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ORIGINAL ARTICLE

Remanufacturing in industry: advices from the field

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Abstract The sustainable management of wastes has attracted in the last decades an increasing number of industrial actors, policymakers and researchers. Environmental improvements, social responsibilities and economic opportunities led many manufacturers to implement different kinds of end-of-life (EoL) strategies. However, in many cases, these strategies are not supported by a correct commitment of top managers, but are implemented only in response to competitor's actions. This paper aims to improve the understanding of management practices concerning remanufacturing activities. A mixed evaluation model based on strengths, weaknesses, opportunities and threats (SWOT) analysis and Analytic Hierarchy Process (AHP) is proposed. Its final aim is the evaluation of top management commitment in driving remanufacturing as an overall sustainable initiative into three different sectors (automotive, aerospace and medical equipments). The survey allowed to define the most critical factors for each sector and, so, to analyse underlying remanufacturing strategies.

Keywords Decision support · Remanufacturing · Survey research

1 Introduction

Depletion of resources and deterioration of the environment accelerated the transition towards a circular economy. However, traditional manufacturing processes, causing these impacts, are hardly adaptable to this new economic context [1]. One solution could be, as highlighted by several papers [2–4], the integration of end-of-life (EoL) strategies within the value chain, in order to improve the sustainability of products and processes.

EoL is defined in literature as the lifecycle phase when products are discarded because of technological obsolescence, deterioration or changes in consumer needs [5]. Different EoL strategies were analysed in literature, and reuse, remanufacturing and recycling are the most cited ones [6]. Among them, remanufacturing seems to be a promising strategy, potentially able to (i) increase the firm's profitability, (ii) create new job opportunities and (iii) reduce environmental impacts [7, 8]. Remanufacturing potential markets are [9, 10]:

- Used products, where they can be acquired at a lower price even if with a lower quality;
- Illegal products, representing the submerged economy that could be counteracted with a policy of life cycle product traceability; this paper considers as "illegal" the products that, currently, are managed in a non-conventional way (e.g. informal systems), by non-authorized actors and through non-sustainable processes. In this sense, remanufacturing could reduce the volume of products entering this kind of unregulated markets.
- Developing countries, where main activities should be done to enhance the functional integrity of remanufactured products (not only the aesthetic integrity) up to offer valuable products with a limited cost.

Sectors where remanufacturing reached a great importance during the years are automotive, aerospace, communication and medical equipments, mass electronics and robotics [11]. However, it is important to point out that not all the products

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can be refurbished/remanufactured, especially if they are characterized by numerous versions and short technological cycles [12, 13] proposes a list of products as example concerning three sector analysed in this paper: aerospace (engines, flight surface actuators, fuel systems, landing gears), medical equipments (diagnostic, medical pumps, patient care apparatus, scanners, surgical, X-ray) and automotive (alternators, brakes, differential carriers, engines, gearboxes, starters, transmissions). Because of the strategic importance acquired by remanufacturing in so many industries, this paper wants to evaluate in a structured way top management commitments in driving remanufacturing as an overall sustainable initiative for their firm. Strengths, weaknesses, opportunities and threats coming from a survey done in three relevant remanufacturing sectors will be analysed.

2 Methodology

Decisional and strategic processes are influenced by a set of multiple factors [14]. From one side, there are top management subjective perceptions of the industrial environment and different objectives they want to reach. From the other side, there are issues coming from the field that have to be adequately managed, as the following:

- The economic assessment in dynamic contexts [15];
- The evolution of remanufacturing business models [16];
- The product mix to be managed [17];
- The identification of different market strategies [18].

To this aim, a mixed evaluation model based on strengths, weaknesses, opportunities and threats (SWOT) analysis and Analytic Hierarchy Process (AHP) was proposed by different experts [19, 20] for the analysis of recycling practices, especially in the automotive industry. This paper wants to replicate what was already done in these studies, but in a new context, as remanufacturing. The methodological phases can be summarized in:

- A remanufacturing literature analysis, from which critical factors of the SWOT matrix were extracted (Section 3);
- A survey involving 40 original equipment manufacturers (OEMs) coming from each of the three selected industries. This survey allowed us to define the most relevant factors for each of the four quadrants of the SWOT matrix in each sector (Section 4);
- An elaboration of the obtained results with the aim to assess the presence of innovative OEM remanufacturing strategies (Section 5).

3 SWOT analysis

The SWOT analysis pervasiveness and simplicity of use for the assessment of strategic behaviours are widely highlighted by the literature [21]. This section proposes the application of SWOT analysis in remanufacturing. Table 1 summarizes all the relevant factors that, better than others, represent critical elements (both in positive and negative terms) when a strategic decision about implementing (or not) remanufacturing has to be taken. In the following subsections, each of the quadrants constituting the SWOT matrix (and related critical factors) will be described into detail.

3.1 Strengths

The following factors have been identified:

- Reduction of energy consumed: The required energy of a remanufactured component is lower than a virgin component, and several papers try to evaluate this value. For example, remanufactured starter motors require seven times less energy if compared to the new ones [21]; the engine remanufacturing process uses 83 % less energy than the manufacturing one [22]; again, remanufacturing is 80 % more energy efficient than traditional manufacturing [23].
- Environmental improvement: Environmental advantages related to remanufacturing are (i) decrease of depleted resources, (ii) reduction of greenhouse gas emissions and (iii) chance to close the loop for a safer handling of toxic materials. For example, by considering a mobile telephone, the global warming potential reduction of remanufacturing, if compared to recycling and landfill, is of about 8 kg CO_2eq and 15 kg CO_2eq, respectively [22]; again, remanufactured turbine blades permit 45 % carbon footprint improvement than new ones [23].
- Job creation: This aspect must be carefully analysed; in fact, remanufacturing requires labour-intensive activities due to specific processes, such as disassembly [24, 25].

Table 1 SWOT analysis

Strengths	Weaknesses
• Reduction of energy consumed (S1)	• Health risks (W1)
• Environmental improvement (S2)	• Production planning (W2)
• Job creation (S3)	• Availability of EoL products (W3)
• Potential profitability (S4)	• Remanufacturing costs (W4)
Opportunities	**Threats**
• Government regulations (O1)	• Internal cannibalization (T1)
• Design for reman (O2)	• External competition (T2)
• Sustainable solution (O3)	• Market positioning (T3)
• Green Marketing (O4)	• Organizational conflicts (T4)

This means that the creation of job allowed by remanufacturing has to be adequately assessed from different points of view that go out from the limits of our analysis. These are the amount of detailed activities characterizing the remanufacturing process (e.g. pre-treatment, disassembly, repair, component's substitution, etc.) and the positive social impact given by remanufacturing activities.

- Potential profitability: The profitability of remanufacturing is obtained through the balance of returns of cores and the demand of remanufactured products from customers [12]. There are two possible profitability scenarios identified: (i) in the presence of high remanufacturing costs, in large functionality-oriented segments and high supply of used products, and (ii) in the presence of low remanufacturing costs, in several cases (except for the ones with limited supply of used products and large functionality-oriented segments). The profitability of remanufacturing processes could be estimated in 60 % of a traditional manufacturing process [26]. As noted by [27], one of the elements favouring this profitability is the chance to develop long-lasting relationships with customers.

It is opportune to highlight that greenhouse gas (GHG) covers six categories of gases (CO_2, CH_4, N_2O, HFC, PFC and SF_6) and is measured in terms of CO_2 equivalents (CO_2eq), a metric used to compare the emissions from the various greenhouse gases based upon their global warming potential. Reduction of energy consumed and environmental improvement are strictly linked, but these parameters are considered separately in accordance with the above-mentioned papers [21–23].

3.2 Weaknesses

The following factors have been identified:

- Health risks: Remanufacturing processes require security measures and equipments that limit the potential interaction with hazardous substances for both workers and local population [28]. Even if these risks are present also in manufacturing, the difference lies in who is responsible for the management of hazardous components. In manufacturing, there are skilled workers managing this kind of elements that are aware of the risks related to their management and of the defence strategies to consider in case of danger. In remanufacturing, there is limited information about the type of hazardous components embedded into a product. This way, the operators are exposed to higher risks.
- Production planning: Production planning in a hybrid context, involving manufacturing and remanufacturing activities, is very complex. Some aspects have been defined critical, as the following: sizing for the optimal combination with daily production flows, processing times, sequencing and quantities of cores to be managed [29, 30]. A literature review on this topic highlighted that a practical research is needed [31].
- Availability of EoL products: Remanufactured product supply depends on factors that are beyond the OEMs' control, as the following: the usage time of consumer, the intensity of use and the condition of the return [12]. Consequently, these uncertainties, concerning times and quantities of cores, complicate the decision-making process. Contracts with suppliers and incentives to return cores can be used to reduce these uncertainties [32].
- Remanufacturing costs: Remanufacturing requires processes (i.e. reverse logistics) and activities (i.e. disassembly, inspection, repair, etc.), which are not present in a manufacturing environment. Consequently, there are additional costs. In hybrid systems, to consider costs of adding remanufacturing to an existing production line and costs of setting up a dedicated production plant is opportune [33]. Furthermore, Sundin and Lindahl [34] defined that the higher number of separating tools and probability of damaging the product can increase total costs.

3.3 Opportunities

The following factors have been identified:

- Government regulations: Governmental directives and legislations are seen as an incentive to conduct remanufacturing activities. For example, Waste Electrical and Electronic Equipment and End of Life Vehicle Directives aimed to foster ecosystem protection [35]. Furthermore, incentives play an active role in improving remanufacturing activities. From one side, governmental tax reduction allows to lower the final price of products; from another side, subsidies can compensate initial costs of emerging technologies that will become less significant once economies of scale will be reached [36].
- Design for remanufacturing: Some authors highlighted that there is a misalignment among firm's divisions on product design needs for remanufacturing, but this approach is very useful for the efficiency and effectiveness of the remanufacturing processes [37]. In fact, the diffusion of these practices can favour an easier disassembly of products without further damages [38].
- Sustainable solution: Remanufacturing is seen by many authors [39] as a key strategy to construct a sustainable development and manufacturing process. There are no doubts that it is the preferable option from the environmental point of view, in comparison to material recycling

or manufacturing of new products. From an integrated economic-environmental view, markets, costs and product conditions represent the main drivers characterizing remanufacturing [40].

- Green marketing: Businesses need to carefully assess the feasibility of adopting remanufacturing before committing to a particular activity or strategy [41]. Firms may see remanufacturing as a strategy to increase the importance

Table 2 Survey participants

No. of firms	Reman title	Country	No. of years of reman experience
Medical equipments			
1	Reman program manager	Europe	4
2	Director of OES, remanufacturing	China	4
3	Manager, reman supply chain	China	3
4	Manager, reman supply chain	USA	2
5	Reman program manager	China	7
6	Director, OEM, aftermarket accessories	Europe	1
7	Reman program manager	China	1
8	Director of OES, remanufacturing	USA	3
9	Director, OEM, aftermarket accessories	Europe	4
10	Manager, reman programs	Europe	2
11	Director, OEM, aftermarket accessories	USA	2
12	Director of OES, remanufacturing	China	3
13	Manager, reman supply chain	Europe	4
14	General manager, remanufacturing	Italy	1
15	General manager, remanufacturing	Italy	3
16	General manager, remanufacturing	Italy	2
17	General manager, remanufacturing	Italy	2
18	General manager, remanufacturing	Italy	3
19	General manager, remanufacturing	Italy	4
Aerospace			
20	General manager, remanufacturing	Europe	3
21	Manager, reman programs	China	5
22	General manager, remanufacturing	Europe	2
23	Manager, reman supply chain	Europe	4
24	General manager, remanufacturing	Italy	2
25	General manager, remanufacturing	Italy	1
26	General manager, remanufacturing	Italy	4
Automotive			
27	Director, OEM, aftermarket accessories	USA	2
28	Reman program manager	China	3
29	Director of OES, remanufacturing	USA	2
30	General manager, remanufacturing	Europe	4
31	Manager, reman supply chain	USA	4
32	Reman program manager	USA	6
33	Manager, reman supply chain	USA	3
34	General manager, remanufacturing	Italy	5
35	General manager, remanufacturing	Italy	6
36	General manager, remanufacturing	Italy	6
37	General manager, remanufacturing	Italy	7
38	General manager, remanufacturing	Italy	4
39	General manager, remanufacturing	Italy	3
40	General manager, remanufacturing	Italy	2

of sustainable innovations in their business activities. In addition, green products and services have found a great interest from investors and consumers [42]. Remanufacturing allows to reset used products to a like-new condition (or to upgrade them to latest versions), so preserving the intrinsic value given by the production process [43].

3.4 Threats

The following factors have been identified:

- Internal cannibalization: Internal cannibalization happens when potential consumers for new and remanufactured products are overlapping [44]. The effect is a reduction of new product sales in favour of remanufactured products, and many firms consider this situation undesirable, even if the profit margin of a new product is less than that of a remanufactured one [45]. It is not a concern for OEMs if new and remanufactured products are perceived as the same thing by customers; furthermore, some products can include reused parts [46].
- External competition: External competition happens when OEMs do not propose a remanufactured version of a popular product. In this case, independent operators (IOs) may decide to enter the market [12, 47] highlighting that if IOs dominate from the beginning of the remanufacturing market, it becomes very difficult for OEMs to compete with them. Brand erosion and the protection of intellectual property are a concern for OEMs whose products are remanufactured by third parties [9].
- Market positioning: Many firms do not have a clear understanding about the market positioning of remanufactured products [48]. This is due to a lack of comprehension about the quality of remanufactured goods perceived by their customers that, in turn, influences their willingness to pay for these products [49]. This concern is greater within the business-to-customer (B2C) market than the business-to-business (B2B) one [44].
- Organizational conflicts: The business unit sale of new products can be in conflict with business unit sale of refurbished/remanufactured products within the same firm. In fact, they are both in competition for the same goal. This determines a non-cooperative relationship that could damage the entire company [50].

4 Analytic hierarchy process

AHP is a measurement theory and process that, through a pairwise comparison based upon the judgments of the experts, tries to derive a priority scale among a defined set of factors [51, 52]. By considering this paper, the survey was conducted on a sample of 40 companies, 19 coming from the medical equipments sector, 14 from the automotive sector and 7 from the aerospace sector. The 60 % of the sample is represented by multi-national companies (MNCs), allowing to widen the paper's boundaries beyond national borders (Table 2). For each of the four quadrants (strengths, weaknesses, opportunities and threats—Table 1) constituting the SWOT matrix, top managers were asked to do a pairwise comparison among different factors, by associating a one-to-nine judgement scale, as recommended by the literature [53]. More into detail, the scores indicated the following:

- 1 = Equal preference;
- 2 = From equal to moderate preference;
- 3 = Moderate preference;
- 4 = From moderate to strong preference,
- 5 = Strong preference;
- 6 = From strong to very strong preference;
- 7 = Very strong preference;
- 8 = From very to extremely strong preference;
- 9 = Extremely strong preference.

Table 3 Pairwise comparisons in the automotive sector

	S1	S2	S3	S4		W1	W2	W3	W4
S1	1	5	6	0.33	W1	1	0.50	0.17	0.50
S2	0.20	1	2	0.20	W2	2	1	0.17	0.50
S3	0.17	0.50	1	0.14	W3	6	6	1	5
S4	3	5	7	1	W4	2	2	0.20	1
	O1	O2	O3	O4		T1	T2	T3	T4
O1	1	3	2	0.33	T1	1	0.33	0.33	3
O2	0.33	1	0.50	0.25	T2	3	1	0.33	3
O3	0.50	2	1	0.33	T3	3	3	1	4
O4	3	4	3	1	T4	0.33	0.33	0.25	1

Table 4 Pairwise comparisons in the aerospace sector

	S1	S2	S3	S4		W1	W2	W3	W4
S1	1	0.50	0.50	0.17	W1	1	0.33	0.33	0.50
S2	2	1	4	0.20	W2	3	1	0.50	2
S3	2	0.25	1	0.14	W3	3	2	1	2
S4	6	5	7	1	W4	2	0.50	0.50	1
	O1	O2	O3	O4		T1	T2	T3	T4
O1	1	7	5	6	T1	1	3	0.17	3
O2	0.14	1	0.33	0.33	T2	0.33	1	0.14	0.50
O3	0.20	3	1	2	T3	6	7	1	6
O4	0.17	3	0.50	1	T4	0.33	2	0.17	1

t5.1 **Table 5** Pairwise comparisons in the medical equipments sector

t5.2		S1	S2	S3	S4		W1	W2	W3	W4
t5.3	S1	1	0.50	3	0.17	W1	1	0.50	3	0.33
t5.4	S2	2	1	4	0.20	W2	2	1	3	0.50
t5.5	S3	0.33	0.25	1	0.14	W3	0.33	0.33	1	0.33
t5.6	S4	6	5	7	1	W4	3	2	3	1
t5.7		O1	O2	O3	O4		T1	T2	T3	T4
t5.8	O1	1	0.50	0.14	0.17	T1	1	3	4	2
t5.9	O2	2	1	0.17	0.25	T2	0.33	1	2	0.50
t5.10	O3	7	6	1	2	T3	0.25	0.50	1	0.50
t5.11	O4	6	5	0.50	1	T4	0.50	2	2	1

For example, if potential profitability is strongly preferred than environmental improvement within the automotive sector, the element occupying the fourth row and the second column within the "strengths" quadrant will assume the value 5. Instead, the symmetric element occupying the second row and the fourth column in the same quadrant will assume the value 0.20. Values selected by interviewees were aggregated, and the mean value was calculated for each sector: automotive (Table 3), aerospace (Table 4) and medical equipments (Table 5).

Starting from these numbers, normalization was selected for the calculation of the weights related to each of the selected factors, among all the different methodologies available in the literature [54]. An example related to factors constituting the "strengths" quadrant is proposed in this section. These data show, for the automotive sector, the potential profitability is the most relevant index, with a weight of 54 % (Table 6). By replicating the process for the other two sectors (Fig. 1) considered in the analysis, strength factors of remanufacturing can be enhanced. The same procedure will be followed also for the other quadrants constituting the SWOT matrix: weaknesses (Fig. 2), opportunities (Fig. 3) and threats (Fig. 4).

By discussing results coming from these four diagrams, what it is clear is that potential profitability represents the main "strengths" factor (common in all the three sectors), driving the implementation of remanufacturing activities. As in many other cases (e.g. in recycling or reuse), the economic sustainability represents, once again, the most important enabling factor towards the introduction of a new market strategy or production technology [12, 55, 56]. From the "weaknesses" point of view, there are different perspectives coming from the three sectors. In fact, automotive and aerospace sectors see the lack of volumes as the most relevant factor; instead, the medical equipment sector sees remanufacturing costs as the most relevant issue [12, 33]. This response could derive from a certain level of knowledge of the market. In fact, the automotive sector and some aerospace sector niches were the first ones to implement remanufacturing and, nowadays, are well informed about predictable volumes and market shares of remanufactured products. Instead, the medical equipment sector has no (or very few) information of these types and is primarily focused on the comprehension of the profitability given by this new process. Furthermore, in the medical sector, it is common that the OEMs receive back used products from the hospital, and second markets are well established [57]. From the "opportunities" point of view, the three sectors seem to be completely misaligned [35, 39, 42]. In the medical equipment sector, green marketing and sustainable solutions represent the main topics. This means that the attention of consumers towards eco-friendly products (especially if this friendliness means lower selling prices and the same quality level) is very high. Aerospace is strongly linked to governmental and military regulations. Instead, the automotive sector sees higher opportunities in green marketing, but only on particularly valuable elements of a car (e.g. engines, gearboxes, clutches, etc.). In fact, trying to exploit in some way customer preferences, automotive companies want to offer only eco-products that are also highly profitable. This way, green marketing campaigns are fundamental. Again, from the "threats" point of view, there is a net distinction between the medical equipments sector and the other two [44, 48, 50]. In fact, the first one sees internal cannibalization and organizational conflicts as the most relevant issues caused by remanufacturing. Instead, aerospace and automotive are more focused on market positioning issues. This could be interpreted, once again, by evaluating the history of remanufacturing in the three sectors. In fact, in the automotive sector and in some cases in the aerospace sector, remanufacturing is a well-established method that found during the years its dimension within the company and the market. Instead, the medical equipment sector is only nowadays facing with remanufacturing and it seems to be not yet ready to exploit all its potentialities. Finally, from

Q10

t6.1 **Table 6** Weight vector—an example

t6.2		S1	S2	S3	S4		S1	S2	S3	S4	Weights
t6.3	S1	1	5	6	0.33	S1	0.23	0.43	0.38	0.20	$0.25 \times (0.23 + 0.43 + 0.38 + 0.20) = 0.31$
t6.4	S2	0.20	1	2	0.20	S2	0.05	0.09	0.13	0.12	$0.25 \times (0.05 + 0.09 + 0.13 + 0.12) = 0.09$
t6.5	S3	0.17	0.50	1	0.14	S3	0.04	0.04	0.06	0.08	$0.25 \times (0.04 + 0.04 + 0.06 + 0.08) = 0.06$
t6.6	S4	3	5	7	1	S4	0.69	0.43	0.44	0.60	$0.25 \times (0.69 + 0.43 + 0.44 + 0.60) = 0.54$
t6.7		4.37	11.5	16	1.67		1	1	1	1	

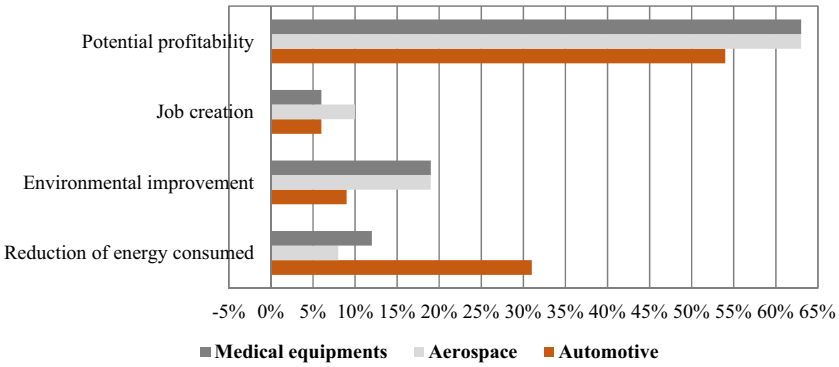

Fig. 1 "Strengths" quadrant ranking

a strategic point of view, the paper enhanced the presence of three different approaches towards remanufacturing, completely unrelated with sectors:

- Companies not implementing remanufacturing focused on core activities with a limited vision towards sustainability. Typically, these are small and medium enterprises (SMEs) not able to enter in the remanufacturing business. The only SMEs implementing remanufacturing activities are the ones strictly collaborating with large industrial groups;
- Companies implementing remanufacturing, with small-medium-term objectives, where external conditions push them to act in this way, but in a limited manner if compared to new products selling activities. Within these companies, there is a lack towards the product sustainability focus, and the management of EoL processes is not completely integrated within the main strategic guidelines of the company;
- Companies implementing remanufacturing, with long-term objectives, where remanufacturing activities occupy a relevant role within the strategic plan of the company, completely oriented towards the promotion of their sustainable image considered as an added value for their brand. Products are presented as eco-friendly and are widely promoted with proper communication campaigns and marketing actions.

5 Discussions

The survey conducted in this paper shows remanufacturing as an activity that, often, is implemented also during the life cycle of a product, in particular when the economic value of a product is high and improvements will be able to offer a significant increase in performances. There are both economic and environmental benefits driving firms to choose remanufacturing as an EoL sustainable strategy. From an economic perspective, remanufacturing allows companies to (i) compete in new market segments; (ii) differentiate the business; (iii) increase profits; (iv) create a reliable, fast and cheaper supply of spare parts and (v) protect brands from competitors. From an environmental perspective, remanufacturing allows to (i) reduce environmental pollutions, (ii) lower the energy consumption and (iii) be compliant with products under EoL international regulations. Q11

However, some authors tend to undermine the energy saving potential of remanufacturing [58]. The SWOT-AHP methodology is an instrument supporting decision-makers in identifying critical success factors (classified in strengths, weaknesses, opportunities and threats) within the three sectors taken into consideration (automotive, aerospace and medical equipments). These factors will influence the management's decision of implementing (or not) remanufacturing within the company, going to compare it with other recovery/disposal activities. However, there are some elements to point out: Q12

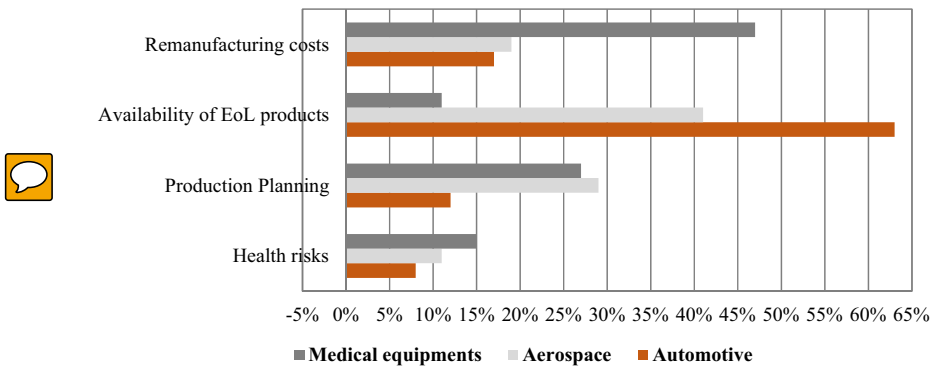

Fig. 2 "Weaknesses" quadrant ranking

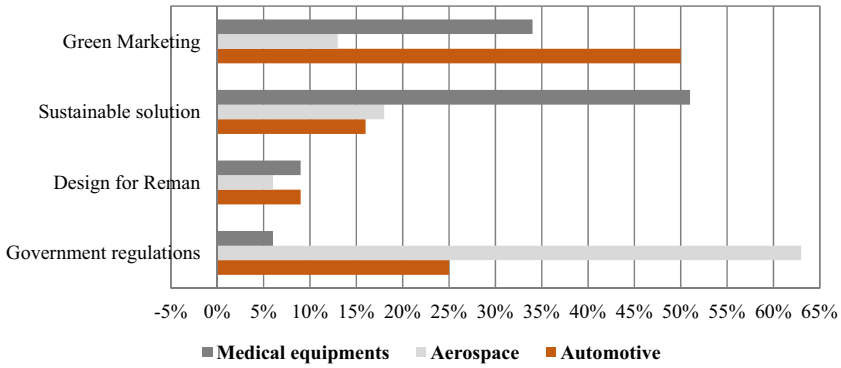

Fig. 3 "Opportunities" quadrant ranking

- The aerospace sector has to be seen as the couple of two sectors (the aeronautic and space sectors). In fact, for space products, the use of remanufacturing is currently not allowed at all because of their working environment (the space) and military regulations. Instead, the aeronautic sector sees many examples of remanufacturing activities, especially on aircraft engines and avionic systems;
- The medical equipment sector is a promising context for remanufacturing. In fact, limited budgets of public administrations push them to prefer remanufactured products instead of new ones.
- The automotive sector prefers recycling to remanufacturing as an EoL strategy, because it allows the easier recovery of valuable materials for the production of new elements.

Again, the interviews evidenced a general misalignment among firms that does not tend to differentiate by sector, but by company's dimension. In fact, speaking about small and medium enterprises (SMEs) was evident that the commitment towards the remanufacturing business is lacking. However, SMEs taken into consideration are Italian SMEs, so this lack could be related only to national firms, without any intent of generalization. Three aspects mainly cause this behaviour:

- Know-how gap, as remanufacturing is simply seen like a facelift of the product and/or as a technological upgrading;
- Value chain's structural problems, given by cores and selling channel unavailability and by remanufacturing costs needed for the recovery of product's original conditions;
- Limited collaborations with large firms, given by the economic crisis that strongly reduced the selling channels.

In contradiction with SMEs, large companies increasingly adopted the circular economy model, and wastes started to be considered no more as an issue, but a resource. This means that a good EoL management is now present in all these firms and it is possible to identify two different strategies:

- Some firms adopted the remanufacturing only by considering economic opportunities related to it, and in some cases, they tend not to publicize these strategies, so avoiding a presumed impairment of the brand's image;
- Other firms integrated the remanufacturing within the company's structure as a success element, by going to enhance the brand's sustainability. In fact, in these cases, firms tend to publicize eco-friendly activities, by going in some cases to define specific product lines.

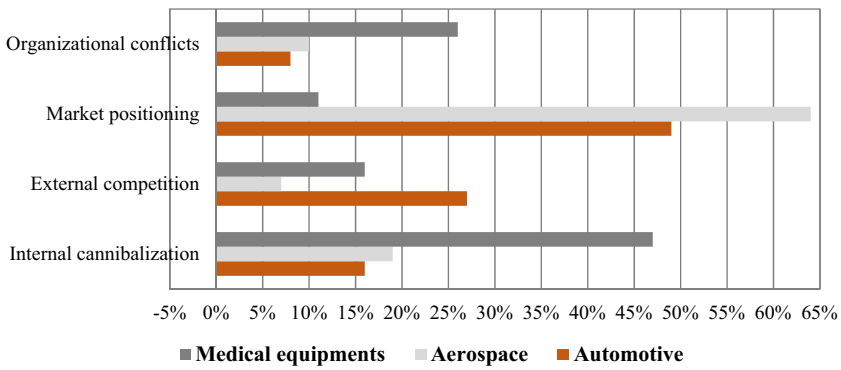

Fig. 4 "Threats" quadrant ranking

This current change is spreading from the use of renewable energies up to the recovery of products and/or materials that reached the end of their life. This happens essentially for two reasons:

- An increasing target of customers focused on the purchasing of green products;
- Management's personal motivations that, trying to counteract the atmospheric pollution, implement an eco-compatible management of processes, especially if an economic feasibility is guaranteed.

Future research trends push towards the need to develop quantitative studies, not only limited to evaluate the environmental impact and economic opportunities offered by remanufacturing but also the development of new business models and informatics instruments supporting the decision-making process.

6 Conclusions

The objective of many countries is to counteract the increasing environmental pollution. Especially in the manufacturing sector, the promotion of more sustainable industrial production processes and products is becoming necessary. Hence, EoL management is acquiring even more relevance. This trend is also evidenced by the scientific literature, where remanufacturing is nowadays analysed by different perspectives and applied in multiple contexts. Trying to summarize, companies can adopt defensive strategies (e.g. the response towards explicit market needs and the maintenance of customer's loyalty), or proactive strategies (e.g. the sustainable brand image promotion and the widening of products variety). This last type of strategies is typically present where there is a strong commitment on remanufacturing, seen as a way to improve the brand's value proposition in sustainable terms. Furthermore, the higher level of customer retention could allow the increase of economic advantages during the after-sales period through the offering of additional services. The selection of the best suitable strategy for a company could be supported by the SWOT-AHP analysis proposed in this paper.

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