, the customer has the responsibility to return it to the manufacturer, who can decide how to manage it. It can be recycled into new products or components, or it can be refurbished and re-entered into the loop.

1.3.4 Challenges to design and develop servitized Circular Business Models

Companies may face some challenges when implementing CBMs. In fact, the adoption of more sustainable practices may be affected by some contextual factors that influence the environment in which the company operates, enhancing or limiting the possibility to effectively implement

PSSs and circular business models. In this regard, Kuhl et al. (2020) analyzed and grouped into six clusters eleven contextual factors that influence how circular practices inside a supply chain (i.e., supply chain circularity, SCC) are implemented. These supply chain contextual factors, and their effects, are represented in Table 1.3.4.1.

Cluster	Contextual factor	Description	Effect on circular supply chain practices
Economic attractiveness of SCC	Cost impact	Additional costs for implementing circular supply chain practices	- Negative by increasing operational, planning, and/or sourcing costs - Positive by reducing maintenance and/or after-sale service costs
	Growth opportunities	Economic opportunities stemming from selling products multiple times	- Positive by creating new revenue sources
	Risk of cannibalization	Risk that circular practices may reduce new product sales	- Negative by threatening sales
Firm sustainability strategy	Firm sustainability strategy	Firm internal sustainability strategy and circular economy policy	- Positive by increasing the organizational and individual commitment to circular supply chain practices
Policy and societal environment	Customer acceptance	Customer acceptance of innovative business models and/or refurbished/ remanufactured products	- Negative due to customer perception that refurbished/remanufactured products have inferior quality
	Laws and regulations	Relevant existing laws and regulations	- Negative by preventing waste recovery; stifling collaboration through competition laws

			- Positive by supporting practices, for example, through tax benefits and/or recycling requirements
	Waste management infrastructure	Existing infrastructure for collection and processing of wastes	- Positive by providing the necessary infrastructure to implement collection and recovery activities
Product category	Product characteristics	Includes product lifetime, complexity of product designs, as well as functional, economic, and aesthetic deterioration over time	- Positive by having stable technology; a core that can be reused; low deterioration of economic value - Negative by limiting recovery options (e.g., material restrictions); being subject to fashion changes
Supply chain relationships	Cross-sector supply chain collaboration	Actors engage in collaboration with actors outside their supply chain to prevent impacts, resources from becoming wastes	- Positive by enabling the development of cascading resource flows
	Supply chain integration	Degree to which intra- and interorganizational processes are managed collaboratively	- Positive by facilitating information sharing and alignment of actors towards desired outcomes
Technology	Digital technologies	Digital technologies around the internet of things, big data, tracking and monitoring	- Positive by providing information on asset use, condition, and location; facilitating maintenance, repair activities; providing information to improve

	product design; facilitating recovery

Table 1.3.4.1 *Supply chain contextual factors that affect circularity developed by Kuhl et al. (2020).*

In another interesting study regarding this topic, Pathak et al. (2020) analyzed every possible obstacle to increase the level of sustainability in manufacturers' operations. They highlighted twelve obstacles, and they grouped them into four clusters: legislation criteria, manufacturing industry criteria, academicians and other experts' criteria, and financial criteria. All the obstacles and the clusters are depicted in Figure 1.3.4.1.

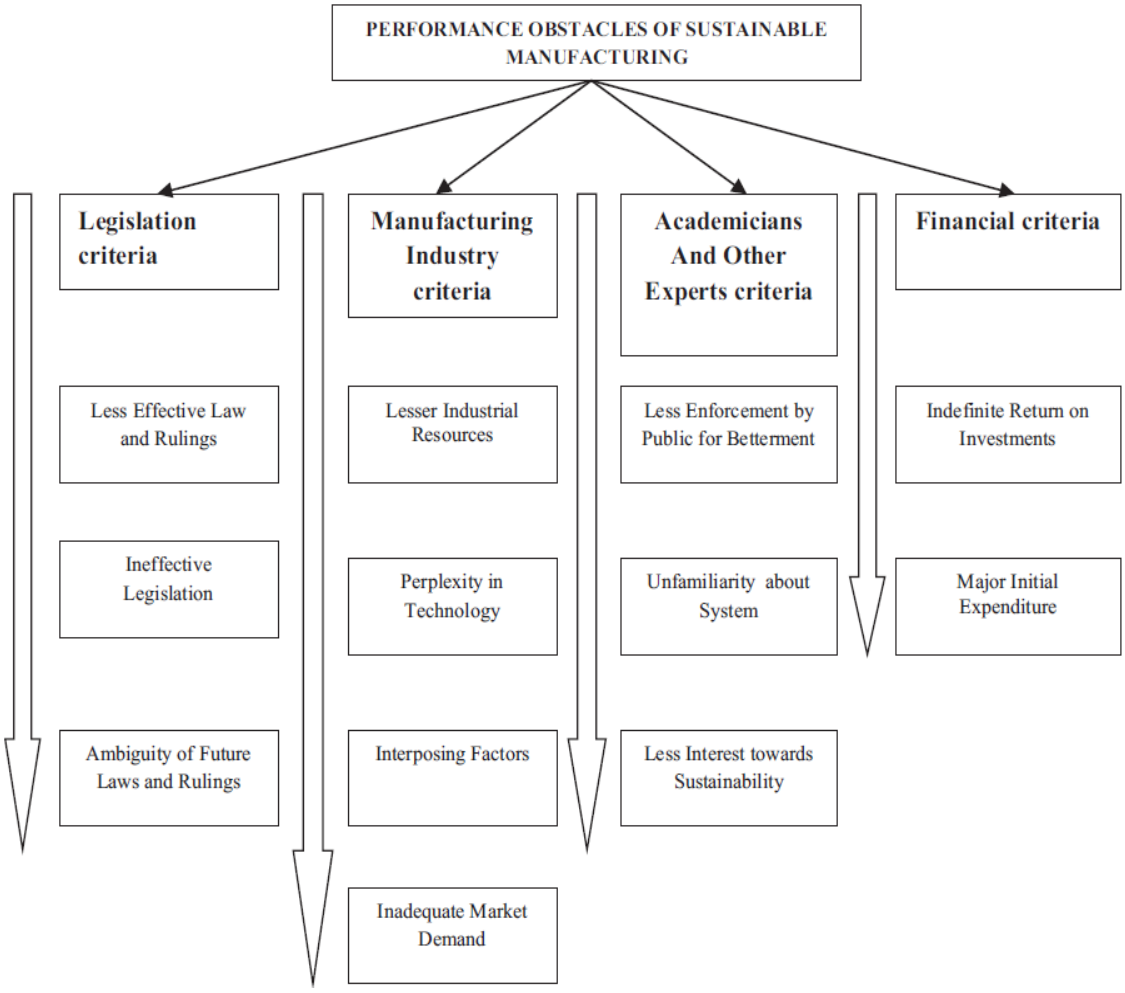

Figure 1.3.4.1 *Obstacles of increasing sustainability in manufacturing companies (Pathak et al. 2020).*

Legislation criteria comprehend:

- Less effective laws and rulings: no one follows sustainability practices if the laws are absent or ineffective (Pati et al. 2016).

- Ineffective legislation: the lack (or weakness) of law enforcement on environmental impact leads to a reduction in the pursuit of sustainability guidelines by companies (Luthra et al. 2016).
- Ambiguity of future laws and rulings can lead companies to disregard sustainability laws (Bhanot et al. 2017; Mangla et al. 2017).

Manufacturing industry criteria comprehend:

- Lesser industrial resources: the lack of financial or human resources may reduce the environmental sustainability's commitment (Koho et al. 2011).
- Perplexity in technology: the adoption of a new technology might take a lot of time, finances, and knowledge (Bhanot et al., 2017).
- Interposing factors: Businesses in any terms always follow the fluctuations of the market demand. This works also for sustainable practices in manufacturing industries, thus the higher the demand for sustainability, the lower the companies' footprint (Mathiyazhagan et al. 2013).
- Inadequate market demand: the market, in particular clients, has to "push" companies to lead them to increase their level of production sustainability.

Academicians and other experts' criteria comprehend:

- Less enforcement by public for betterment: the push of mass media, municipal majors, politicians, and funding authorities toward increasing sustainability is too low (Bhanot et al. 2016).
- Unfamiliarity about the system and of sustainable practices (Bhanot et al. 2015; Mangla et al. 2017).
- Less interest towards sustainability of all the stakeholders, decreases the level of sustainability of an industry (Mathiyazhagan et al. 2013; Malek et al. 2019).

Financial criteria comprehend:

- Indefinite return on investment, given the fact that it is a relatively new type of investment, companies are unclear on the success rate of these investments and their return (and costs) (Mathiyazhagan et al. 2013).
- Major initial expenditure for the implementation of new technologies or to upgrade the oldest one (Amrina et al. 2011; Mangla et al. 2017).

1.3.5 Midlife product upgrades reduce companies' environmental impact

As already mentioned, prolonging the lifetime of a product is one of the main strategies to obtain a CE through an increase in resource efficiency. In fact, servitization strategies and PSSs are strictly connected to product life cycle management (PLM). The life cycle of a product is

divided into three main stages, beginning of life (BOL) (i.e., design, tests, and production phase), middle of life (MOL) (i.e., product usage phase), end-of-life (EOL) (i.e., dispose, recycle or refurbish phase) (Khan et al. 2020). The MOL phase is the most important phase for a PSS provider, because it is when all the customers' requirements are met, and the value can be increased by adding services to the offer for creating the PSS. In fact, it is true that from a circular perspective also the BOL (by designing product to be easily maintained) and EOL (through the right disposal activities) are fundamental to achieve a more sustainable offer, but it is in the MOL phase where products can be upgraded, combined into new product and services, or can be incremented the products' lifetime through revamping activities. In addition, if we consider complex equipment or machinery (for example with a lifespan of between 10 and 30 years) the opportunities to implement PSSs especially aimed at maintenance are enormous (Wang et al. 2020). The upgrade of products is defined by Khan et al. (2018, p. 1160) as all the actions aimed at "effectively (ensuring consumer value) and efficiently (ensuring positive cost-benefit performance) modernize by incorporating functional and performance improvements during the usage and/or remanufacturing stage". Umeda et al. (2005) distinguishes between two types of upgrades: functional upgrades, which add or remove functions to the product, and parametric upgrades, which alter the performance of the product. Khan et al. (2022) identified some drivers that can lead manufacturing companies to propose MOL upgrades in their offer. They clustered these drivers into three groups: strategic drivers, that mainly regard the increasing of the competitive advantage over the competitors by differentiating the offer. The marketing drivers, which regard all the efforts to meet market requests, which can come from customers, but also from the government, for example through new regulations. Finally, the financial drivers that concern the willingness to stabilize the revenues and to increase profit margins.

Strategic drivers	Marketing drivers	Financial driver
- Upgrading competitor's equipment helps to grow the aftermarket service base. - Reduced time to market for newly developed technologies.	- Upgrades enable compliance with new regulations (e.g., safety or environmental). - Obsolescence of subsystems for which spare parts are no longer available.	- Better profit margin compared to new equipment sales. - Comparatively stable revenue during economic downturn.

- Having a portfolio of upgrade offerings facilitates new product sales.

Table 1.3.5.1 *Drivers that leads manufacturers to offer equipment upgrade service (Khan et al. 2022)*.

Anyway, in order to obtain a circular economy, it is fundamental that the environmental impact of the actions to achieve lifetime extension, is lower than the impact of what companies want to avoid (e.g., increase production, regeneration) (Cooper et al. 2017). Indeed, there are many products in which lifetime extension reduces the environmental impact, but there are others that may not. For example, it may be better to replace some types of products with more technological or energy efficient ones rather than extending their life (Ardente et al. 2014). For this reason, companies should evaluate case by case the environmental convenience to extend the useful life of their products.

From the business model point of view, giving the possibility to upgrade leads manufacturers to consider the fact of involving additional partners who may help by ensuring the efficiency of the upgradability services (Pialot et al. 2017).
The most used tools to quantitatively assess the effects of increasing the durability of products, instead of replacing them with more efficient ones, are life cycle assessment (LCA), and life cycle costing (LCC). The latter also provides a cost analysis (Kaddoura et al. 2019).
Usually, the main reasons to replace a good are the maintenance costs that are getting too high, the introduction in the market of technological improvements that make the existing good obsolete, some changes in the law or regulations (Khan et al. 2020). As a result, MOL upgrades are a key to achieve a CE, and prevent products from being replaced constantly.
However, manufacturers might be hesitant from continuously upgrading their products because this could lead to a cannibalization of the new products and reducing revenues. For this reason, Simons (2017) proposed that manufacturers should change their business models in order to increase the value obtained from upgrades, and to solve some problems deriving from cannibalization. This can be done by switching to CBMs through the implementation of PSSs, in which the focus of the company is on the management of every product's lifetime phase, and in particular where the responsibility of MOL upgrades is transferred to manufacturers, so that users have only to pay for the service and for the value received. It is particularly true in result-oriented PSSs, where consumers are only interested in having a nice performance (Khan et al.

2020). Anyway, as aforementioned, it is fundamental to understand the importance of MOL upgrades already in the early stages, in order to design products in such a way that it will be easier for manufacturers to upgrade those products in future stages of their lifetime. One of the most important ways of doing this is through modularization and standardization of the components.

Moreover, usually it can be useful to install numerous sensor (when possible) for monitoring the performance of the products, decide the right time to contact the clients for preventive maintenance (Wang et al. 2020), control the environment while the product is used, collect useful data, and for implementing the right PSS that is effectively able to satisfy the customers' needs.

A practical implication may be that the aforesaid scarcity of financial resources for SMEs as a PSS implementation barrier, could be overcome, for example through the renting or leasing of machinery and equipment. In fact, upgrading the equipment is the responsibility of the provider, and this reduces the costs for the SME (Wang et al. 2020). Given that manufactures retain product ownership, they can manage the technology cycles and consequently efficiently plan all the upgrade operations and reduce their costs (Copani et al. 2018).

2. Empirical investigation

2.1 Methodology

Given the fact that the topics covered in this thesis are still not thoroughly explored and not yet fully understood, there was the need to perform qualitative research through interviews in addition to the literature review. The subjects who were interviewed deal with these dynamics on a daily basis and therefore can offer a more concrete (and complete) contribution to my analysis.

The case study analysis was developed in two steps: in the first step two experts were interviewed, in order to facilitate the process of selecting the right companies to be analyzed and for trying to deepen a relatively new and unexplored topic. In the second phase, interviews were held with companies deemed suitable and interesting for the purposes of the thesis.

In detail, it has been used the multiple case study technique (i.e., a case study that includes the examination of many companies) (Yin 1983), through the analysis of different subjects in order to enable a deeper understanding of a phenomenon that is still evolving and has not completely understood. In all the case studies analyzed, the focus remained on the implementation of CBMs and/or achievement of sustainable practices through the design and development of product-service systems. Thus, the case study analysis was carried out to empirically understand if there is a concrete relation between the implementation of services or the adoption of a servitized BM and the increase of the company sustainability (that is the main focus of this thesis project).

2.1.1 Servitization and circularity in experts' opinions

In the first step of the case study analysis, I decided to interview a servitization expert and an expert in the field of circular economy, to further understand the two main topics of this thesis project. The main reason was to deepen a topic that is relatively new and unexplored, and to understand which were the most interesting cases to analyze.

Themes	Stefano Butti	Gianmarco Bressanelli
Company size benefits in implementing CBM	Startups have advantages over large corporations on servitization	- Large companies have access to more resources that facilitate the introduction of CBM - Flexible and agile small business

		structure as an advantage in implementing CBM
Servitisation enables the transition to the CE	- Result-oriented BMs lead to increase the products' lifetime - Servitized BMs lead to CE - Increased demand for services aimed at giving "peace of mind" - Digitization helps in the transition to servitized CBM - End-of-life management is easier if data is collected throughout the life of the product	- Servitization as the key to boosting the circular economy and enabling CBMs - Ownership and responsibility for the good remain with the producer as an incentive to circularity
Barriers to servitization and circularity	- The new advanced services risk cannibalizing the sales of some products - Widespread environmental sustainability will only be achieved if it guarantees an economic return	- Cost, culture, technology, and legislative barriers as challenges to implementing CBM - Cultural barriers to servitization in BtoC - Financial barriers to servitization in BtoB - The economic return in CBMs occurs in the medium-long term
Evolution of circularity and servitization in the future	- The unsustainability of the linear model pushes towards a future evolution of servitization	- Sustainability as a necessary condition required by the market

Table 2.1.1.1 *Main themes that emerged from the interviews with the experts.*

The first respondent was Stefano Butti, CEO and founder of Servitly, an Italian company based in Como that provides software to equipment manufacturers who want to create value and compete through connected services. Servitly exploit the existing IoT of the companies to collect useful data, elaborate them, and to use this information to support manufacturers. Stefano Butti, thanks to the experience gained in the sector, is an expert in servitization and

product-service systems. This interview was carried out on January 9th, 2023 and lasted around 39 minutes.

The second expert interviewed was Gianmarco Bressanelli, post doc researcher at RISE (Research & Innovation for Smart Enterprises) laboratory of the University of Brescia. Moreover, he is a senior consultant at IQ Consulting S.r.l., that is a spin-off company of the University of Brescia. In his research activities he is engaged in the fields of circular economy and sustainability, in particular their implications on companies' businesses, supply chains and organizations. This interview was done on January 10th, 2023 and lasted 38 minutes.

Both interview guidelines can be found in the Appendix A, and a summary of the main themes emerged on these interviews in shown in Table 2.1.1.1.

From the interviews with the two experts, 4 common themes emerged:

- Company size benefits in implementing CBM. It emerged that the company size can have benefits and disadvantages on the implementation of servitized CBM. In fact, for example small companies have a more flexible structure that allows them to change easily their strategy. At the same time, they have less resource to invest in the transition.
- Servitisation enables the transition to the CE. As mentioned in the literature review, for example the lack of ownership on the product induces companies to prolong the lifecycle of the goods reducing the environmental impact.
- Barriers to servitization and circularity. As emerged in the literature review, the implementation of servitized CBM is not easy and companies may face several challenges.
- Evolution of circularity and servitization in the future. In the experts' opinion the in the future, environmental sustainability will be a necessary condition for corporate business models, and one of the methods to obtain it is servitization.

After interviews with experts, interesting company names emerged to be analyzed, but difficulties arose in contacting some of them. In fact, not all companies were willing to give an interview, often due to their time constraints, thus creating further difficulties in the selection of companies.

2.1.2 Selection of business cases

The selection of the business cases was carried out according to four criteria:

- First, the company should have a service-oriented strategy and a relevant presence of services in the offering (related to the industry).

- Second, the company should be oriented toward a reduction of the environmental impact and/or should have adopted the circular economy paradigm into its vision or mission.
- Third, the cases must be coherent with the companies recommended by the two experts.
- Fourth, the companies must be available to grant an interview and to indicate a contact person.

	Montecolino S.p.a.	**Astelav**	**Ricoh Italia**	**Aquafil Group**
Business	Production of textile floors and coverings	Distribution of accessories and spare parts for household appliances	Production and sale of office equipment	Production of synthetic and artificial fibers
Turnover 2021 (million euros)	15	21	205	574
Number of employees 2022	73	60	730	2805
Name and role of the respondent	Nico Fontana (CEO)	Manuel Odasso (CEO Ri-generation)	Ilia Terlizzi (Head of Service Planning and HSEQ)	Giulio Bonazzi (CEO)
Servitized activities aimed at achieving CE	EOL management	EOL management	EOL management, Predictive maintenance	EOL management
Duration of the interview	1h 28 min	40 min	1h 4 min	25 min

Table 2.1.2.1 *Overview of the case companies.*

Following the criteria, four companies have been selected (Table 2.1.2.1).

The first case selected is Montecolino S.p.a., that is a company based in Brescia, it produces textile floors and wallcoverings. Montecolino has been operating since the early 1970s, but it is from 2017 that they started to evolve their offer and propose a servitization strategy with implications for their sustainability. In fact, starting from 2017 they started to manage all the

life cycle of their products providing the product collection service to have it subsequently recycled by a third party.

As said previously, according to Mont (2002), even service providers (and not only manufacturers) can benefit from the introduction of PSSs in their business model. For this reason, the second case analyzed was Astelav, in particular its spin-off, Ri-Generation. Astelav was founded in Torino by Giorgio Bertolino in 1963, and it is one of the main European distributors of accessories and spare parts for household appliances with the aim of way prolonging the lifetime of products and reducing the environmental impact. Astelav in 2017 created the *Ri-generation* project that is a perfect example of a circular economy because with this project the company gives new life to household appliances, otherwise destined for landfill. In fact, their business model is based on a completely sustainable idea of collecting used appliances (Wastes from Electrical and Electronic Equipment, WEEE) and subsequently regenerating or refurbishing them.

The third case analyzed is Ricoh. Ricoh was founded in Tokyo by Kiyoshi Ichimura in 1936. Between the late 1990s and early 2000s, the company grew, becoming the largest photocopier manufacturer in the world. In 1990 Ricoh Italia S.p.a. was born. They produce and offer software and hardware for workplaces. In particular, they offer office printers, audiovisual systems, software and apps to increase the productivity and efficiency of document management. The printers are made in Japan and shipped all over the world.

They basically have only clients in the BtoB market, and they do not sell printers, but they rent or lease them. In such a way Ricoh retains the ownership of the products enabling them to manage the life cycle of the printers, by providing consulting activities, maintenance, end-of-life management, constant optimization of the equipment through middle of life upgrading, and remote management of product issues. In their value proposition there are many services, such as the “Pay Per Seat” that is configured according to customer priorities, and the payment system is flexible and based on consumption.

Given the high level of servitization of their BM, the variety of solutions offered to the customer, and the implementation of services with the desire to reduce the environmental impact and increase the circularity of the processes, Ricoh can be considered the benchmark in this analysis. In fact, the photocopier industry is considered as one of the main early adopters of servitization (Visintin 2014).

Finally, the fourth case is Aquafil Group is an Italian company listed on the Milan stock exchange that produces synthetic and artificial fibers. It was founded in 1965 in Arco (Trento), where it is still based today. In 1998 Aquafil started recovering waste to make technopolymers, and now they are able to obtain regenerated raw material starting from the recycling of nylon

waste. Their main business is the production of textile flooring yarns. Aquafil is one of the main suppliers of sustainable synthetic fibers for carpet flooring around the world. In fact, a considerable share of flooring yarn sales involves recycled nylon that is collected from their clients (and not) and then recycled. They also recover all the production waste deriving from the use of their fibers (especially from their customers) to recycle them.

Montecolino and Aquafil were chosen because they are manufacturers belonging to a very active industry in the field of the circular economy.

All these companies have in common the management of the end-of-life of the products, giving an additional reason for choosing these four companies to have a common ground of analysis. In fact, the EOL management is one of the main servitization strategies that drives companies toward a circular economy.

2.1.3 Data collection

The main tool used for the analysis of the case studies was the semi-structured interview format, in order to give to the interviewees a certain level of freedom, but at the same time to have a common guideline for leading them to answer the questions useful for the thesis purposes. I developed the interview guidelines (Appendix A) based on the information analyzed and extracted in the papers read for the literature review. The interviews were conducted through the Zoom and the Google Meet platform, and they lasted between 25 and 90 minutes. All the interviews were recorded, with the authorization of the interviewees, for later transcription and analysis. In addition, all the interviewees made themselves available for further clarifications and follow-ups of the interview.

2.1.4 Data structure

Data analysis was carried out through a coding activity to offer a complete and reliable analysis of the empirical data and enabling a connection between the theoretical and empirical concepts (following the Gioia method, Gioia et al 2012). In particular, I first systematically coded the interview transcriptions, by transforming phrases and terms into first-order categories codes. Then, through the analysis of similar patterns between the first-order codes, I grouped together all the similar first order codes into second order codes. Finally, through a combination of deductive and inductive analysis, based on what has been analyzed in the literature review, I identified five aggregate themes: Servitization increases the CE, Customers as a push towards servitization and CE, Legislation as a key in adopting CE, Eco-design as a key in adopting CE, Current consumption and production patterns are very rigid.

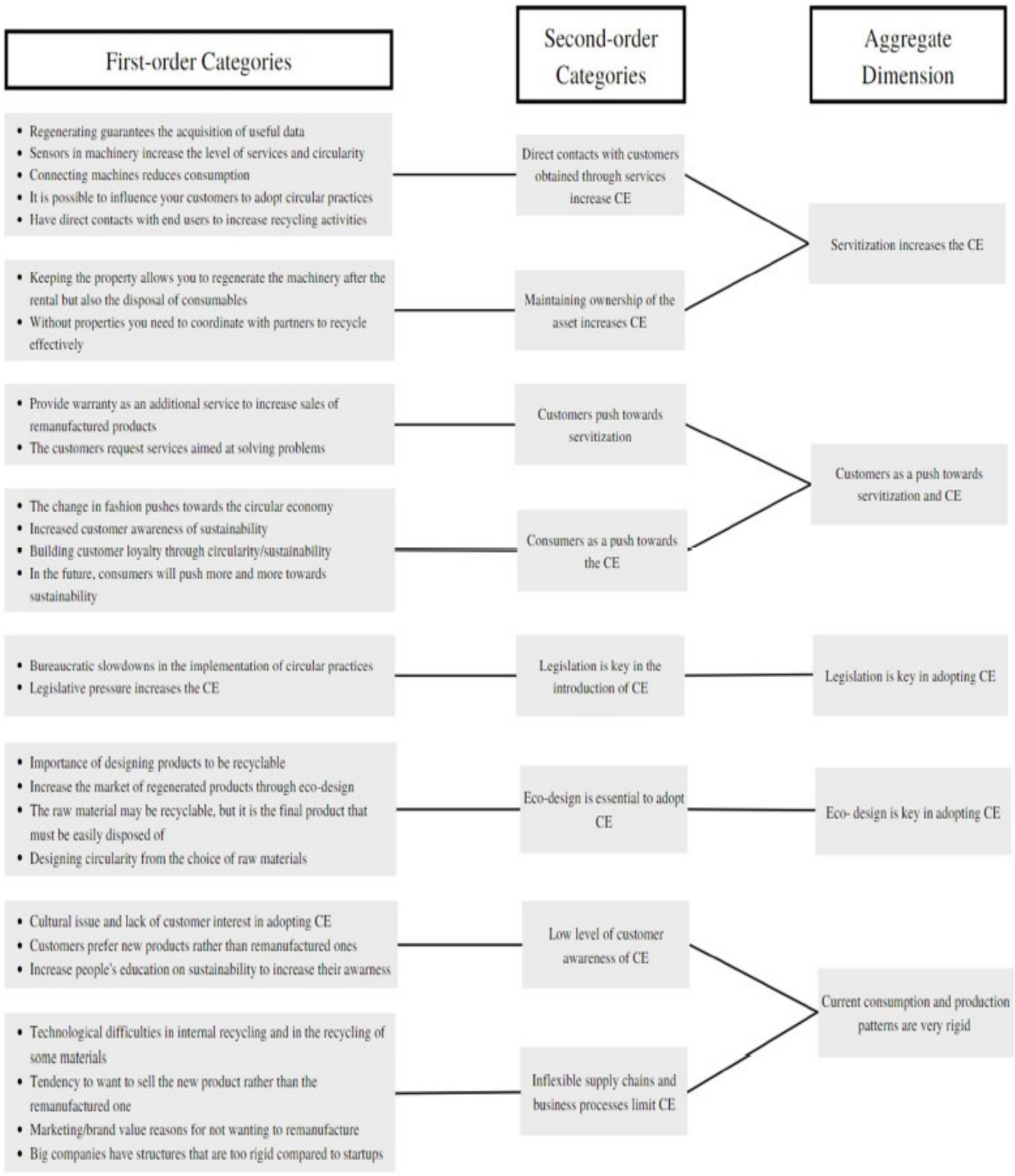

Figure 2.1.4.1 *Data coding.*

2.2 Findings

This section presents the internal analysis of each case study derived from the interviews. A comparison between these insights and the related reflections are included in the discussion and/or conclusions.

2.2.1 Servitization increases the CE

In all the case studies emerged that the introduction of services in the business models help the introduction of circular/sustainable practices.

In particular, in the Montecolino case, in 2017 due to a change in fashion (consumers no longer wanted carpets and wall coverings in their homes) and consumer sustainability requirements, they decided to start producing exhibition carpets and to change the value proposition by adopting a servitized business model. They started to manage all the life cycle of their products (in particular exhibition carpets), from the carpet laying, its collection and its recycling. They carry out collection services for used carpets that come from the fairs, and relying on third-party companies, the carpets are transformed into raw material for new products.

Furthermore, Ricoh with the "Sustainability Management Services" provides a full range of services, products and solutions that ensure energy efficiency, resource conservation and a better quality of life, offering also counseling activities. The "Resource Smart Return" program allows customers to return Ricoh spares and consumables for disposal. These consumables are recycled, and the secondary raw material con be used to produce other products: *"For example, there is a process that dematerializes the toner cartridge and the resulting powder can be reused, for example to make ceramics"* (Ilia Terlizzi, Ricoh). The "@Remote" technology permits to collect and analyze data relating to company machines. This allows to increase the company sustainability by analyzing the performances from an environmental perspective and to carry out preventive maintenance, or to manage the replacement of spare parts and consumables. Moreover, it gives the possibility to automate the toner change process by warning that the printer is running out of toner and consequently automatically calling the technician: *"The machine has a counter, so it communicates the consumption to us daily, and therefore our operators receive a warning on the depletion of toner"* (Ilia Terlizzi, Ricoh).

In Aquafil they offer a collection service for production waste in the manufacturing processes that use their fiber (especially from their customers): *"We recover both waste deriving from processing and also post-consumer waste from products, which can have up to 20% waste during the manufacturing process"* (Giulio Bonazzi, Aquafil).

2.2.2 Current consumption and production patterns are very rigid

It emerged that one of the biggest problems to the introduction of circular business models is the rigidity of the current consumption and production patterns. In fact, the supply chain, the production processes inside the firms, and the consumption choices of some customers, are

limiting the introduction of sustainable practices. This rigidity of the production processes is a common problem in the adoption of CE practices (Bressanelli et al. 2018).

For example in Montecolino case they do not directly use the new raw materials that derive from their recycling activities as the machineries they use to produce the carpets need only virgin materials: *"We have the difficulty that the fiber we use (to produce the carpets) is a very fine fiber, therefore, using a regenerated material, that certainly contains some foreign material inside, into our machineries would certainly mean having production blocks"* (Nico Fontana, Montecolino). Anyway, this increases the level of servitization of their business model and the link of this latter to a CE, because their value proposition includes the management of the end-of-life of their products even though they are not directly interested in the use of these recycled materials.

However, it is important to point out that not every product can be recycled easily, and that there are industries in which it is easier to implement EOL management practices and recycle activities. In fact, Nico Fontana (Montecolino) said: *"the advantage we have is that our raw material, polypropylene, is a plastic material that adapts well to subsequent transformations. Therefore, it does not have a loss of technical characteristics, while other materials, such as for example polyester, which generally in the textile world derives from the recycling of bottles, once it has become a textile product, then it is difficult to be used for other uses".*

In addition, also supply chains have very rigid structures: many companies in some industry (i.e., white-goods industry) prefer to throw away used or damaged products because they fear the cannibalization of their new products: *"There are some companies that still throw away the whole product just because it's ruined, or just because the packaging is damaged. In fact, they have to sell new products. They have an order from the headquarters, that all products that cannot be resold must be destroyed"* (Manuel Odasso, Ri-generation). This is also due to the fear of damaging the brand value of the company, because of the difference in price of the remanufactured new product. This not only causes a shortage of products to regenerate, but also increases the difficulty for remanufacturing companies to sell their products, for example to large-organized distribution (LDO): *"They (LDO) are also perhaps a little forced by big companies to sell their new products"* (Manuel Odasso, Ri-generation).

Furthermore, the supply chain has to be coordinated in the CE transition, and everyone must be focused on their tasks to get to the final goal. At the moment there are some difficulties in achieving this, for this reason Aquafil is carrying out large backward integration activities to be more efficient in wastes collection: *"The collection phase is much more effective and efficient if you can be perfectly coordinated with the recycling phase, so in recent years we have also*

started an upstream integration process, therefore direct waste collection" (Giulio Bonazzi, Aquafil).

This problem did not emerge in Ricoh, because the printers are owned by Ricoh, and at the end of the renting contract, they take back their printers in order to refurbish them, in their dedicated department. They are able to carry out this process several times, in general as long as the customer accepts remanufactured machinery. In fact, in this case another form of rigidity arises: the unwillingness of customers to rent/purchase remanufactured products. In fact, even though the printer is still functional some clients do not accept refurbished products because of their lack of trust on the quality, or because they just prefer to buy new products. Those printers are no longer rented but sold to developing countries, losing the possibility of managing the end-of-life.

Furthermore, it emerged that startups may have an advantage in the introduction of servitized BMs and circularity, because thanks to their flexibility they are able to change faster and without risk. In fact, especially big companies (even more listed companies) have much to lose in changing their business model, which can usually take years before bringing benefits (especially in economic terms): *"Large companies have less motivation to change than smaller ones, so it is much easier to find a startup that changes its model, because these changes may not be reflected in a return in terms of profitability in the next 12 months, so why should they make an effort to worsen the perception of their company's value in the market"* (Giulio Bonazzi, Aquafil).

2.2.3 Eco-design as a key in adopting CE

It emerged that even in industries (or products) that are suited for recycling activities and that have not rigid structures, the lack of collaboration along the supply chain to achieve a circular economy is a strong barrier to its implementation. The cooperation has to start in the very early stages, right from the beginning of the product conception, otherwise the difficulties in recycling rise. Companies has to design products for remanufacturing (eco-design), otherwise at the end-of-life it would be impossible to remanufacture the product.

This emerged particularly in the Astelav (Ri-generation) case because their business is very limited by the eco-design of the products that they have to remanufacture. In fact, Manuel Odasso (Ri-generation) explained: *"We managed to industrialize the process a bit, but obviously yes, it's not an assembly line. Here comes the product, we disassemble it, and we discover that it is not eco-designed"*. Therefore, if products were eco-designed it could guarantee to increase the industrialization of processes such as the remanufacturing of products,

in this way increasing the number of regenerated products on the market and therefore a reduction in the production of new ones, decreasing wastes.

In the Aquafil case arose that the fiber that they produce can potentially be recycled indefinitely, but what limits this great potential is the lack of eco-design by the manufacturers that use this fiber. In fact, Giulio Bonazzi (Aquafil) explained: *"The products made by our customers are not made to be recycled, so we started a process for redesigning the products together with our customers in order to (at the end of their life) be able to make them recyclable. Hence, we basically create circularity at the molecule level but not at the product level"*. In his opinion the transition to a more sustainable economy has to start from the selection of the raw materials: *"The system built to be circular starts from the identification of the ideal raw materials or ingredients that are no longer designed only in terms of their cost or on their performance"*.

2.2.4 Customers as a push towards servitization and CE

As long as there is demand for current products, it will be difficult for companies to decide to change. In fact, one of the strongest pushes towards a change in the companies' BM and in their offers comes from customers.

The exemplary case of this analysis is Montecolino who decided to change their business model due to a change in fashion and consumer tastes. Moreover, they decide also to adopt a servitization strategy because this allowed them to gain an advantage on their competitors thanks to their ability to retain customers by offering a service that helps their clients to dispose of a product that takes up a lot of space and at the same reduces the environmental impact. This also leads to increasing barriers to new entrants due to customer retention. In fact, it is the end customer who is increasingly asking for sustainability: *"the sensitivity of the end customer is increasingly driven towards sustainability, so the customer appreciates the fact of carrying out an action that does not harm the environment"* (Nico Fontana, Montecolino).

Customers are increasingly oriented towards the provision of services because they want to have as much "peace of mind" as possible in all those operations not related to the core business, such as the printing activities. In fact, a service that is highly requested to Ricoh is the provision of a professional figure that helps to resolve all the issues related to the services provided by them: *"the customer asks us for a professional figure for example when we install meeting rooms, because if something happens, the monitor doesn't work, they can't connect the pc, then they can ask someone to solve those problems"* (Ilia Terlizzi, Ricoh). In addition, they propose a service that includes the replacement of defective parts, or in any case the maintenance, during the night, in order to have the machine always running.

Due to the growing sensitivity of customers to paper and toner consumption, Ricoh is carrying out a strong M&A activity because of the uncertainty in the printing industry. In fact, they started to acquire IT companies that offer services like document management and digitalization of documents.

2.2.5 Legislation as a key in adopting CE

Finally, in this analysis emerged that if there is not an appropriate legislative environment, companies are less willing to increase the sustainability of their operations.

The main challenges derive from the lack of awareness of the clients on sustainability and the excessive presence of bureaucratic procedures: *"The problem is that it is difficult to convince all customers, because very often, even for bureaucracy reasons, they prefer the simplest way, that is to throw away"* (Nico Fontana, Montecolino). Thus, the macro environment (cities, regions, states) through politicians must make customers aware of issues related to circularity and make them understand that adopting sustainable practices not only benefits the environment, but also benefits customers. In addition, the bureaucracy to implement CE practices has to be reduced.

Moreover, to adopt a circular system, not just at the company level, it is important that exist an adequate legislative system that pushes towards real change in terms of incentives and pressure from politicians, but also an evolution of the educational system toward sustainability: *"To change the world are needed three fundamental elements: an adequate legislation, an increase in education, and the eco-design, therefore a general process of the industry and of the various sectors, and their willingness to change the way products are made"* (Giulio Bonazzi, Aquafil).

2.3 Discussion

In this section, the five cases are compared and analyzed, to find similarities with the literature and insights for further analysis.

First of all, it emerged that being close to the end customer can influence them to adopt sustainable practices. Montecolino fully manages the relations with its customers (exhibitions), therefore they can influence them in making decisions about sustainable consumption. In particular, they can sell their carpets declaring that they will not go to landfill but will be recycled. This may induce their customers to buy their products because of a reduction in the environmental impact, but also because the end customers (the fair's clients) are increasingly interested in sustainability. In fact, this emerged to be an important push towards sustainability (Section 1.3.1.3). If companies are able to push customers to become aware of environmental

sustainability issues, then the latter will also drag other companies towards a reduction in their environmental impact. Ricoh also has a direct contact with their clients, and they can influence them on a reduction of the production of waste through the implementation of services, or by making them aware that a reduction in waste can also lead to a reduction in costs (i.e., toner consumption). Moreover, they are able to collect a lot of data on their customers through the sensors installed in their printers, and this is very important because it allows companies to understand customers' habits and implement the right strategies for them to accept their circular services or products. In fact, digitalization capabilities (Section 1.3.3) help companies in the change process, enabling the introduction of services that help to achieve a circular economy (Bressanelli 2018).

In the case of Astelav, they founded Ri-generation principally as a source of know-how to collect useful data on the machines that they regenerate, but also on the clients that used those machines. It is a competitive advantage on those companies that originally produce those products but that do not manage the end-of-life, thus they do not collect those data relating to the use of their machinery. Indeed, many companies do not have a direct contact with the final users because they sell their products to LDO, and if they do not remanufacture the used products, they may risk losing every possibility to collect final user data and influencing them on their consumption.

That is also the case of Aquafil that has not a direct contact with its clients, or at least only partially, consequently it is unable to influence their choices in terms of sustainable purchases or circular consumption. For this reason, they have started a project to introduce e-commerce, to be closer to final users and to understand their habits.

Moreover, it emerged that the corporate production structure is a barrier to the introduction of a circular economy. Montecolino owns machineries that can use only virgin raw materials, then they cannot use the secondary raw materials deriving from the recycling of their carpets. Instead, Aquafil has adopted another model, i.e., buying waste materials to produce a secondary raw material to be used in the production processes of their clients.

Indeed, as analyzed in Section 1.3.4, one of the main challenges for adopting CBMs is the risk that companies (especially well-structured ones) may run into implementing new technologies or new processes. This problem is easily overcome by startups that already start their business with circular ideas or servitized business models, but also thanks to their flexibility caused by their size can easily change their strategy and their production processes without incurring in big losses or risks.

Furthermore, it emerged that the current business models and the supply chains have very rigid structures: defective products (even just scratched or with small defects) are thrown away rather

than regenerated. This happens in many industries, for example, supermarkets (where fruit and vegetables are sold only if in excellent condition and aesthetically beautiful), domestic appliances (Ri-generation case) where damaged washing machines (or even with damaged packaging) are sent to landfills. Astelav (Ri-generation) has entered, as a service provider, in a sector that is not currently interested in regeneration or renewal practices, because it is very rigid and inclined to find the simplest solution (i.e., the landfill). This rigidity can also be due to a lack of confidence in the quality of the used products, or to a tendency of customers to always look for the newest product, as reported in the Ricoh case, where the regenerated printers, even though still functional, are sold to developing countries, because clients are reluctant to rent them. However, given the current shortage of raw materials, rising prices, and the fact that companies have to wait a long time to receive new printers, the market for remanufactured/refurbished machinery is growing.

Moreover, the linearity of the current consumption and production model is also due to the lack of eco-design of the products, leading to an increase in the difficulty to recycle and remanufactured products. The design for remanufacturing must be done starting from the choice of the raw materials, no more prioritizing the performances or the costs, but starting to think about the end of life of the products and how to recycle/remanufacture them. For this reason, Aquafil is collaborating with its clients (who manufactures the final products) to design their products to be remanufactured. They are cooperating with them to try to produce single material products, therefore in addition to the fiber to produce the products, they are also starting to supply them with other components of the products always made with their fiber (in the case of a jacket, for example, they also supply the zips or the padding). The collaboration between partners (i.e., meso level) has been highlighted several times in the literature review as a fundamental element for the implementation of circular business models. Sometimes the collaboration is not simple and the cooperation to achieve a common goal can be hampered by several challenges. For this reason, Aquafil has begun to acquire upstream companies (engaged in waste collection) in order to better organize activities and be more efficient in recycling activities, in such a way increasing their network of partners.

Ricoh partially reduced the problem of this rigidity because they do not sell their products, but they rent them. In such a way they are able to manage all the life cycles of their products. They can increase the lifetime of the products through predictive maintenance and middle of life upgrades, and at the end of the life they can retire the printers and refurbish them to restart the process (assuming that customers accept remanufactured products). However, this brings up other difficulties (Section 1.3.1.2) such as the increase in financial risk and operational risk,

given the fact that they have to manage a lot of tasks that in a linear/traditional business model are carried out by clients.

Furthermore, it also emerged that protecting corporate brand's reputation and value can hinder circularity and partly explain the reluctance and lag in some sectors (i.e., white-goods industry) (Section 1.3.1.2). Some strategies such as remanufacturing and selling under a different brand so as not to confuse customers can reduce this phenomenon. Companies should sell refurbished products at an advantageous price, but with a different brand name than new products, in order to position the refurbished products in a different range and not cannibalize the sales of new products. In addition, if the remanufacturing process is not done by the original company that manufactured the product and the remanufactured product has some quality problem, it may also damage the brand reputation.

Anyway, also the management of the remanufactured products is not easy, with the risk of taking resources and time away from the core business. This can be done through the creation of a new business unit (or a new firm like the Astelav case) which manages the regeneration of products that would otherwise be discarded. This allows companies to earn even on those products that should be thrown away and therefore identified as costs. However, the risk of a reduction in sales volumes of new products (cannibalization) is concrete, but the advantages deriving from a BM of this type are also concrete, especially in the presence of a reference BM based on ownership. In a service-based BM (i.e., Product as a Service), the issue of reconditioning or regeneration would on the contrary become one of the critical elements for the (economic) sustainability of the BM.

CONCLUSIONS

CE and servitization are relatively new concepts that need to be further analyzed and developed. But despite their importance at the moment, it seems that the structure of the system is still very much based on linearity. However, there are some industries that can be defined as the forerunners (Visintin 2014) of servitization and consequently of practices that increase sustainability, such as the photocopier industry.

Moreover, there are some industries that are now acting as first mover in adopting circular economy in their business model, because even though in the short term these practices may not give a concrete return, especially in terms of profits, they can guarantee to acquire know-how of activities which, as seen, could be very difficult to carry out. This in turn leads to obtaining a competitive advantage over all those competitors who have moved late from this point of view.

One way that has proven successful in the implementation of circular business models is servitization. In fact, in the literature review, in expert interviews, and then in the case study analysis has emerged that the service offering in the business model enables companies to achieve an increase in their sustainability. In fact, it can be seen in Ricoh, who oriented its BM on maintaining ownership of assets, allowing them to manage the entire life cycle of products in such a way decreasing their environmental impact; in Ri-generation who has developed a BM entirely based on circularity and servitization; in Montecolino, where they offer the service of picking up used carpets to be able to recycle them; in Aquafil, where they collect the wastes of production, or used products especially of their clients to recycle them.

In both these last two cases it is important to point out that to implement these services and to (at the end) recycle the used products, companies along the supply chain must cooperate and must be coordinated to obtain a common goal. To overcome this problem an orchestrator (Parida et al. 2019) could act as coordinator. In fact, in the case of Montecolino they manage all the life cycle of their carpets (even though they are not exactly the ones who carry out the activities), instead Aquafil has started to backward acquire the waste collection companies. Another way to solve this problem is to keep the ownership of the product, such as Ricoh, to continuously increase the performance of the product, to also recycle the consumable parts during the usage phase, and at the end of the life (upon expiry of the lease) retire the product, remanufacture it and re-start the cycle.

At this point another question emerges, which is linked to the rigidity of the consumption and production patterns, and that is related to all the difficulties of the market for remanufactured products. In fact, customers are still reluctant to adopt this kind of product due to a distrust in

their quality or always looking for new products. Moreover, manufacturers companies tend to prefer to throw away used or damaged products because of the fear that remanufactured products may cannibalize the sales of their new products or that the presence of products with the same brand but with a lower price (because remanufactured) might ruin the brand image. This problem emerged in both the Ricoh and the Astelav cases. In addition, in all the cases emerged the design for remanufacturing problem (eco-design), that hampers the possibility of recycling and remanufacturing. Once again, it is necessary that all companies have a clear objective, i.e., the achievement of the circular economy. This must be done right from the beginning, from the choice of the raw materials. In this case, Ricoh does not have this problem because they are the ones who produce their own machinery and then remanufacture them, also given by the fact that they retain the ownership of the asset.

Hence, to achieve real change and obtain circular economy in a system that is still based on linearity, both in terms of production and consumptions, the entire system has to collaborate at three different levels: micro (single company), meso (collaboration of companies), and macro (cities, regions or nations) (Bressanelli et al. 2019; Geng et al. 2008). This emerged particularly in the case studies, where has been highlighted the importance of design for remanufacturing (micro), the necessity of a network of partners that collaborate for the achievement of circular economy in the whole supply chain with the intervention of an orchestrator (meso), and the importance of the intervention of the right legislation that pushes (or obliges) companies toward the transition to circular economy (macro).

Anyway, the strongest push comes from consumers, who are increasingly asking for more and new services, leading companies implementing servitized business models, which as mentioned are one of the best ways to obtain the CE. In any case, if customers still prefer to purchase linear products and are not interested in circular consumption, companies will not be induced to change their BM and to take risks for a market that does not ask for circular products. This is the reason why increase customers' awareness on sustainability is the key to obtain the CE at all the three societal levels.

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APPENDIX

Appendix A – Interview guidelines

Gianmarco Bressanelli interview guide

Interview to: Gianmarco Bressanelli
Date:
Duration:

Interview guide

1. Can you give us a brief introduction about your professional profile and the companies and institutions in which you operate?
2. What are the drivers that push manufacturing companies to implement circular business models (CBM)?
3. Are there tools that companies can use to measure their performance in terms of circularity?
4. What are the industries where the circular economy is more widespread and/or has the greatest potential for diffusion?
5. What are the main challenges that manufacturing companies face in the transition to CBMs? (i.e., cultural, costs, organizational)
6. Can you point us to exemplary case studies (company names) in this regard?
7. How will servitization and circularity in manufacturing companies evolve in the near future? What will be the possible obstacles to their convergence?

Stefano Butti interview guide

Interview to: Stefano Butti
Date:
Duration:

Interview guide

1. Can you give us a brief introduction on how the Servitly business idea developed and what is your role in the company?
2. How does your solution help companies' servitization processes? And what advantages can it present from the point of view of sustainability and circularity?
3. What are the sectors where solutions like yours are more widespread and/or have the greatest possibility of diffusion? And what are the main elements of resistance among customers to adopt these solutions?
4. From your point of view, what are the main challenges that manufacturing companies face in implementing a service-based business model (lack of incentives, high costs, speed of technological changes, culture)?
5. In your experience, is there a relationship between the increase in services in the business model and circularity? And how will servitization and circularity in manufacturing companies evolve in the near future?
6. Can you tell us some names of companies that in your opinion could be useful research cases for the thesis on the relationship between servitisation and circularity? What is the sector that best lends itself to this type of connection?

Interview guide for the case studies

Interview to: (name and surname, role and company)

Date:

Duration of the interview:

Interview guide

1. Brief description of the interviewee's role and the company's business model (BM); brief description of the typical life cycle of the main product
2. Importance of services in the BM:
    a. What are and how important are the services in your BM (in terms of turnover and from a strategic point of view)?
    b. What are the drives to adopt a servitized BM (e.g., customer and stakeholder demands, market strategy)?
3. Importance of circularity in BM:
    a. How important is the dimension of sustainability, and in particular of circularity, in your business?
    b. What are for you the strongest motivations towards circularity (e.g., social and environmental pressures, customer and stakeholder demand, market strategy)?
    c. What are the advantages and challenges of circular business models for you?
    d. Do you have an analytical calculation system for the impacts and costs of circularity?
4. In your experience, is there a relationship between the increase in services in the BM and circularity?
5. In the future, is there further room for growth in servitization and circularity? If yes, what kind of growth and/or convergence between the two? What are the obstacles, if any?

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