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A Perspective on Remanufacturing Business: Issues and Opportunities

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1. Introduction

Nowadays, the continuous technological innovations and the growing consumerism accelerate the rate at which products are replaced, causing the exponential increase in the production of waste and landfills' saturation. The production processes of many products, however, requires a large amount of non-renewable resources and of substances that represents a potential threat to environment and human health if those products are not recovered or disposed of properly. This situation has turned on the environmental awareness of consumers and sensitized legislator from different countries to enact and implement specific laws and directives for the management of the end of the life cycle of products and to regulate the employment of hazardous materials. However, although disposed product represent a threat, they represent, also, a resource for companies that have to manage them, more if the recovery activities are properly integrated into the product' design phase and manufacturing activities. In fact this situation is pushing toward new profit models, based on an integrated product life cycle management. The innovative policies oriented to recover disposed products on the one hand improve the efficiency in natural resources consumption, but on the other hand show new business opportunities to original equipment manufacturers and third-party companies. Among the different recovery options, remanufacturing is an important and interesting one. The aim of this chapter is to increase the wealth of technical/managerial ability to integrate the production cycle of new manufactured products with the recovery of discarded products. In particular the multifaceted field of remanufacturing will be targeted identifying those strategic factors making the remanufacturing business sustainable from an economic point of view. In the second section the various models for an integrated product life cycle management will be presented together with the several recovery options. A brief discussion will be conducted on the impact of these choices on configuring a reverse logistics network. In the third section a profile of the remanufacturing industry has been drafted considering in particular its model of business. In fact, factors that have led various OEMs to undertake remanufacturing

programs on their products are different and in many cases dependent on actors' geographic location and the product category. Although many companies have started this activity as a mere compliance against increasingly compelling regulations aimed at products recovery, the empirical evidence shows that in the most successful cases companies simply tried to seize business opportunities already identified on that market. Companies designing remanufacturing programs within an integrated business model, with the aim to build a durable competitive advantage, put profit before legislative requirements and incentives. The purpose of this section, then, is to dissect the business of remanufacturing in order to highlight their strengths and weaknesses, its opportunities and its dangers. In the forth section we sum up some results of this study and future possible developments.

2. The recovery of the product at the end of life phase

The recovery of the product ,as an alternative to traditional disposal, is a response to environmental damage caused by the disposal of end of life products. Product recovery, in fact, minimizes the demand for energy and raw materials and the environmental impact of waste, and also provides the opportunity to start a profitable business. Therefore, environmental issues, eco-sustainability and production cost aspects are linked together.

Product recovery implies reviewing the management logic of product lifecycle, from an "open" production system to a "closed" one of variable length [1]. In the open loop logic, the process starts by taking resources from the ecosystem, when raw materials and energy are channeled into the transformation process, and ends with landfill disposal or incineration process. This situation is sustainable only if the natural resources consumption is lower than eco-system's ability to regenerate them.

On the other hand, in a closed loop supply chain some recovery activities delay the product disposal by starting new production cycles on the product, its part and components or raw materials. The adjective "closed", however, should not suggest a completely self-sufficient system, since the use of new resources is almost always necessary at each new cycle and it is related with the recovery option considered. Undoubtedly such a new approach to product lifecycle management improves the efficiency of the exploitation of natural resources and opens, at the same time, new business opportunities. The end of life phase is transformed into a testing time, to establish the most suitable recovery option to extend the product's useful life. (Figure 1).

Products at final stage of their lifecycle, can be recovered in many ways and with different levels of efficiency in exploiting natural resources. In literature, these recovery options can be found (Figure 2):

- reuse;
- restoration;
- refurbishing;
- remanufacturing;
- cannibalization;
- recycling.

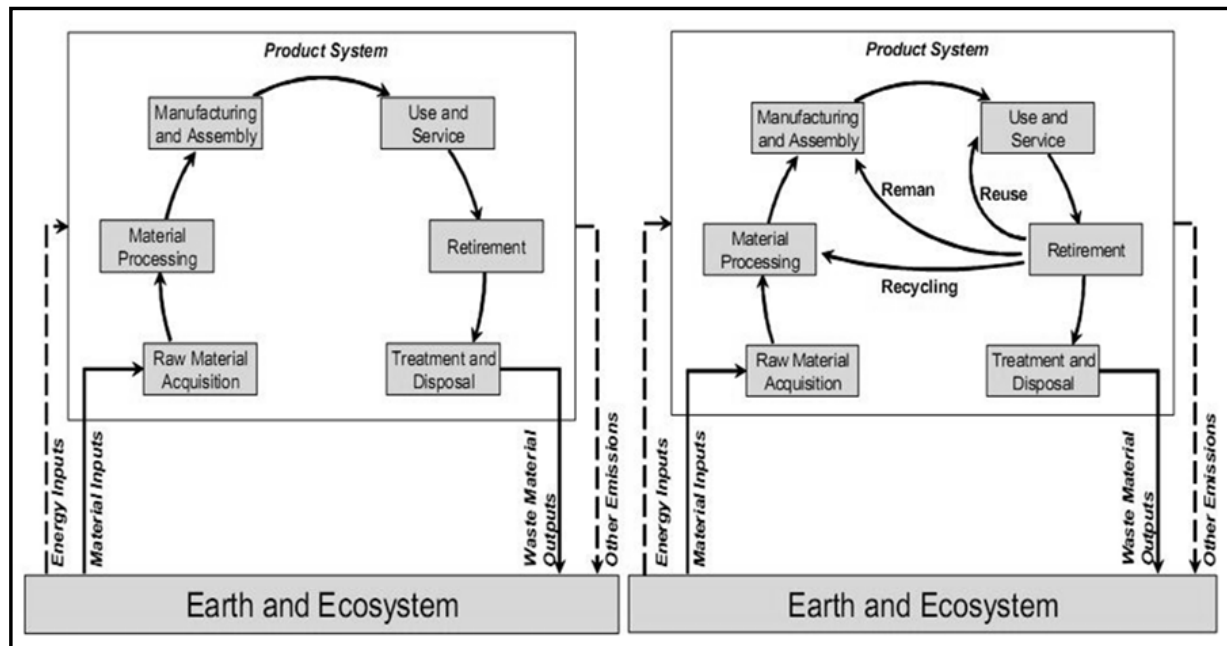


Figure 1. Open loop and closed loop supply chains [1]

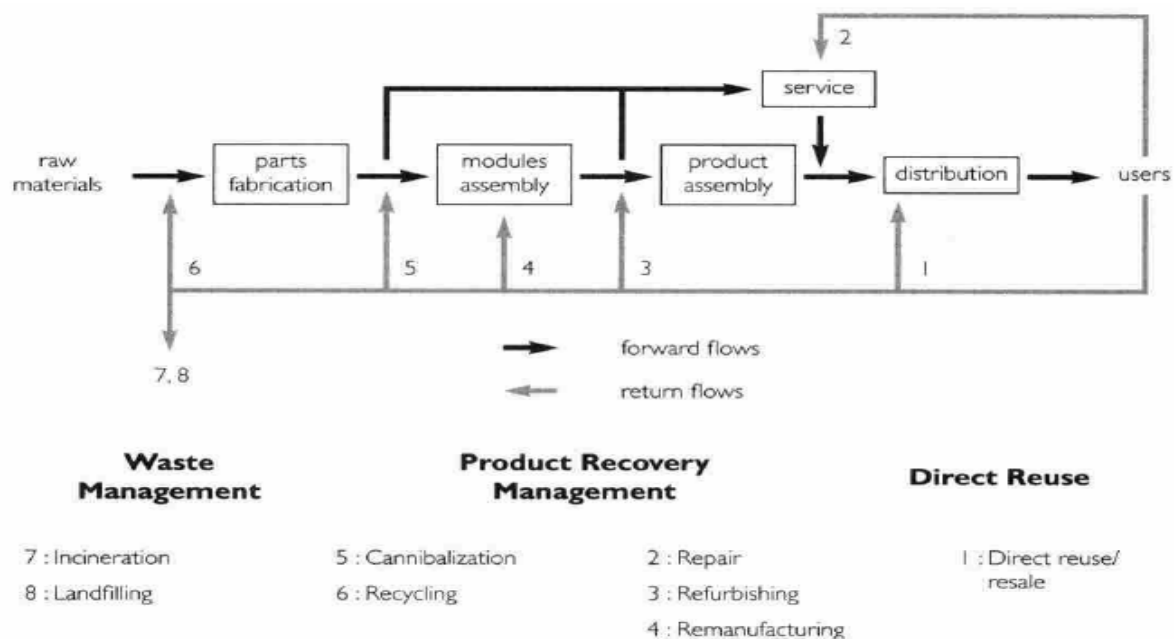


Figure 2. Recovery options in a closed loop supply chain [2]

The recycling process is at the lowest level of recovery efficiency, it allows to recover only raw materials but not the added value of production cycle. Higher efficiency options, where the whole product, part or components are recovered, are reconditioning, remanufacturing and cannibalization. Intermediate options, are repair and reuse. A closed loop system consists of distribution, product recovery and waste management. The products and/or components, that come back through the reverse logistics channels, can be directly sold, recovered or disposed off.

2.1. Remanufacturing

The original definition of the remanufacturing concept is due to Robert Lund, professor at Boston University, a luminary in the study of this sector. His contribution paved the way for a systematic study of this recovery option. In literature there are many definitions of the remanufacturing concept [3,4] and a meaningful one is: "...remanufacturing is an industrial process whereby products referred as cores are restored to useful life. During this process the core pass through a number of remanufacturing steps, e.g. inspection, disassembly, part replacement/refurbishment, cleaning, reassembly, and testing to ensure it meets the desired product standards" [5].

The previous definition clearly refers to remanufacturing as a process, a set of linked activities, rather than a single step aimed at restoring the performance of a product. The same cannot be said, for example, for repair or reuse, which are simply defined as an activity.

This option is applied firstly to electronic and mechanical products and components, as they maintain, when recovered, a relatively high added value with respect to the market evaluation or to their original cost [6]. Gaudette and Giuntini consider this practice as the most evolved form of recycling: "...It Conserves not only the raw material content but also much of the value added during the processes required to manufacture new products " [7]. In fact, the energy used to remanufacture a product, basing on a study of Lund, is, on average approximately 20-25% of that required for an ex-novo manufacture, while the remanufacture cost is equal to about 60% of the original [8,9].

In Figure 3, the fundamental differences between the options of remanufacturing, reconditioning and repair are depicted, basing on three dimensions: warranty, product performance and content of work needed.

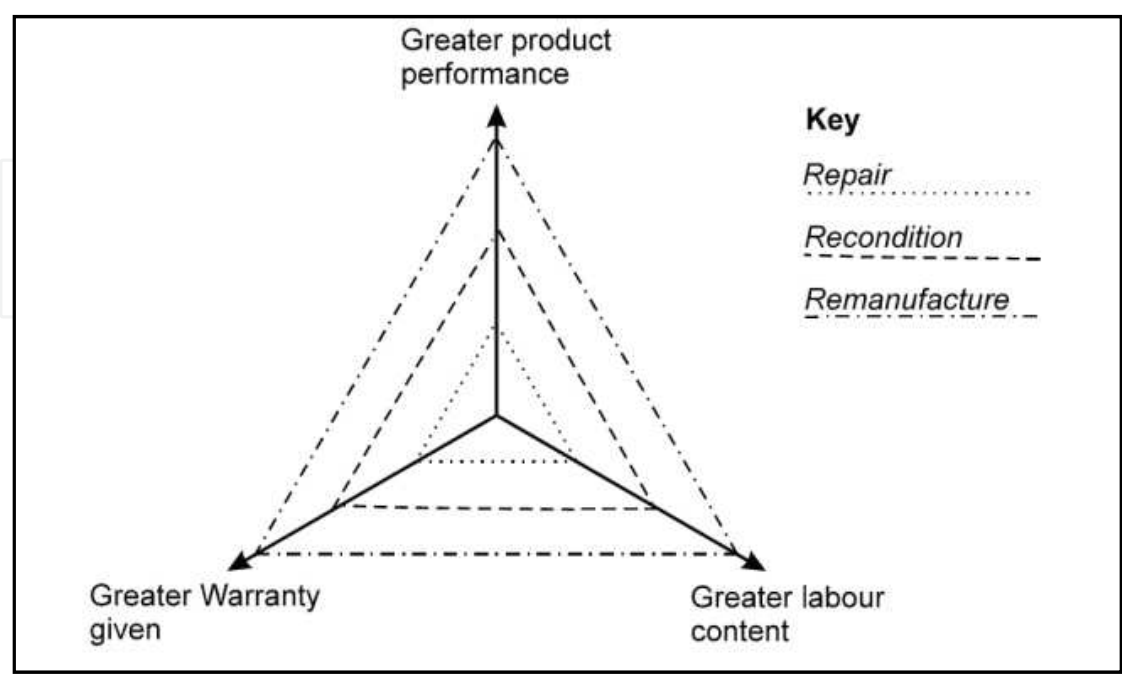


Figure 3. Hierarchy of recovery processes of a product intended for a secondary market [10]

The entire remanufacturing process can be decomposed in three sequential sub processes: disassembly, overhaul, reassembly. “The coordination of these sub-systems is key for a successful production planning and control system” [11].

2.2. Analysis of the remanufacturing process

According to Steinhilper [12] and Sundin [5] the activities composing a remanufacturing process can be divided into (Figure 4):

- disassembly;
- inspection;
- sorting;
- cleaning;
- reprocessing;
- reassembly;
- checking and testing.

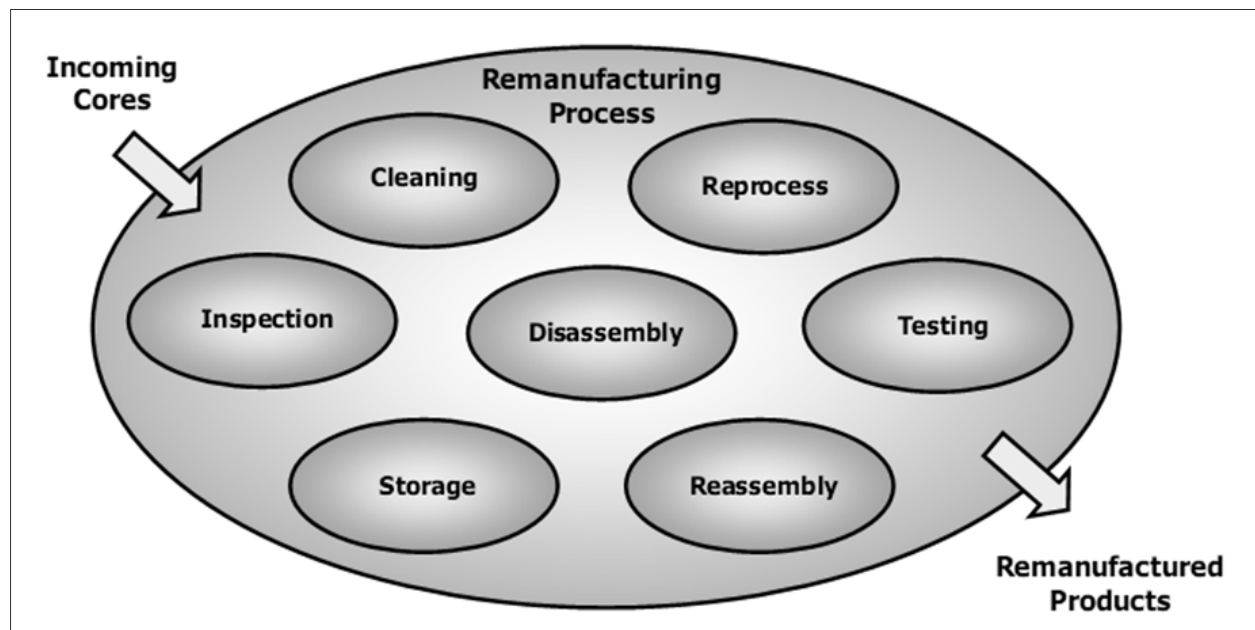


Figure 4. A generic remanufacturing process [5]

Empirical evidence shows that companies, involved in remanufacturing activities, organize their processes in different ways. Although the sequence disassembly -restore-assembly appears to be a fixed point, activities such as inspection, cleaning or testing have not a unique position into the process. The sequence, therefore, must be chosen considering the recovery process, the characteristics of the product, and the technology available for treatment.

The disassembly activity is located upstream of the entire process and it is extremely critical, since its implementation directly affects the quality of recovered material for successive activities. This step plays a central role in preserving the value of recovered cores. The main

reasons for that are high incidence of manual labor, necessity of specialized equipment or time required. These issues are directly influenced by the design quality and its capability to respond not only to customer requirements but also to recovery necessity with higher environmental-friendly criteria. Several researches report that this phase is mainly carried out in a manual way, while the use of automation occurs only in case of large batches of standardized products [13]. The disassembly activity could be more complicated, if conducted by a third-party operator as it must develop a reverse engineering, rarely having access to OEM specifications.

The inspection and sorting phases are closely related: the second activity can be seen as the completion of the first one. The result is the sorting of cores into three subgroups:

- "as is" reusable cores without need of revision;
- Recoverable cores, for which a refurbish activity is necessity;
- Not recoverable cores.

After inspection and sorting, it is possible to proceed to the cleaning phase of recovered parts. Cleaning goes beyond the elimination of dust and dirt from components [12]. Many cleaning processes cannot derive from the common ones of manufacturing processes. Therefore, the development of new ad-hoc solutions is necessary. As new methods are developed, they are more and more environmental friendly. It is crucial to implement such an operation with techniques and products that do not affect the component quality and combine a low environmental impact.

Reprocessing activities involve all those operations necessary to the component to provide a planned performance (or even higher if compared to new ones). The technical tools normally used are the same of manufacturing processes. The small size of batches can lead to the prevalence of manual work. There are some cases in which production lines, used for manufacture new products, have been "updated" to remanufacture recovered products.

The reconditioned components represent a large part of the remanufactured product. In order to limit the use of new parts, many times, the number of disassembled units can be increased if compared with the units to be re-assembled with the aim to recover enough parts from the cores.

The reassembly is the final phase to obtain remanufactured products. The greatest difficulty arises from ensuring a continuous flow, quantitatively and qualitatively adequate, in order to avoid blocks or slowdowns, inevitably resulting in higher costs and lower profits. The reassembly operation can be carried out with reprocessed or reused components, with new components or with cannibalized components. A monitoring problem arises as it is impossible to know in advance how many components can be reused or reprocessed. A possible solution is to purchase and store new components in case of need. However, this solution is not always suitable, because it increases the inventory level and obsolescence problems. It can be difficult to coordinate the reassembly of the various parts, if the reprocessing lead-times are uneven.

At the end of the whole process, there is a testing phase to ensure the achievement of quality standard set for this kind of products. Testing in remanufacturing contexts affects all products and is more rigorous than the random sampling in new products case.

2.3. Managerial issues of the remanufacturing process

Remanufacturing systems have a high level of uncertainty and complexity if compared to the traditional production systems. The management of these aspects makes the role of planning and control systems critical. In fact, companies, involved in remanufacturing activities, have to face a series of problems that limit the efficiency of their production process. These problems are typical of this sector and cannot be addressed by the traditional tools of planning and control. In literature, several technical and management issues have been identified [14]:

- difficulties in disassembly of the product;
- uncertainty about the quality of returns;
- difficulties in matching of the parts;
- uncertainty in working cycles and processing times;
- the lack of correlation between returns and demand;
- uncertainty in quantities and timing of returns;
- configuring and managing a reverse logistics network.

From the Table 1 it can be argued that these features impact at various levels on the management of remanufacturing systems and in particular on the planning and production control activities.

Complicating characteristic	Production planning and control activity			
	Forecasting	Logistics	Scheduling/shop floor control	Inventory control and management
(1) The uncertain timing and quality of returns	✓	✓	✓	✓
(2) The need to balance returns with demands				✓
(3) The disassembly of returned products			✓	✓
(4) The uncertainty in materials recovered from returned items			✓	✓
(5) The requirement for a reverse logistics network		✓		✓
(6) The complication of materials matching restriction			✓	
(7) The problems of stochastic routings for materials and highly variable processing times			✓	

Table 1. Relationship between production planning and control activities and the characteristics of a remanufacturing system [14]

3. Remanufacturing as a business sector

3.1. Features of a remanufacturable product

Virtually every manufactured product may be remanufactured at the end of its life cycle. However, aspects such as the business model or product's design makes remanufacturing a certain product more profitable than others, or in some cases totally not convenient. Literature has tried to trace the profile of a remanufacturable item, using some parameters.

The main orientation of the research activities on this subject has been, not only to evaluate the "remanufacturability" from a strictly technical point of view, but also to verify the conditions that allow a sustainable business for the company. Parker identifies three key parameters for remanufacturable products [15]:

- the intrinsic value, the market value of the product being reprocessed;
- the re-constructability, the ease of disassembly a product and then its assembly at the end of recovery process;
- the evolution rate, the speed at which new variants of the product are launched on the market.

Basing on these parameters, Parker recommends a legislative intervention intended to allow the reuse of components into new products, investments in research to develop the Design for Remanufacturing (DfRem) and the development of a system of services to extend product's lifecycle and, if possible, to update it from a stylistic and functional point of view [15].

Robert Lund identified 75 categories of remanufacturable products and developed reference criteria also confirmed by subsequent research [6].

These criteria are:

- the product is durable;
- the product has only failed in its functionality;
- the product is standardized and consists of interchangeable parts;
- the added value at end of life, is high;
- the cost to obtain the core is low if compared with the remaining intrinsic value;
- the product's technology is relatively stable over a period of time that exceeds the single lifecycle;
- the consumer should be informed about the availability of remanufactured products, so to create an adequate demand on the market;
- a technology exists to remove parts from products without damaging them and to restore the product.

Sundin identifies in a empirical way four relevant characteristics of product/component to simplify the implementation of activities required in a process of remanufacturing [5]:

- wear resistant;
- easy to identify;
- easy to remove;
- easy to be reprocessed.

These analysis provide a valuable support to identify those concerns during the design phase to facilitate a proper and simple reprocessing at the end of life.

In the current scenario, there is also the additional requirement of a minimum market value for certain categories of products, to secure a profit at the end of reprocessing. In fact, only on this condition, today, remanufacturing may be considered as an attractive business and not only conceived for environmental issues, but physiologically in loss. The low profit margin is due to the high labor cost involved in the various recovery options. This, however, should become secondary in the future thanks to the increased volumes of products to be treated with positive implications on economies of scale and experience, as well as the degree of automation in the process [16].

3.2. Remanufacturing business figures

The remanufacturing business was born in United States during the Great Depression of the '30s and achieved the final consecration during the Second World War, when the plants were converted to military commitments. Most of the available resources were reserved for war needs, while those for civilian use were very low. In this context, to balance the decreasing in supply of new products, used products were reprocessed extending their useful life.

This recovery option is currently used for several categories of products among which:

- Aerospace and aeronautical;
- Automotive ;
- Industrial machinery;
- gaming machines;
- data communication systems;
- robot;
- electrical and electronic equipment with high residual value ;
- compressors;
- office supplies;
- copiers;
- printer cartridges;
- musical instruments;
- refrigeration appliances;
- ATMs.

As it can be seen from the above list, the remanufacturing field mainly concerns consumer and durables goods for professional use. This recovery option has had, until today, a little

impact on consumer goods. On these products, in fact, aspects such as fashion design or status, have a strong relevance on the purchase decision.

Today, remanufacturing is widespread in the sector of high value and high technology products. In addition, this recovery option thrives in those sectors that have adopted the concept of Product Service Systems (PSS), the customer has access to the service provided by the product, without having the property of it. In this case, when the product is no longer able to deliver its performance, it is recovered to be used by other customers, satisfying shared goals of longevity, durability and performance.

The remanufacturing industry is defined by Lund as an "hidden giant", in fact many companies operating in this sector is not devoted exclusively to remanufacturing activities, but practice them as an aftermarket service.

Data on the remanufacturing sector are rather difficult to find, because of the overlapping between Original Equipment Manufacturers and remanufacturers, among which there are OEM and "third party" operators, independent or working on commission. However, the potential growth of this business is very high, especially in new sectors and in the EU market, where it has so far been undervalued.

Industry Sector	Products	Firms in the Database	Estimated firms not in Database	Total
Automotive	Alternators, Starter Motors, Water Pumps, Clutches and Engines	4 536	46 000	50 536
Compressors & Refrigeration	Air conditioner and Refrigerator Compress.	55	100	155
Electrical Apparatus	Transformers, Electrical Motors and Switch gear	2 231	11 000	13 231
Machinery	Machinery and Equipment for various industries	90	30	120
Office Furniture	Desks, Files and Partitions	220	500	720
Tires, retreaded	Truck, Auto and Off-road Tires	1 210	180	1 390
Toner Cartridges	Laser toner cartridges Ink jet cartridges	1 401	5 100	6 501
Valves, industrial	Control & Relief valves	110	300	410
Other	Diverse	50	200	250
Totals		9 903	63 410	73 313

Table 2. Distribution of companies engaged in remanufacturing by industry sector [17]

Basing on the research of Lund [17] the majority of companies engaged in this activity are independent actors with OEMs playing a restrained role. From Table II. 1 it can be argued that most of the US remanufacturers operate in the automotive sector, about 70% of the total. No coincidence that the automotive industry has a long tradition in the recovery of engines, but also of other vehicle parts, which can be used in several lifecycles before the final disposal. However, Table II 1 refers to data older than ten years. Today it is estimated that the weight of the automotive sector has been reduced in favor of other product categories such as office supplies or photography.

Turning to specific examples there are independent firms such as Flextronics, a US firm, with an international vocation and a comprehensive know-how to recover printers, PDAs, cell phones, medical equipment, notebooks and desktops.

About the OEMs, Xerox is a global leader in the remanufacturing of photocopiers and other office equipment, whose return is secured by lease sales [18]. The greatest obstacle to the success of remanufacturing program, according to officials, has been the spread of the idea among some customers that products containing some used parts, may be less in terms of performance to products consisting exclusively of new parts. The unique process, the technologies used and the product's warranty should ensure that all products regardless of the presence of remanufactured parts, have the same quality standards, the same performance and the same reliability. Other companies like Kodak and Fuji normally practice this option on disposable cameras returning for the development of films. Caterpillar, involved in this business from 1972, recorded in 2005 for "Remanufacturing Division a revenue of \$ 1bn. Other well-known brands involved in this field are General Electric, Boeing, Deere, Navistar, HP and Pitney Bowes. In the U.S., however, the larger remanufacturer still remains the Department of Defense.

Basing on these data it can be noted an intense activity, which, however, is still restricted within specific business ambits. Only in particular cases and conditions, products are recovered on a large scale. However the remanufacturing process has difficulty to come out these limited areas and it is struggling to establish itself as an industrial application on a large scale, beyond the traditional sectors in a consumer goods application.

3.3. Business model

3.3.1. Value proposition

Remanufacturing companies tend to frame the satisfaction of customers' need by placing on the market a product that optimizes also its life-cycle costs. More than through the selling activity, they try to create value providing a service through the product in a Product Service System concept, "a system of products, services, infrastructure and support network designed to be competitive, satisfy customers and have a lower environmental impact than a traditional business model" [19].

This business model has a central focus on customer satisfaction and value creation, keeping in mind that these results are not achieved only through technological development, but also emphasizing the contribution of intangible assets such as intellectual property, image, brand, design or style. These aspects, in fact, help the company to differentiate its products from the competition, improving the degree of "customization" of supply and strengthening the relationship between supplier and consumer.

The PSS model is widespread in various business sectors, where the relationship between consumers and companies can be articulated according to the three main approaches in Figure 5 [20]:

- product orientation, where the product sale is also associated with additional services such as maintenance contracts and end-of-life repurchase agreements to ensure the functionality and the conservation of the product;
- user orientation, where the product still remains central in the relationship but the service provider has the property of the product, that is available to consumers through various contractual arrangements such as leasing etc.;
- result orientation, where the supplier and the consumer agree on a service delivery (without specifying a particular product).

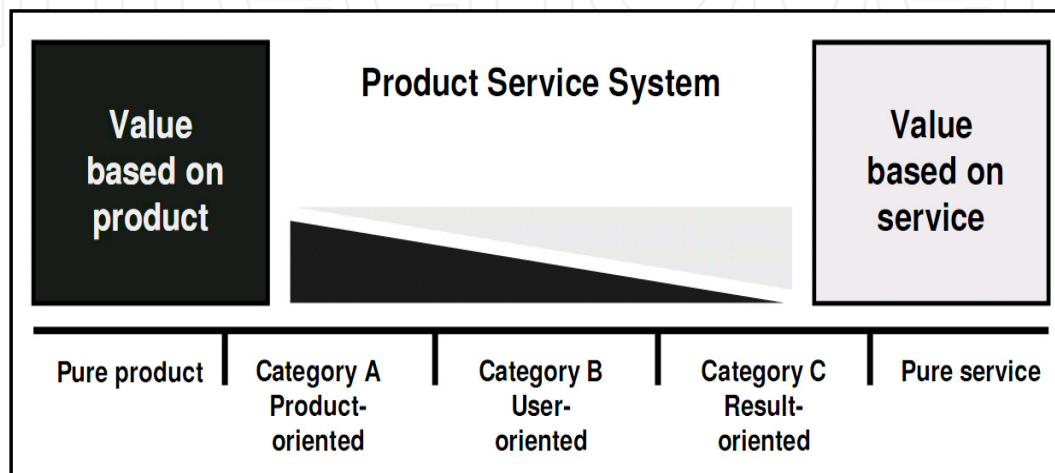


Figure 5. The product-service concept [21]

Whatever is the orientation of the company, in general the value proposition relies on a combination of product and service with different weights. “The *orientation to result*, however, is the most popular definition and the most sophisticated interpretation, and with the greatest potential for a PSS model” [22].

In remanufacturing case, the value proposition is based more on a performance value than on product’s property. Corresponding to low economic sacrifices there are functional and psycho-social benefits. A PSS model emphasizes the de-materialization of the offer and the strict relationship with the consumer. The company’s competitive vision moves towards a product life-cycle perspective that starts from the product development and production, passes through additional services delivery, and ends up with product recovery or final disposal [23]. In addition, a co-creating value process is highlighted: the end user is requested to work together and more closely to the supplier, moving from a logic of satisfaction based on property of the product to one based on access to benefits deriving from its functionalities [24].

Those producers, providing a combination product / service through the remanufacturing option, focus, of course, on the product’s use and on end of life phases aiming at a cost reduction. In this perspective, in fact, many levers of profit for a traditional business (i.e. supply of spare parts and maintenance service) are transformed into additional costs that the company must internalize. Considering that a product will have multiple life cycles, a correct life cycle cost/benefit analysis must take into account not only the initial cost (to which apply the markup), but also those costs related to the whole useful life of the product

and the corresponding revenues. The pricing strategy, in particular, will be evaluated according to criteria of multiperiod choice.

The relationship between customer and company becomes very strong. In a traditional business model the profits to companies derive from the costs incurred by customers (e.g. price of the product, cost of spare parts, etc.). The transition to a PSS model, however, distributes these benefits among the actors of the economic system. Both the company and the consumer obtain benefits, creating conditions for a win-win situation.

3.3.2. *Players*

Remanufacturing business can involve OEMs, which remanufacture their own returned products, independent remanufacturers working on products from various producers, and committed, when OEMs decide to outsource remanufacturing activities. OEMs could face a great difficulty in controlling the entire product's value chain and this can create the conditions for market entry of independent remanufacturers. In this case, the end of life products are remanufactured by small independent companies, faster to take market opportunities than the large ones. However, when the OEM itself chooses to rely on these independent remanufacturers, as in the automotive sector, contracts on orders are developed.

OEMs are becoming increasingly aware of the opportunities offered by remanufacturing. Beyond the possible profits, it offers feedbacks on failure modes and duration of the products, moreover controlling the remanufacturing process allows companies to maintain a good reputation of their brand.

However, for different reasons not always managers have had a positive attitude towards this type of activity. Primarily they raise the problem of cannibalization between new and remanufactured products. "...Cannibalism occurs when the sale of some of a company's portfolio of products reduces the sale level of one or more products in the company's portfolio of products" [25].

Although in literature the issue of cannibalization between products has been treated from different point of view, there is not an organic study concerning the cannibalization of new products by the remanufactured ones. However, that is to be considered desirable if it allows to maintain company's market share [26]. In fact, the incertitude of an OEM may represent a business opportunity for independent remanufacturers, but also for direct competitors.

Even if Linton verifies, for an OEM introducing on the market a remanufactured version of its product, a decrease, in relative terms, in profitability, considering all the market this trend is not so obvious [27]. An increasing in sales of remanufactured products could be accompanied by a lower decrease in sales of new products, perhaps because a diversification of the offer reaches customers who would never have bought new products, or because this move would make the remanufacturing business less attractive to independent actors with a consequent decrease in their competitive intensity. So, there are many good reasons to believe that a certain type of cannibalization can increase the overall level of sales, especially under two conditions:

- the remanufactured product, if sold at a lower price, could be used in alternative ways;
- the product could be offered to market segments very sensitive to price

The importance of the participation of an OEM to the remanufacturing process causes usually a positive effect on return rate and quality of cores (intermediaries, engaged in the collection of cores, may retain only those of higher quality). However, third parties cannot have the same economies of scale of an OEM and compensate this weakness with a wide freedom of movement both from a strategic point of view (an independent remanufacturer can treat cores of different brands) and technological.

The use of outsourcing for remanufacturing activities can be a complicating factor in this context. Toffel, in fact, recognizes a trade-off between internalization and outsourcing [28]. According to this author, an OEM should consider a vertical integration (or even a joint venture), rather than relying on independent companies, when tacit knowledge, confidential information related to the design, engineering and production phase, are involved. Moreover, this choice should be made when there is a risk of becoming dependent on third-party because of components becoming rare.

So, a competitive or collaborative relationship may develop between the players of this business. The competition may concern both the final market and the procurement market of cores. For this reason, there are various deterring actions for new incomings. They range from legal restrictions (which prohibits a third party to remanufacture products) to technological or economic restrictions, such as encrypted code known only by OEMs or prohibitive tariffs on relicensing software, in order to discourage or, at least, make the process more expensive.

The possible collaboration relationships may be work on commission or full outsourcing. In some cases the practice of de-branding could occur, i.e., the OEM requires that its products, entering a secondary market through third parties, have a different look, in particular, the original brand is removed. However, this operation requires additional work and may be expensive [29]. It is also possible to find cases of *coopetition*, where two or more independent producers agrees to develop a specific partnership, while maintaining a competitive relationship in other areas.

3.3.3. Value system

The system value of a remanufacturing process is depicted in figure 6. From this figure it can be argued that the value systems of direct production and remanufacturing are strictly integrated, sharing some upstream stages (on the supply side) and some downstream (on the distribution side). There is a very little difference if an OEM or an independent remanufacturer is involved in the remanufacturing process, in fact the current trend for OEMs is to devote different facilities to manufacturing and remanufacturing activities. In some cases they employ hybrid systems rather than fully integrated production systems because of the specificity and uncertainty characterizing the remanufacturing process. The trend is to configure two different networks for forward and reverse flows.

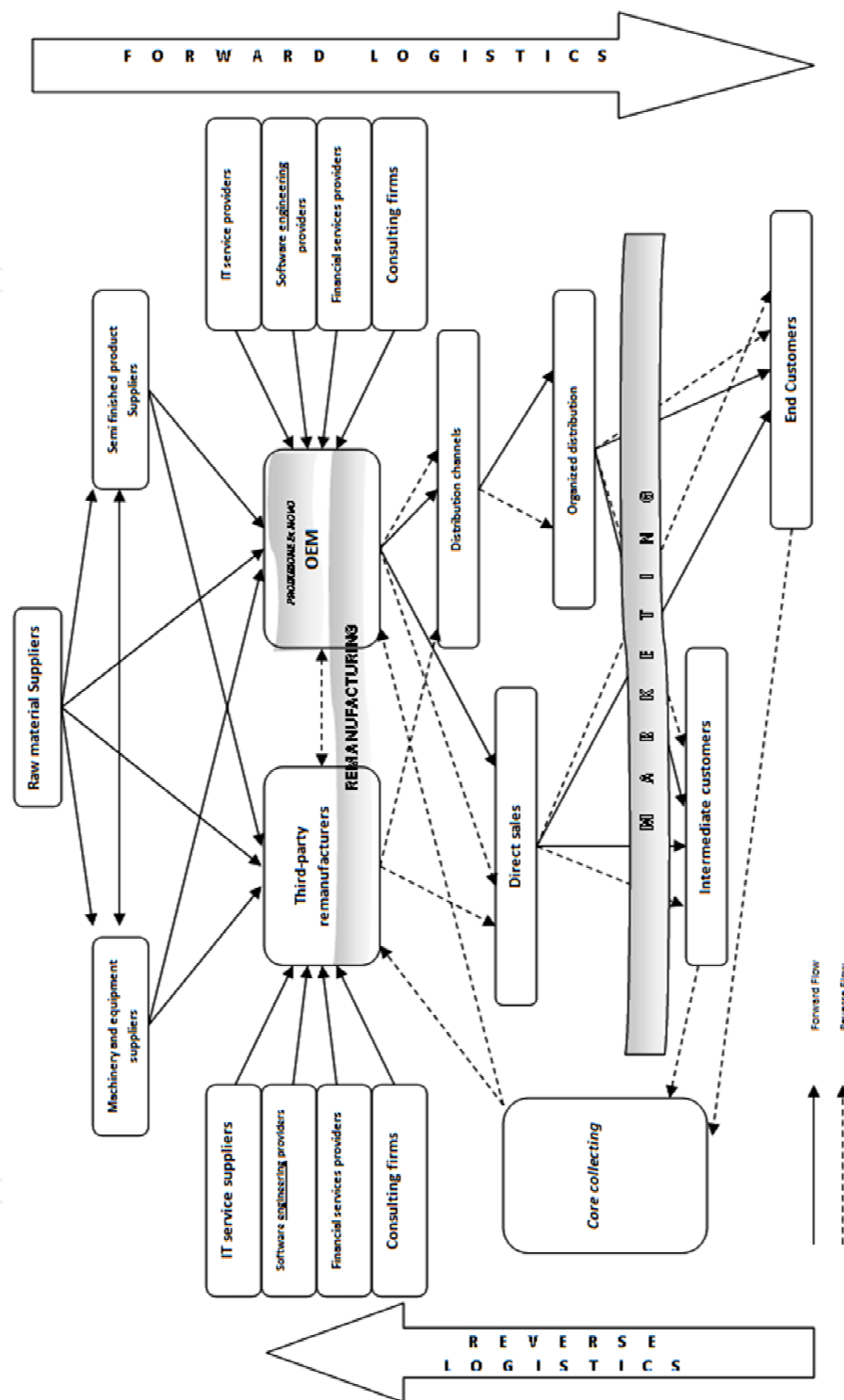


Figure 6. Value System of remanufacturing The role of information is crucial in influencing consumer's behaviour. Unfortunately there is not a systematic study on this subject. Nevertheless, basing on [30], it is possible to make some considerations on the relationship between customer and company, in the remanufacturing case. It is no coincidence that the most difficult obstacle in this business has been and is the prejudices of the market towards this category of products. As a remanufactured product is by definition not new, many consumers associate to it a judgment of low quality. This implies a low WTP, but it may be increased by working on communication.

What distinguishes the *value configuration* of a remanufacturing process is the creation of a reverse logistics system supporting the direct one to ensure the return of end of life products as input for the remanufacturing process. Actually, at network level the reverse channel can be seen as a further lengthening of the direct one. In this model, in fact, the use phase is not the final phase of life cycle, but rather an intermediate phase, to which the collecting phase follows to close the loop.

This model of value creation integrates the end customer, not only, as a player in the use phase, but also as a potential supplier of products to recover. The customer becomes a node of the network and with his behaviour impacts on the effectiveness of reverse logistics. If consumers does not return back their end of life products, there is a lacking of raw material to remanufacture. The reverse logistics system creates physical flows of products, but also intangible flows of information. So, the remanufacturing player bets on a collaborative attitude of consumers, moreover it work to formulate specific policies to facilitate it. Remanufacturers rely on networks allowing to save resources and to spread fixed costs over more use cycles of products, whit physical return flows supporting feedback on products' performance and on market evolution in terms of requirements.

3.3.4. Customer relationship

Consumers' behavior is particularly complex to analyze with reference to the remanufacturing business, since they can cover two potential roles:

- purchaser of a product (new or remanufactured);
- supplier of a core.

According to a microeconomic approach the preferences of a consumer can be analyzed through the "Willingness to Pay", the maximum price he are willing to pay for a certain good. This parameter can be measured through questionnaires, games, auction mechanisms, etc.. Camacho et al. studied the willingness to pay for an environmentally friendly product using surveys and economic experiments [30].

An interesting aspect of this study is that the participants said they were willing to pay for a product improvement in an ecological sense, but this inclination was not related to the magnitude of improvements made. This situation has important implications for corporate strategy, because the company could benefit from a rise in consumer WTP only marginally improving product's environmental performance. Therefore, it depends much on the marketing policy adopted, than on the actual environmental performance delivered. Needless to say that situations which may lend themselves to abuse must be faced.

An index to monitor the behaviour of the consumer as a supplier of used products may be the "Willingness to Receive" (WTR:), the minimum price at which a person is willing to make his product available to supply a reverse logistics program. In this situation, the customer must be encouraged to return its product through specific policies (e.g., repurchase price, leasing, buy-back transactions, etc.).

The WTR is, also, influenced by the exchange of information between the parties. With other conditions being equal, we can expect a high WTR if the company organizes an effective collecting system for end of life products, because this can be interpreted by customers as the demonstration of company's interest towards the product.

On the contrary, if the collecting phase is conducted by a no profit organization the WTR lowers significantly and philanthropic purposes take over. Contracts, linking enterprise and consumer, may be critical: in a leasing case, in fact, the company don't have to push the consumer to return the product back. Moreover, it is important how the consumer perceives the value of used products. The remanufacturing is focused on preserving the added value of products, but in many cases the consumer is not aware of it [31].

It must be also considered the fact that, although European legislation is based on maximum transparency in order to promote an informed purchase, in many countries, especially developing ones, there is no obligation to communicate to consumers the status (remanufactured or not) of a certain product. In these cases firms may exploit the information asymmetry to their advantage, keeping silent about product's nature. In contrast to it, there could be an information campaign with emphasis on the value proposition, namely low economic sacrifices to get the product in exchange for high returns for consumers in both functional (performance is comparable or higher of new products) and psycho-social (think about the value of environmental benefits for ecologically sensitive subjects). In many cases the result of information campaigns has been to overcome the distrust of the market, especially if it starts from a proper definition of the target customer profile.

3.3.5. Target market

The potential market consists of consumers and businesses. The drivers, that may spark interest for a remanufactured product, environmental sensibility, or in the case of durable goods, product's features that discourage or not allow access to a new one. In a vertically segmented market, a company may choose to serve two different target customers with the same product, using variables such as price and quality. So, on the same iso-value line, it is possible to locate "the primary market" and "the secondary market". The two offers are the same in relative terms, but different in absolute terms.

On the primary market the value proposition concerns the best quality products sold at a high price, on the secondary market, on the contrary, are sold low quality products sold at a lower price. The product's quality refers not only to functional aspects but also to product's image and its perception by the customer himself. In fact, many remanufactured products are sold at a lower price than the new ones, even if they have similar characteristics, due to its perception by the consumer, who associates the concept of remanufactured product with that of used product.

The different perception linked to new and remanufactured products is closely related to the philosophy of product recovery and not only to the specific required remanufacturing

activities. Some firms, for example, might sell new products at a certain price and remanufactured products (or *as-is* or repaired / refurbished products) at a lower price. Others, however, could sell remanufactured or returned products as new ones on the primary market.

The type of products (new, remanufactured or refurbished) sold in the primary market, depends on the specific situation considered. Primary and secondary markets are generally separated from a geographical point of view, but this is not always true because in some cases they can even overlap. This is the case of offers devoted to consumers sensitive to the environmental impact of purchasing decisions, to the less affluent social groups most sensitive to price or, in general, to consumers of products with very high price elasticity (i.e. office consumables materials).

However, in these evaluations are also involved aspects such as product's characteristics, its intrinsic value or its propensity to technological obsolescence, brand policy, characteristics of the target market. For example, primary and secondary markets, which tend to be separated in the case of mobile phones, overlap when automotive components and industrial machinery are considered. The concept of primary and secondary markets are connected to the several possibilities of product recovery and to different prices of recovered products.

The development of secondary markets, especially for Electric and Electronic Appliances, is strongly linked to growth in demand for these products in developing countries. It is easy to understand how these markets are definitely the most attractive to businesses. In areas like Latin America or Equatorial Africa, in fact, demand for these products is growing at two-digit rates. For example in Nigeria that, from 2000 to 2006, there has been an increasing number of mobile lines (from one to about 25 million). Because of the economic conditions of that population, a significant share of this demand was satisfied with mobile phones and accessories (210,000 used cell phones imported only in 2005) used or remanufactured imported from more developed countries.

In Nigeria there is a high rate of repair and reuse of mobile phones. This extends their life from about 18 months in developed countries to approximately 7 years. A further aspect that encourages the use of remanufactured products is the high availability of cores, especially in developed countries.

In addition to Nigeria and other African countries, a significant demand also comes from countries of South America and Asia, particularly from Brazil and China. It has been estimated that the demand for second hand mobile phones is still higher than their availability [32].

Offering a remanufactured product can increase the usefulness perceived by the consumer, whose willingness to pay for products in like-new conditions should increase with respect to second hand products. Meanwhile the manufacturer can increase its profits leveraging on products that can become attractive after appropriate transformations. Therefore, changes on the demand level and price could occur [33].

The importance of secondary markets for companies is demonstrated, also, by the fact that often a product not having demand in the primary market, could still have a certain attractiveness in secondary markets. For mobile phones, for example, the secondary market cannibalizes less than 1% of sales of new products [29]. Another type of secondary market is that of components. For example, computer chips may have an alternative use in devices simpler from a technological point of view, like toys etc..

3.4. Benefits of remanufacturing

3.4.1. Environmental returns

A remanufacturing process can allow an higher saving of natural resources if compared to other forms of reuse. According to the Energy Systems Division of Argonne National Laboratory, through this type of product recovery the equivalent of $422 \cdot 10^{21}$ J of energy per year can be saved. This energy would be used to satisfy the need of new components, that in the remanufacturing case is reduced of about 80%.

The energy saving is associated with lower emissions of carbon dioxide in the atmosphere for 800.000 t. In a long term perspective if everything would be recovered from returned products, a closed loop cycle for management of products / wastes could occur eliminating the use of landfill.

Waste from electronic and electric appliances, in particular, can cause serious health damage, since they contain a wide range of hazardous substances such as cadmium, chromium or mercury. For these reasons, the legislation from several countries in the world have been improved several times to ensure a correct management of potentially dangerous products during their lifecycle.

However from an environmental point of view it is important to check the opportunity of prolonging the life of a product, especially if potentially obsolete or polluting. In fact, that the impact of many products is higher during the use phase than in the disposal one [34].

Therefore even the best environmental intentions can lead to product take-back regulations counterproductive if not coordinated with the type of materials resulting from the recovery process. This lack coupled with the breakthrough role of technology has created a strange situation that still does not find solution.

3.4.2. Economic aspects of remanufacturing business

The product recovery can be a profitable business, in fact a remanufacturing process can allow a general price reduction of 35% - 40% with an average margin of 20% [16]. Furthermore, the reuse allows saving in raw materials and energy, avoiding the disposal costs that OEM by law have to support.

The cost reduction is at the base of profitability of this business and can ensure appropriate returns on investment. This will benefit the competitive position of the company that can share these benefit with its customers.

In a multi period perspective, the cost reductions do not affect only remanufactured products, but also the new ones. The pricing policy, in fact, has to take into account that many of the costs incurred ,during first production cycle, can also be amortized in the following remanufacturing cycles. Often, recovery programs are not started fearing for the negative effect on sales of new products. This is a *push* view of business, that does not consider the profile of the target market and competitive intensity. Actually, nothing ensures that the condition of maximum profit passes necessarily through a new release of product. The company can profit from new products on the primary market and from remanufactured ones on the secondary one, and if these markets are separated, there is no risk of demand substitution.

Moreover, the strong tensions on market prices of materials, due to the rapid growth of some developing countries, are making the direct costs of materials an increasingly important factor of business profitability, as the labour costs. "...As valuable resources become scarcer and more expensive, companies managing their resources efficiently are likely to gain a competitive advantage" [31].

In many cases, strategies aimed at exploiting the added value of the product, as a policy of relocation, could be source of competitive advantage. Therefore, the profitability of this business is more pronounced if the incidence of raw materials, on the full cost of the product, is high.

Among the benefits of a remanufacturing program we can find the achievement of economies of scale and experience. The increase of production size allows to spread fixed costs over a higher volume of output. However, the economies of experience allow to maximize the overall efficiency of the process optimizing the use of variable factors and the time required for operations. For example, the benefits may relate to aspects such as quality of recovered materials, waste reduction, processes organization. In this case tacit knowledge is very important. It becomes crucial how this resource is managed by the organization to allow a wide spread use and exploitation, through various stages of socialization, externalization, combination and internalization in order to create explicit knowledge [35].

Ferrer and Guide argue that ethical and environmental reasons alone are not sufficient to justify a remanufacturing program [36]. Each firm to produce profits focuses on core activities and outsources the others. Eco-friendly production logic and principles of CSR (Corporate Social Responsibility) follow this approach.

In the US the business of product recovery and remanufacturing, has not developed only for regulation reasons or environmental awareness. Legislative obligations, incentives and taxes intended to address the problem, were not the key determinants for the emergence of this industry. This is also testified by the fact that the remanufacturing business was already established in different sectors before the concepts of EPR or Product Stewardship, grow up. The determining factor turns to be the business profitability, beyond environmental aspects or taxes.

3.4.3. Business strategy motivations

The aspects related to policy and corporate strategy, although not directly related to the purpose of profit, could be particularly important for OEMs in starting remanufacturing activities. Among these there are the connotation of brand, the corporate image, the aftermarket coverage, feedback on sold products.

The image is a very critical factor in a successful business because it can only be built through a shrewd marketing policy and substantial investment diluted in time. Products devoted to remanufacturing activities, if not consistent with market expectations, could significantly damage the relationship between consumer and OEM regardless of who has carried out the remanufacturing activities.

For this reason it is crucial for an OEM to be interested in these activities. The purpose may be to stop any remanufacturing activity on its products, preventing others players from exploiting its brand image and possibly causing unwanted effects through lock-out systems, or to manage remanufacturing activities on its products.

As regards the implications of building a strong brand image, the company that enhances, in the public eye, its focus on the environmental problems by means of a suitable marketing strategy, can create an *environment friendly* image. The key element to have an environment friendly approach rewarded by the market, is its correct presentation highlighting the commitment made by the company and providing data that spell out the benefits obtained by consumers and all stakeholders.

The information used can be of two types: associated with the lower environmental impact of products and / or related to its higher performance. These two types are not mutually exclusive, rather, from their synergy the company can get the best results in terms of image return.

The first type of information is intended to highlight the aspect of product such as reduced use of resources, greater durability, the reduced number of components, the absence of environmentally hazardous materials in the product or its production process. The latter, instead, aims to highlight the performance which consumers can expect using it as, for example, greater accuracy, increased flexibility, modularity, etc.. The latter, instead, aim to highlight the performance which consumers can expect using it as, for example, greater accuracy, increased flexibility, modularity, etc.. All these information are intended to influence judgments and feelings of consumers, to amplify the potential value of the offer, working on those aspects to which the target market is more sensitive.

For an OEM collecting used components and products from its customers allows to preside over the aftermarket. In many cases this market turns out to be very profitable even more the main one. Recovery activities through the collection of end of life products is a way to preserve the aftermarket by competitors or potential players. The take-back activity represents an opportunity to maintain and increase the value of customer relationships. The product return represents a moment of interaction with customer with the chance to

establish a new relationship. Hence the importance of policies aimed at valuing this phase, perhaps through an incentive system that motivates the customer to return the product. Business models like "System Lock-In, Competitor Lock-Out" oriented to a "Restricted Access" can limit the opportunities for contact between the customer and competitors preventing new consumer experiences, and comparisons of several offers. The complementary aspects of the offer and the economies of the system should be taken into account, considering also those systems that allows the multi-period use of products [37].

Conversely, avoiding to consider this option, means not to cover a market opportunity, waiving a retention action, and, yielding to competitors. A evidence of that is represented by the statements of a German manager of the automotive industry: "officially a remanufactured engine can be purchased only if a core is returned. But if a customer provides the core without buying a remanufactured product , we tend to buy it anyway, because otherwise it could become "food" for competitors "(Seitz, 2007).

The remanufacturing process allows to extend the offer and introducing also low-cost options, to conquer new market spaces. This could be particularly important when spaces are not relevant [38]. Moreover, for products with a very long life-cycle, remanufacturing represents the only option to ensure replacement parts, because it is very difficult that companies provide new manufactured parts beyond a certain period of time. Remanufacturing activities allow a continuous monitoring of customer needs and conditions of installed products. Basing on these information, companies may decide reformulate its offer in a proactive way. Information highlighting the strengths and weaknesses of products can be collected as an input for the design phase of the product. In particular, the most critical data are the deterioration under the actual operating conditions, since many information are impossible to anticipate or difficult to simulate during experiments.

4. Conclusion and future developments

There are several reasons for considering remanufacturing as a business opportunity very attractive in a competitive advantage view. Savings in terms of natural resources through remanufacturing may be viewed as a reduction of the transactions between the actors involved in order to improve the overall efficiency of the economic system.

However, this improvement should be not considered only from an environmental and sustainability point of view, as produces lower production costs for companies. In fact they limit the purchase of raw materials and maximize the added value of their products with the additional benefits of feedback on products, image, customer relationships, and diversification.

A virtuous business, recovery-oriented, requires the transition from an industrial economy to an access economy, where services and the dematerialization are predominant. Hence, the most advanced form of value proposition based on a remanufactured product is represented by a result-oriented positioning, where there is an agreement contract with the customer based on target performance.

However, not always the relationship between customer and producer has evolved into a pure access one for several reasons: a marked relationship with the ownership of the product still remains for certain categories of products; the companies have not been able to promote correctly their value proposal to the market; the market is not ready yet for this kind of experience.

The criticality of technical, technological and design aspects in remanufacturing, shows that the value system of a remanufactured product goes towards a situation where the presence of independent actors decreases in favor of OEMs, who should overcome, therefore, fears of a possible substitution effect of remanufactured products with new ones.

A future development of this study could be, as a preliminary activity to any remanufacturing program, the development of a logical model for the evaluation of remanufacturability a generic product taking into account logistics, demand and technology aspects of the recovery process.

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