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The strategy for implementing remanufacturing process in a commercial enterprise, the case study of a French company.

Yahya Lahrour[a]*, Daniel Brissaud[a], Peggy Zwolinski[a].

1 Univ. Grenoble Alpes, CNRS, Grenoble INP, G-SCOP, 38000 Grenoble, France*
**Institute of Engineering Univ. Grenoble Alpes*
* Corresponding author. Tel.: (+33) 476 575 082. *E-mail address:* yahya.lahrour@grenoble-inp.fr

Abstract

Remanufacturing is considered one of the most effective and efficient end-of-life strategies of the circular economy, in terms of environmental benefits and economic viability. Products are circulating all over the world, coming from multiple sources and numerous intermediates. Thereby, making the supply chain between the user and the Original Equipment Manufacturer (OEM) very complex when it comes to recovering products at their end-of-life. In fact, local sellers have direct contact with users, as they are geographically close, which makes it easier for them to recuperate worn out and obsolete products. However, these sellers lack the know-how and the technical knowledge necessary to develop the remanufacturing process. This paper presents the strategy to be followed by small companies to adopt and implement the remanufacturing process, in order to give these end-of-life products a second life and to make a profit from both new and remanufactured products. In particular, it focuses on the specific case of a small company in France, that included the process of remanufacturing air compressors and electric motors in its business model and started selling them directly to users. Therefore, this study will display the multiple advantages that this remanufacturing strategy has to offer and will also show the barriers that can be faced when applying this strategy.
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Keywords: Remanufacturing; Commercial Enterprise.

1. Introduction

In a globalized world, companies offshore their manufacturing plants to reduce the cost of their production. Indeed, products circulate from a region to another flowing through thousands of kilometers, and that, by going through several intermediates from the remanufacturer to the user. For instance, one in three products consumed in France is imported [1]. Once the product is used, it is gathered by the local public services to be discarded or recycled. Products at their end-of-life are treated depending on the legislation enforced in the region where they were discarded. Policies as Extended Producer Responsibility (EPR) tries to oblige the producer to recognize the impacts of their products throughout its entire life cycle, including waste management or recovery at end-of-life. Remanufacturing is the process of bringing a used product to at least its original performance with an equal warranty as an equivalent new product [2]. Unlike, the globalized circulations of products, those policies are not globalized to all fields of production neither in all the countries. Among the factors that block the implementation of remanufacturing by OEM is the complexity of the reverse supply chain [3]. The intervention of many intermediates from the production to the use phase confuses the responsibility of each intervenient. In addition, the geographical disparity makes the reverse supply chain complicated and ecologically less efficient and more impactful. In fact, OEM leaves the remanufacturing market and does not seize a valuable economic, social and environmental potential. Local sellers of the products have the advantage to be in direct contact and geographically close to the users. The direct contact

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allows the sellers to have a mutual sharing information with users about the products, the difficulties of use, the spare parts needed during the use phase and eventually, the possibility to take back the product at the end of life. Remanufacturing by sellers may increase the efficiency of remanufacturing compared to OEM remanufacturing thanks to the geographical proximity and the seller-user direct relationship. However, the seller has not the knowledge related to the product expertise neither the technical "know-how" to establish the remanufacturing process. Considering this context and the aforementioned difficulties, we will present in this paper the strategy adopted by a French small company to implement remanufacturing. This strategy is based on the economic viability of remanufacturing, the acquisition of the technical "know-how" of both the products to remanufacture and the process of remanufacturing and finally the environmental impacts of their remanufactured products.

2. Background of the study

Firstly, an exploratory review of the literature on the classification of companies doing remanufacturing, and the incentives and barriers for each type of company faced to implement a remanufacturing activity will be done. The result of the literature will allow us, in one hand, to look at the important incentives, economic and environmental, that will be considered as a necessary conditions for the implementation of remanufacturing by an independent remanufacturer, in another hand, to tackle the barriers, that if are neglected it will lead to the failure of the implementation of remanufacturing.

The second step was to develop a strategy for independent remanufacturer to verify the financial viability of remanufacturing, to assess the environmental impact of remanufacturing, and to acquire the knowledge of the functioning of the recovered products in order to implement the remanufacturing process.

The third step was to carry on a case study on an independent company that does not manufacture the products that will be remanufactured later. The case study will be an application of the strategy of the implementation of the remanufacturing process. One French company was selected and accompanied for 14 months to build its own remanufacturing process.

2.1. Categories of remanufacturing enterprises:

In the literature addressed to remanufacturing companies we can find that remanufacturing companies are globally divided into two types of companies, Original Equipment Remanufacturer (OEM-R) and Third party Remanufacturer, each one have different characteristics. The Third-Party Remanufacturers are also divided to two categories of companies. On one hand we find Outsourced Remanufacturers that coordinate directly and deeply with the OEM, and on the other hand, we have the Independent Remanufacturers that start the remanufacturing of the product from their own initiative and mainly without the intervention of the OEM.

- Remanufacturing by the Original Equipment Manufacturer (OEM-R)

OEM-R is a company that remanufactures parts and equipment that were produced for the first time by the same company. The OEM-R masters the process of their initial products from the creation to the commercialization. By receiving back used products they select them, clean them and build new ones with similar quality level as the products firstly manufactured and conform to the specification of the firm. The activity of remanufacturing allows OEM to get some benefits as savings in material, energy costs and labor time, and creating new market opportunity and also, a positive social image [4]. The OEM has the product expertise and knows the specifications and valuable information for the remanufacturing operations.

- Third-Party Re-manufacturer (Third-Party-R)

We can find two types of Third-Party remanufacturer, the outsourced one and the independent one. The outsourced Remanufacturer (Outsourced-R) is a third-Party Remanufacturer that carries out the remanufacturing operations, but the other activities as marketing and reverse supply chain are carried out by the OEM itself [5]. The OEM works closely with the Outsourced-R and delivers information about the product, technology secrecy, the use of the OEM brand name and workers may be trained by the OEM [6]. In the other hand, the independent Remanufacturer (I-R) is a remanufacturing company that takes back products at the end-of-life directly from the users by the core suppliers. Due to the lack of cooperation between the I-R and the OEM, I-R companies proceed by reverse engineering to acquire the knowledge related to products for remanufacturing operations. Generally, those companies are small companies that work locally and directly with the users of the product.

Globally, we can divide the remanufacturing companies into two types of companies, OEM-R, and third-party Remanufacturer. The division made between both companies is based on the implication of the OEM in the remanufacturing operations.

Table 1 summarizes the similarities and differences between these companies. We can see that the outsourced-R can be a better option for remanufacturing if independent and OEM cooperate, but we lack information about this type of remanufacturing companies.

2.2. Motives and barriers for type of Remanufacturing companies:

Remanufacturing is an industrial activity with high and wide uncertainties coming from both the volume and quality of cores [3]. Thus, companies remain skeptical about the economic feasibility of remanufacturing and it leads to a large untapped market for product remanufacturers [7].

Remanufacturing has an environmental and economic potential but it still faces many technical and legislative barriers. The incentives for each type of remanufacturing company, OEM-R or Third Party-R, are different. In a research [8] based on a multi-case study and 130 interviews addressed to 5 automotive remanufacturing companies, found that classic incentives as, the fear of legislation, profitability, moral and ethical concerns have low influences on the decision to remanufacture for OEM-R. Due to the uncertainties of core

acquisition, the unpredictable reverse supply chain and the high cost due to manual labor, OEM-R still considers the remanufacturing profit is lower than the profit of a new product. Rather, future spare parts supply, market share, and brand protection are identified as the underlying motives with high influence for OEM-R to take up Remanufacturing. Similar incentives for OEM-R where indicated as competition and strategic advantage [9].

Table 1. Characteristics of remanufacturing companies at the implementation of the remanufacturing process

Type of Remanufacturing company	Level of product knowledge	Level of technology	Reverse supply chain	Marketing
OEM-R	High	High	Complex for offshored OEM	The use of the brand name
Third-Party-R:				
Outsourced-R	Transferrable from the OEM	Transferrable from the OEM	–	–
Independent-R	Low	Lack of technologies	Local and facilities to get cores	The green benefits of remanufacturing

In the other side, Third Party-R has other reasons to start remanufacturing. Third party remanufacturers are interested in the environmental concerns that remanufacturing can partially solve by reducing CO2 emissions and the less use of natural raw materials [10]. These companies use this reason also as a marketing argument to green their image. They are also interested by the business opportunity, since that the remanufactured product is made from used products which allow competitive prices compared to the new products. Remanufacturing enables them to deliver faster products to customers with expanding the market range to customers and including the customers who are looking for remanufactured products.

Despite all these incentives of remanufacturing, it presents many barriers for both types of companies. The main challenges to remanufacturing are uncertainty and complexity. Uncertainty in remanufacturing comes from the variability of the quality level of the product at the end of life [11]. Each product is used during its lifetime in a certain manner so it leads to a large variation of deterioration from one product to another. The second uncertainty comes from the complexity of the reverse supply chain since the number of used products and the time when the product will be discarded are unpredictable. OEM-R companies still perceive remanufacturing products as a cannibalization of the market and sales for their new products [12]. Another great barrier for OEM-R is that remanufacturing does not fit easily the process and complicate the existing operations [13]. Cannibalization and the lack of control of the process are the main barriers for OEM to start remanufacturing since that they have a higher level of knowledge on the product, the process, and the supply chain. Otherwise, Third Party-R faces a different type of barriers. The most important barrier is the lack of knowledge, related to process and product, the lack of technology and legislation restriction [11].

We can add the consumer perception as a barrier for both types of companies. Consumer perceives remanufactured products as products containing used components. The low prices of remanufactured products can be perceived by consumers as that remanufactured products are products with low quality [9].

As shown in the studies above, the main motives and barriers of remanufacturing companies are mainly technical and profit-dependent, but we can add also legislative barriers that change from one country to another and the absence of policies for remanufacturing. In fact, the incentives and barriers for remanufacturing are dependent on the type of the company. We can conclude that remanufacturing present for OEM-R an activity that can increase the availability of spare parts and cut off the potential of the remanufacturing of their products by an independent remanufacturer. Because in the situation where Third-Party-R starts remanufacture, any indulgence about the quality of remanufactured products will lead to the degradation of the image of the OEM. In the other side, Third-Party-R is interested in remanufacturing for the potential profit that they can make and the environmental aspect of remanufactured products that can green their image. But the lack of knowledge of the product and the lack of technology creates a high barrier for third-party-R.

3. The strategy to implement remanufacturing by Independent Remanufacturer with the results of the case study

3.1. The company subject of the study

The company under study, named AQUA-Assainissement, was created in 2015 to sell online products and spare parts of Micro-Water treatment plant for professional and non-professional use. The main products are electric motors and air compressors. The Micro-Water treatment plants in France start aging and need to be replaced. The company was launched to seize this important pointed need of these type of products. The used equipment's where discarded in landfills, and had to be in the best case recycled. From this context, the company starts gathering the used product and launched a remanufacturing project to extend the lifecycle of the products. The company is not the OEM. So, they buy from agents of the OEM who is settled in Asia, after, Aqua sells those products or the spare parts to French users. The real barrier of the implementation of the remanufacturing process is that the company does not know the manufacturing process. In the other side, the financial motivation is the principal motivation for the company. They wanted to seize the expansion of the market of these products, by offering similar products with less environmental impact.

3.2. Financial aspect

The financial dimension of the remanufacturing activity is the central motivation for independent-R, even more, it is the principal condition guarantying the vitality of remanufacturing.

Companies, OEM or Independent, that are selling new and remanufactured products have a concern with the effect of remanufacturing on the sales of new products [14]. As said above, cannibalization is seen as a major barrier to the growth of remanufacturing, and those companies consider that offering remanufactured products will cannibalize their new product sales [15]. Knowing that remanufactured products have the same quality as new products with the advantage of lower prices, remanufacturing may strongly reduce the sales of new products. This phenomenon is mainly visible for products that do not have high technology. The cannibalization is difficult to control because it depends on the behavior and the preferences of the consumer. The remanufacturer has to be sure that the global profit made from new and remanufactured products is maximized.

The profit from the remanufactured product = Selling $price_{rem}$ – Remanufacturing cost.

The Selling $price_{rem}$ is defined by:

Selling $price_{rem} = \varepsilon * \text{Selling } price_{new}$, with $0<\varepsilon\leq 0.8$

The profit from the new product = Selling $price_{new}$ – the price bought from the OEM.

At the operational level, the remanufacturing cost depends on the quality of the returned cores. The margin obtained from one remanufactured product can be calculated only after the control quality of the returned product. It means that the decision between remanufacturing one product and selling a new product can be made only after the control quality of the returned product. Which implies, that all the costs before the control quality are incurred costs and inherent to both remanufactured and new products. Figure 1 shows the detailed cost of the remanufactured product.

We propose to adopt a Go/No-Go test at the operational level, to test which product, remanufactured or new, has a better profit for a specific returned core. If the maximal profit is obtained by selling a new product, the returned product does not have to be remanufactured. The remanufacturing cost includes all the costs below

- The cost of buying a used product
- The transport cost 1 (from user to remanufacturing plant).
- The labor cost 1 (Disassembly and control quality).
- The cost of the new components.
- The transport cost 2 (from the remanufacturing plant to users).
- The labor cost 2(Assembly and cleaning).

To observe the results obtained by applying the Go/No-Go strategy at the operational level we will test it on real data. We will test it by comparing the three following scenarios:

Scenario1: Only new products are sold. If the remanufacturing activity is not existing yet.

Scenario2: Only remanufactured products are sold.

Scenario3: The strategy Go/No-Go is applied. Only the type of the product with the biggest profit is sold.

The Go/No-Go test is calculated, table 2, for each returned product, it delivers the best profit that the company can make by choosing between remanufacturing this core or selling a new one. For the 26 products studied, the best margin profit is obtained by buying only new products. However, selling a mix of new and remanufactured products can attain a maximum profit that is not far from the first scenario. While the company can reduce its environmental impacts, the remanufacturing activity may increase the market share of the company by attracting new customers more interested in green products. The presented strategy does not study this effect and is focused on the worst case where the remanufactured products cannibalize the new ones and reduce the profit of the company.

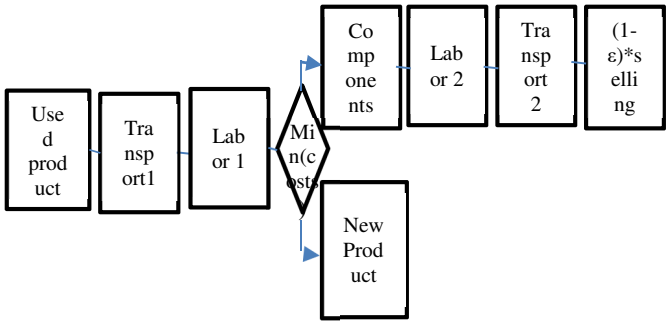

Fig. 1. The mode decision between remanufactured and new product

Table 2. Characteristics of remanufacturing companies at the implementation of the remanufacturing process

Scenarios	Profit (euros)	New product	Remanufactured Product
Scenario 1	2060.7	26	0
Scenario 2	1714.97	0	26
Scenario 3	2037.3	12	14

3.3. Technical aspect

Independent-R companies suffer from a lack of technology and the knowledge of the remanufacturing process. They do not have, at the implementation for remanufacturing, the means to know the functioning of the products neither the reasons of dysfunctions nor how to overcome them. The independent-R has to appropriate the knowledge related to the product. More the product is developed with advanced technology more difficult the appropriation will be for the Independent-R. The product functions and the user's requirement have to be defined in the early stages of the implementation. The independent-R has to organize technical workshops directed by a technician knowing well the functioning of a product in order to decompose the product to elementary components. The decomposition will allow the company to make an exhaustive description of the materials, the conditions of use and the technical variation between models. So, it allows to create the bill of material of the components and also to observe visually the quality of each one, and, further to compare the differences of quality between the used and new components. The workshops enable to externalize the tacit knowledge of the technician in order to formalize the bill of material and the required quality of each component. The remanufacturing process is labor intensive and mainly manual, indeed, the clarification of the knowledge related to the product and the process is useful to decrease the work time.

The remanufacturing process follows the sequences of disassembly, inspection, cleaning, reprocessing, reassembly and diagnosing. The crucial phase in the process is inspection. It enables to decide about the ability of the components to be remanufactured. Cores, either entire products or individual components, must be classified into products to be either reused, reconditioned or wasted. All cores which must be wasted are called sacrificial cores [16]. The assessment step of used products is mainly visual and manual based on the comparison between the characteristics of new and used components.

To inspect the product in a procedural way, we adapted the Failure Mode and Effects Analysis to fit with the inspection of the used products for remanufacturing. The FMEA allows getting the Diagnosis Procedure Tree that gathers the symptoms observed in the returned products and gives information about components that must be inspected in the first place. Figure 2 shows the diagnosis procedure tree.

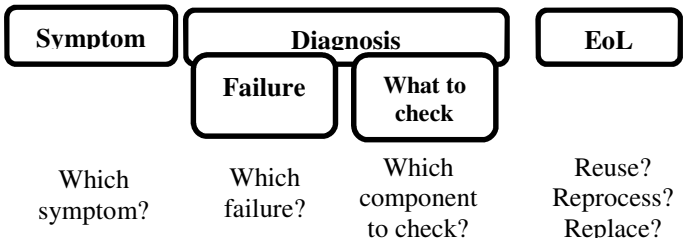

Fig. 2. The diagnosis procedure tree.

3.4. Environmental impacts of remanufactured products

The remanufacturer companies want to point out, for marketing reasons, the environmental benefits of Remanufacturing. The principal tool used to measure and compare the environmental impacts of the new and remanufactured products is the Life Cycle Assessment (LCA). The LCA standards and guidelines must be followed correctly to get valid and meaningful results. However, for the system boundaries selection in the LCA for remanufacturing, the standards and guidelines do not contain sufficient guidance for practitioners [17]. In a critical review of LCA studies for remanufactured products, they identified two perspectives adopted by practitioners, the 'supporter' perspective that maximizes the benefits of remanufactured products and the 'neutral' perspective. The majority of studies in the literature assess remanufactured products by adopting a 'supporter' perspective. In the 'supporter' perspective practitioners evaluate only one remanufacturing cycle and do not take into account the environmental burdens of the original product.

Rather than the commercial and the communication concerns behind the LCA results, it allows, fundamentally, to assess the environmental impacts of the remanufacturing activity. In this perspective, we adopted an assessment of a multi-cycle remanufacturing by comparing the use phases that can offer the new or the remanufactured products. We added also in the system boundaries of the model an important assumption that not all used products that ended in the remanufacturing plant can be remanufactured. We supposed that the remanufactured product has the similar quality and lifetime as the new product.

The figure 3 shows the life cycle inventory of one new product returned to the remanufacturing plant. The returned product cannot be able for remanufacturing. In this case, the product is recycled.

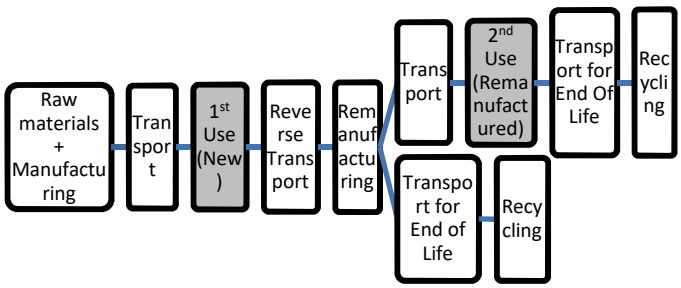

Fig. 3. Life cycle inventory for the remanufactured product.

The functional unit was defined to fit with the goal of the study. We wanted to compare two life cycle of a new product with a lifecycle of the new and remanufactured product as in figure 3. The product of the Independent-R is an air compressor designed to compress air for 25000 hours in 10 years. We expressed the functional unit as: "Generate compressed air for 50000 hours in 20 years".

The result was positive and the remanufactured had fewer impacts for CO_2 emissions equivalent to 27% for the multicycle.

The summary of the strategy with all the aspects is presented in figure 4.

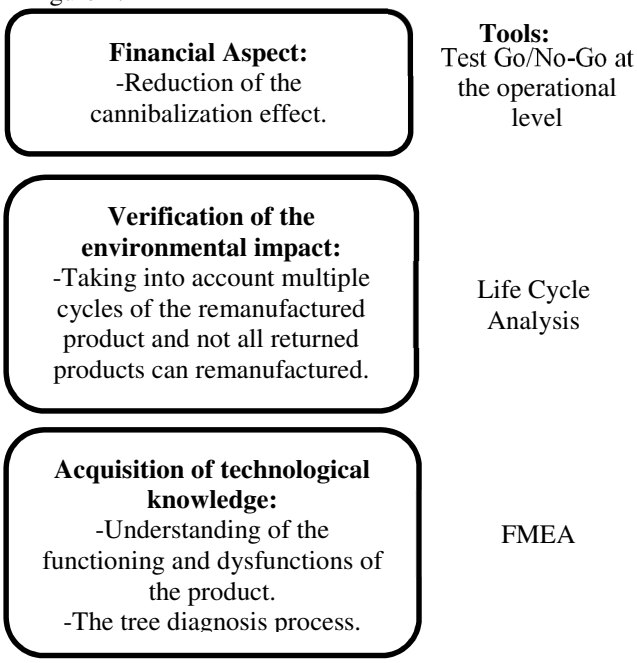

Fig. 4. The strategy for Independent-R to implement Remanufacturing.

4. Conclusion

The strategy presented is addressed to Independent-R that are starting the implementation of the remanufacturing. This strategy allows, in one hand to validate the main motives expressed in the literature for this type of remanufacturing companies and on the other hand to overcome the main barrier to the implementation of remanufacturing. The main motives

for Independent-R founded in the literature and expressed by the company subject of the case study are the economic viability of the activity and the possibility to be more sustainable. The strategy proposed allows verifying the economic profitability of each remanufactured product by reducing the effect of cannibalization which Independent-R sellers of new products are confronted to. We have to notice that the OEM have more margin for their new products than the independent sellers so the Go/No-Go strategy may be not useful for OEM-R. Except if their specialized knowledge of their process and products can lead to low remanufacturing costs. For the environmental evaluation we were aware of the lack of guidelines in LCA to assess remanufactured products and we propose for this strategy a system boundaries with multi-cycle and we included assumption related to the percentage of returned product to the plant that can be remanufactured, points that are missed in many studies about remanufactured products [17] and allows to be more neutral about the possible environmental of the remanufactured products. The main barrier to implementation of remanufacturing for Independent-R is the lack of knowledge related to the product and the process. To overcome this lack, technical sessions guided by an expert on the product has to be done with a Diagnosis procedure tree based on FMEA and value analysis for the inspection phase, considered as the most important in remanufacturing. To our knowledge, the literature does not contain studies or methods that support Independent-R to implement remanufacturing activities. As in the study [10], we consider that the Independent-R present the advantage of having an easy accessibility to cores and have more freedom and facilities to remanufacture. Deep cooperation between the Independent-R and the OEM may help to overcome the barriers related to the lack of product knowledge and to be sustained by the brand name of the OEM.

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