POLITECNICO DI MILANO

School of Industrial and Information Engineering

Master of Science in Management Engineering

Master thesis project

Analysis of key success factors for an effective implementation of remanufacturing for product upgrading as a new service–based circular economy solution

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3rd October 2017
Academic Year 2016 / 2017

ABSTRACT

Increasing volume of waste in Europe, reduced availability of critical primary resources and new emerging sustainable trends push European manufacturers towards the implementation of new circular economy business models. Product upgrading, i.e. the process of providing new functionalities to products through collection, disassembly/substitution and remanufacturing of cores, could represent an effective solution to support this transition. However, industrial benefits of design for upgradability and upgrading remanufacturing are still debated in many sectors, and companies still perceive high risks in this transition.

The aim of the research is to study the favourable conditions and the potentiality of upgrading remanufacturing as a new sustainable service-based circular economic model solution for companies that have the willingness to include it in their businesses. An emphasis is placed on how the application of new service-oriented business models for product upgrade and product modularity can support this implementation and bring high value-added to circular economy businesses.

The methodology used to reach the aim of the research was as follow: existing business approaches and upgrading strategies were searched through a literature review; next, an analysis of real existing case studies of product upgrading was developed; subsequently, the operations and business model of a successful Swedish reconditioning company were mapped. Within these steps, the identification of common success factors and a favourable scenario for the implementation of upgrading remanufacturing was conducted. The research ends with the building of an iterative algorithm that includes the factors identified. The tool works as a support for manufacturers that want to introduce upgrading services in their business value offers. In the end, the description of a business model to describe the main business characteristics and the time needed for the transition was presented as conclusion.

Keywords: Upgrading, Remanufacturing, Modularity, Case Study, Product Service System, Business Model, Circular Economy

ACKNOWLEDGMENTS

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1. INTRODUCTION

1.1 SUSTAINABILITY IN MANUFACTURING

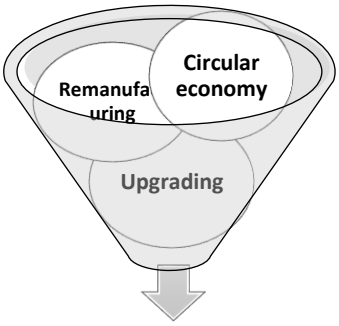
Changes in economy conditions of recent years pushed industries to find new economic paradigms to run their businesses in order to maintain them profitable and more sustainable. Increasing volume of waste in Europe, reduced availability of critical primary resources and new emerging trends towards "green" products push European manufacturers towards the implementation of new circular economy business models. Manufacturers and academics are studying new way to maintain and/or create new profitable business more oriented to sustainability in order to meet market needs and be cost effective at the same time. Use of secondary resources, recycling, reuse of cores, remanufacturing, closed loop production chain and similar techniques linked to the main concept of circular economy, result effective solutions to them. At the same time, there is the necessity to design models that can work and spread in the market. Until today, it is difficult for sustainable business to substitute the traditional ones, but improving them they could become common practises. This research contributes in this direction to the sustainable scenario.

1.2A NEW SUSTAINABLE SOLUTION: UPGRADING REMANUFACTURING

One practise, based on circular economy, that had spread in market in recent years is remanufacturing, i.e. the process of recollecting and restoring of used products. Thanks to *cores* (used products) recovering it is able to provide high performant products to resell to the same users or new ones. But traditional remanufacturing has one important limitation: when a product is remanufactured its functionalities are restored, but not improved or updated. This means that, sooner or later, the technology of the product would become obsolete and the market would not ask for it anymore stopping, inevitably, the remanufacturing cycle.

What is merging nowadays is the idea of a remanufacturing for upgrading that, not only restore existing functionalities, but improve the existing ones and add others. In this way, is possible to extend the value life of product and maintain it on the market, being able to meet customers' developing needs. *Upgrading Remanufacturing* is defined as the process of providing new functionalities to products through remanufacturing. It's a long process that starts since the previous stages of product design and continues during all product life cycles covering production, selling, managing of customers, recollection, repairing, upgrading and new delivery. Remanufacturing with upgrade aims to extend products' value life enabling the introduction of technological innovation into remanufactured products by creating new updated products' versions and, at the same time, preserving as much as possible the physical resources employed in the process. It would imply some changes to business in terms of customers' relation, production process and introduction of new processes.

Indeed, there is the necessity of defining new strategies and business models to sustain this new technique that now is largely discussed at academic level but still seldom applied.



Upgrading Remanufacturing

Fig. 1 – Research's Logic Funnel

1.3 OBJECTIVES AND EXPECTED RESULTS

1.3.1 Objective and research questions

The main objective of the thesis is *to study the favourable conditions and the potentiality of upgrading remanufacturing as a new sustainable service-based circular economic model solution for companies that have the willingness to include it in their businesses.*

To achieve this main objective, the work was structured as follow: it starts with an *Exploration Phase* to build a solid theoretical framework to refers to; it follows the *Generation Phase* in which the identification of key success factors in Upgrading Remanufacturing application are first identified and then used to build an iterative algorithm and a final business model as supportive tools for its implementation. Then the *Evaluation* of the model and subsequent conclusions and reflections about future purposes are discussed (*Communication Phase*).
In order to orient and better organize the research development, these research questions were identified:

1- Exploration phase - What is upgrading remanufacturing and which are the techniques related to it? Which are the consequences and changes demanded to industries for its application? And how do customers perceive it?
2- Exploration phase (I) - In which context (sector, type of products, market) and in which measure (kind of upgrade) its application resulted profitable and why?
3- Model Generation phase - Which are the main key success factors for a performant application of upgrading remanufacturing?
4- Model Generation (I) phase- Which would be the steps to follow and the business conditions to have for a successful adoption of upgrading remanufacturing?
5- Evaluation phase – is upgrading remanufacturing a sustainable solution from an economic, environmental and social point of view?
6- Communication phase - Why upgrading remanufacturing can be considered an innovative solution? And, does it have the potentiality to spread and be adopted by firms in the future?

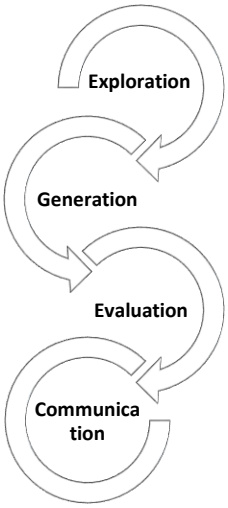


Fig. 2 - Research development

1.3.2 Expected results

The results of the research would be outputs that answer to the research questions:

1- A complete literature mapping about upgrading remanufacturing
2- A companies' comparison framework for the identification of key success factors and a favourable scenario for the application of upgrading remanufacturing
3- A business model analysis based on a company in Sweden
4- The development of an iterative algorithm and of a sustainable business model based on services (*sustainable product service system*) as a tool for an effective shift to, and implementation of upgrading remanufacturing

1.3.3 Limitations

The evaluation and communication phase would not be developed due to time constraints. The evaluation phase would need tools that require long analysis. In order to evaluate the environmental and economic sustainability of remanufactured and upgraded products Product Life Cycle Assessment methods, or similar, should be used, and, make a proper analysis would require resources and knowledge that were not possible to obtain in the time dedicated to the research development. On the other hand, also the communication phase was not deepened. The study of the of the possible spread of upgrading services would require economic and market analysis that were different from the ones conducted on the specific operative implementation of them. However, the questions remain and the project could work as starting point for future research developments.

2. METHODOLOGY

For each research question, different methods were used. Theoretical and practical approaches were adopted with the aim to analyse the main topic from different point of view and at different levels. A mix between literature, case studies research and company analysis were used to make the research more valid and reliable. In the next paragraphs the process followed to reach the study results are described. In Table 1 the main objectives with the respective methods, activities and outputs are shown.

Table 1- Methodology framework for the research development

Breakdown Objectives	Methodology	References and Activities	Output
Understand and link together different topics related to upgrading remanufacturing. Identify and resume what already exists and target what is still missing (research question 1-3)	Literature review	Reading and analysis of the actual published papers about the topic	Literature mapping and thesis objectives
Understand the context, the business characteristics, and identify key success factors for the practical applications of upgrading remanufacturing in industries (research question 2-3)	Case studies analysis Field research in Sweden	Finding companies that apply upgrading remanufacturing, listing and confronting them	• Framework for case studies mapping • Business Model and process mapping of a Swedish company
Building of a theoretical framework to apply effectively upgrading remanufacturing process in industries (research question 4)	Theoretical model Field research in Sweden	Reading and analysis about business model application Visiting to industries	• Iterative algorithm • S.PSS Business model
Underlying the economic and environmental sustainability of the model	Theoretical model	Experts consultation	Future open questions

The research project started in October in collaboration with the mechanical department of the university of Politecnico di Milano as a master thesis final project. The initial period of study was held in Milan during which the literature review was conducted under the supervision of Marcello Colledani, an associated professor from Politecnico di Milano, Giacomo Copani a researcher from ITIA – CNR (Istituto Tecnologie Industriali e dell'AUtomazione – Consiglio Nazionale delle Ricerche). Subsequently, the research was moved to Sweden at the industrial department of Linköping university under the supervision of Erik Sundin, an associated professor from university. During that period, some meetings were scheduled in order to keep the research group updated and to discuss together about the thesis development. In the end, the conclusions and the final presentation were done in Milan.

2.1METHODS FOR THE FIRST RESEARCH QUESTION

To obtain a complete literature mapping of upgrading remanufacturing a theoretical approach was used. Desk researches with the support of research group meetings were held. The specific purpose was building a complete literature review about the topic of upgrading remanufacturing that, even though is discussed at academic level, result still fragmented.

The papers search process about upgrading remanufacturing started with some key words (Fig. 3) in order to target and collect the highest number of articles related to it. Thus, it was also possible to identify which topics and sub-topics are generally related to upgrading remanufacturing and service business models for upgrading remanufacturing. A paper was considered relevant if it discussed topic related to the strategic and practical implementation of upgrading remanufacturing. The search conditions were the article should include a key words combination among:

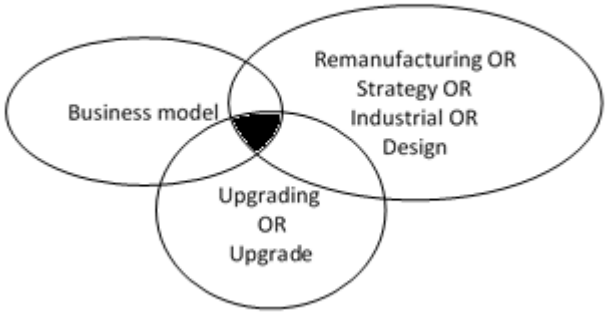


Fig. 3 - Search key words combination for the literature review

The sources used were Politecnico di Milano Database, Liu Database and Science Direct database.

40 articles were identified, among which 13 were used, because were recent, relevant and not redundant for the main subject. In order to decide which article were relevant, and which not, a first consideration was done looking at the title and the date of publication, then at the abstract, and then reading the whole paper targeting new and/or original topic/technique related to the upgrading remanufacturing. After this first search, literature resulted fragmented and divided into different separated sub – topics (Table 2). The search ended in the moment in which no more new topics, respect to the ones that were already found, emerged. Once the search exhausted the different areas and techniques founded in the different papers were put together in a unique preliminary report, in order to obtain a generic but overall view of what implies talking about upgrading remanufacturing.

Table 2 - Sub - topics linked to Upgrading Remanufacturing identified during the first phase of the literature review

Kinds of Upgrades	Modular Design and/or Modularity
Upgrade Plan	Management of Cores
Design for upgradability	Product Service System

The preliminary report consisted in a document (10 pages) that sum up the basics of upgrading remanufacturing. The next step consisted in reviewing the references of the relevant papers used to write this first report to enlarge the searches population and deepen the topic and sub topics of Table 2. The snowballed papers comprehend all references starting from ten years before (2006/2007) until nowadays. A paper was taken into consideration if considered relevant to the scope per title, abstract and year of publication. 14 snowballed papers were added, for a total of 27 useful references.

The complete papers selection process of literature is described in Fig. 4.

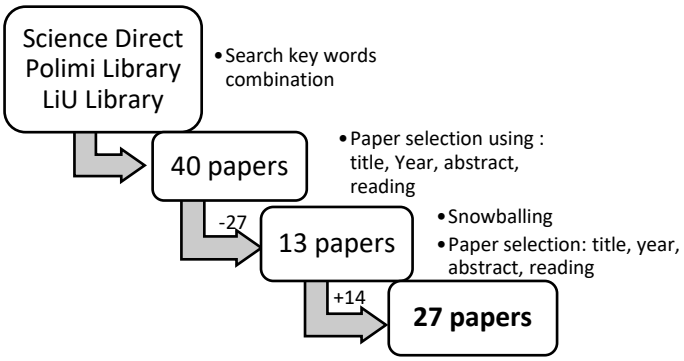


Fig. 4 - Papers process selection about upgrading remanufacturing for the literature review

2.2 METHODS FOR THE SECOND AND THIRD RESEARCH QUESTION

The second and third research question generated two different outputs: a case studies mapping and analysis of remanufacturers that offer upgrading services in the world and the business model and process mapping of a real company in Sweden that applies upgrading remanufacturing. The first output contains key success factors and the description of a scenario that makes favourable the introduction of upgrading in remanufacturing processes while the second one is more oriented to the practical operations and tactics that make upgrading remanufacturing a winning strategy for a business. These two outputs would be used as input for the generation phase of the research.

2.2.1 I OUTPUT: framework for case studies mapping

Starting from the building of the comparison framework, an empirical approach sustained by inductive reasoning were used. Induction is a logic process that want to extract general rules starting from the empirical observation of reality. Therefore, the search started with the collection and analysis of specific real examples in the world of upgrading remanufacturing application. The cases were classified using a common framework, according to some pre-determined common variables, in order to ease the identification of key success factors and conditions that are determinant for a successful application of upgrading remanufacturing. It followed the statement of general rules or winning practises for the process implementation.

The first step consists in the collection of the higher possible number of case studies, that saw the implementation of upgrading remanufacturing, to create a reliable sample. The optimal solution was using some already existing case studies databases or case studies dissertations. The sources used were Google Scholar and Science Direct. Some universities databases (Polimi Library, LiU Library) were added as sources as well. However, the most important databases used were the European Remanufacturing Network[1], Ellen MacArthur Foundation[2], Centre for remanufacturing and re-use[3] and Resource Conservative Manufacturing[4] that deal specifically with circular economy and remanufacturing.

[1] European Remanufacturing Network (ERN) is a European Commission funded two-year project with the ambition to study and spread remanufacturing through Europe. It counts more than 250 firm partners that cooperate to improve circular economy processes

[2] The Ellen MacArthur Foundation is a British registered charity with the stated aim of inspiring a generation to re-think, re-design & build a positive future through the framework of a circular economy.

[3] Centre for remanufacturing and reuse (CRR) an independent organisation specialising in advice and promotion of remanufacturing, reuse and reconditioning.

[4] Resource Conservative Manufacturing (ResCoM) was founded by the European commission with the aim to develop an innovative methodology and software platform for the industrial implementation of closed-loop manufacturing systems

The word *Upgrading Remanufacturing* was inserted in each database search function. But the use of *Upgrading Remanufacturing* as search word resulted too specific and did not produce any relevant results. Probably because upgrading is still considered a surplus for industries and not a core activity of remanufacturing and, so, do not appear in titles, abstracts or in papers' key words. For this reason, the search word was changed instead in simply *Remanufacturing (*together with the words *Case Study* or *Example),* to start targeting, at least, the highest number of firm that has as part of their core business remanufacturing. 67 case studies were found (42 from The European Remanufacturing Network, 8 from Ellen MacArthur database, 9 from CRR, 5 from ResCoM, 2 from Science Direct, 1 from Polimi). Once a satisfied amount of papers was reached, the root *-upgrad** was search in each paper were the case studies were discussed. In this way, it was possible to identify all remanufacturing case studies in which some upgrading activities were performed or taken into consideration by firms. After the skimming 27 case studies remained. These were read and if there was a real application of product upgrading during the remanufacturing process were kept, on the other hand, they were discarded: 20 out of 27 were kept (Fig. 5). It is important to have clear that this sample contained exclusively firms that make their remanufacturing and upgrading activities public (and so that perform this operations in their daily business). There are, for sure, other still no structured attempts (in the form of pilot projects) of using upgrading but they remain hidden from the available public data. Besides, as they are not structured and their effectiveness could not been proved, they were not included in the analysis.

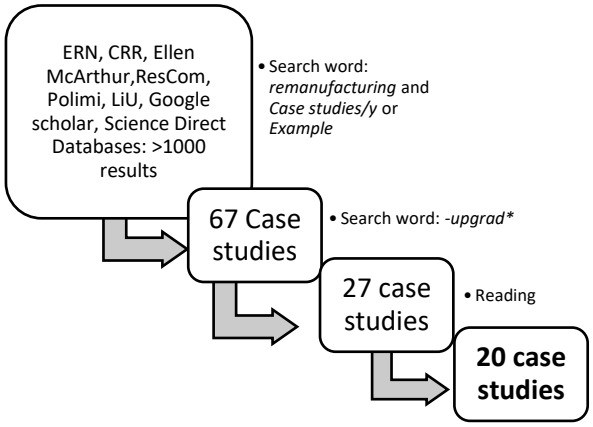


Fig. 5- Papers selection process for case studies collection

The next phase consisted in the building of a framework for the classification and comparison of the cases studies collected. **In this framework are classified exclusively remanufacturers that includes upgrading activities in their businesses**. The choice of variables used to categorise the firms were driven by two needs: to answer the research question number two, and so identify which sector, which products and in general which context make remanufacturing for upgrading a feasible and sustainable solution; and to identify some best practices (key success factors – Question 3) to help the future building of the business model.

Table 3 - Variables used in framework for the mapping of case studies

Variable	Purpose
Name and Year of foundation	Univocally identify each firm
Location	Understand in which countries upgrading activities are applied the most
Sector	Identify if exist one/more sectors in which upgrading activities are more present than others and deduct why

Product	Understand on which products upgrading is applied the most
Market (B2B/B2C)	Verify if upgrading remanufacturing is offered more in the B2B or B2C market and if one prevail deduct why
Kind of remanufacturer (OEM/CM/IM)	Identify which actors have the tendency to do upgrade and, in case a group prevail, deduct why
Customer target	Understand which kind of needs remanufacturing for upgrading is fulfilling and who are and which are the main characteristics of this set of people
Product Service System	Corroborate the hypothesis that the most spread business model used in the remanufacturing with upgrades is the serviced based business model
Core acquisition strategy	Describe which strategies are used to acquire cores
Kind of upgrade	Describe the different kinds of upgrades
Application of remanufacturing design (e.g. Modularity)	Corroborate the hypothesis that remanufacturing with upgrade involves design for remanufacturing techniques
Value Proposition	• Verify if firms that adopt remanufacturing with upgrades are aware and want to share the principles of circular economy • Verify if they are considering upgrading an important part of the value they are providing to their customers

The variables chosen try to cover all the main themes discussed in the literature to give a proper answer to the research questions derived from the first theoretical review.

The information used to fill the framework were searched in the papers were the cases were discussed and in firms' official websites and relative published documents (e.g. annual report, sustainability report). Attention was given to the companies' strategy and values and how they present themselves and their products to the market. In the luckiest cases, some companies have already built their specific *value proposition*[5]. In other cases, there was not a pure value proposition sentence but only a list of values and *vision*[6] and *mission*[7] statement. However, from those it was possible to deduct the value they want to offer to the market and derive the right conclusion. Sometimes annual reports were used for this purpose too. Looking at the firm's' pages it was also possible to deepen the remanufacturing process and understand how the relation with customers was managed and so to help in understanding if they were applying a Product Service System Business Model. Brief companies' presentations were written too, to maintain a trace of this information and to present generically the firm.

[5] A *value proposition* is a promise by a company to a customer or consumer segment. It is an easy-to-understand reason why a customer should purchase a product or service from that specific business. A value proposition should be a clear statement that explains how a product solves a pain point, communicates the specifics of its added benefit, and states the reason why it's better than similar products on the market. The ideal value proposition is concise, and it appeals to a customer's strongest decision-making drivers.
(http://www.investopedia.com/terms/v/valueproposition.asp#ixzz4aH0GSlax)

[6] A *vision statement* is an aspirational description of what an organization would like to achieve or accomplish in the mid-term or long-term future. It is intended to serves as a clear guide for choosing current and future courses of action.
(http://www.businessdictionary.com/definition/vision-statement.html)

[7] A *mission statement* is a short sentence or paragraph used by a company to explain, in simple and concise terms, its purposes for being. It expresses the concrete objectives and results it wants to achieve in the medium term.
(http://www.investopedia.com/terms/m/missionstatement.asp#ixzz4aH1DG9eg)

In the end, to write the conclusion some preliminary statistics computations were used to show the main importance results. Those results were discussed leveraging on the experience of the different members of the research group (brainstorming) and the right reasons and comments were set. A third meeting was necessary to improve and detail the discussion and final conclusions. The main step of the methodology are shown in Fig. 6- Methodology process for the case studies analysis

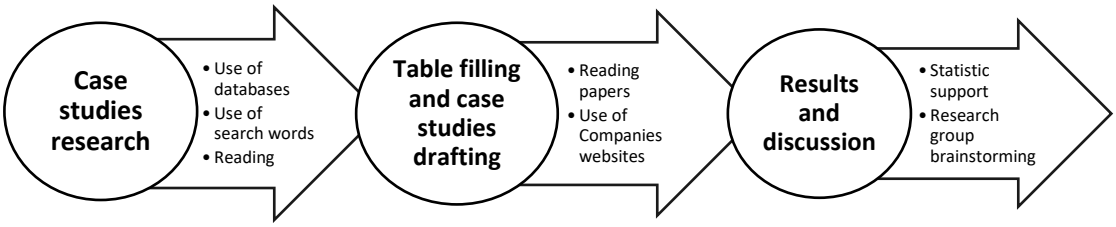


Fig. 6- Methodology process for the case studies analysis

2.2.2 II OUTPUT: Sustainable Business Model Canvas and process mapping of a Swedish remanufacturer

2.2.2.1 *Data gathering*

The company chosen for the case study analysis is INREGO, a Swedish company that collect, repair and upgrade IT products in Sweden. INREGO is one of the example found during the case studies research. It was chosen because it was an interesting case to deep for different reasons. First, for the type of products treated. INREGO deal with IT devices that belong to the wide set of the EEE sector. EEE is the second bigger sector in which upgrading activities are run. It presents good opportunities to grow but there are still some limitations and difficulties that are preventing upgrading techniques to spread among it, especially for some type of products and market. Thus, an analysis of the model used by a firm that succeed in its application in this context had good potentiality to reveal new interesting results. Secondly, INREGO serves both the B2B and the B2C market. Companies still have difficulties in working with end users as resulted from the previous analysis. The example of INREGO can help in finding more factors and give an overall view of the different practices used in the two markets. Besides, INREGO is one of the few companies analysed that explicitly state the possibility of upgrading in its value offer. In addition, it is a rare case of successful Independent Remanufacturer. In fact, according to literature and the statistic of the case study framework, usually are Original Equipment Remanufacturers that succeed in using upgrading remanufacturing. Clearly INREGO make good use of its capital and leverage on some factors that make it succeed in the business. These factors could result new practical key success factors for Upgrading Remanufacturing. In the end, INREGO has a long-lasting collaboration with the department of Management and Engineering at Linkoping University. A climate of trust make easier the access to true and complete information.

This research would provide the company with some useful outputs that could be used for future development, internal discussion or improvements. The didactic and methodological approach would give the research objectivity and precision. The firm could think about this work as a preliminary consultancy evaluation of its operations and strategy. Besides, if the company would agree, the results or part of them, would be listed in a scientific paper. Giving visibility to the company as a good example of provider of an innovative and sustainable practice and open the possibility to further collaborations. In the end, it would contribute in spreading the remanufacturing culture, a topic of great importance both for academics and for the ones which are implementing it.

To gather all the necessary information for the building of the business model and the process mapping, different activities were conducted (Table 4).

- A visit of two hours at the company headquarters in Stockholm during which all the different process stages were shown and explained (Fig. 7, Fig. 8, Fig. 9, Fig 10)

Fig. 8 - INREGO Entrance

Fig. 7 - INREGO Data wiping of the IT devices

Fig 10 - INREGO Data wiped and categorized Laptops

Fig. 9 - INREGO Data wiped and categorized smartphones

- One hour presentation from the Sustainability Manager of the firm Erik Petterson (Fig. 11) who started outlining the main values and history of the firm and continued underlying the necessity of a change in practice. He explained how the environmental urgent issues have been growing in the last years and are forecasted to become worse in the next decades in terms of waste, availability of resources and pollution. Such as it would become impossible to keep producing the kind and volume of products we are used to nowadays.

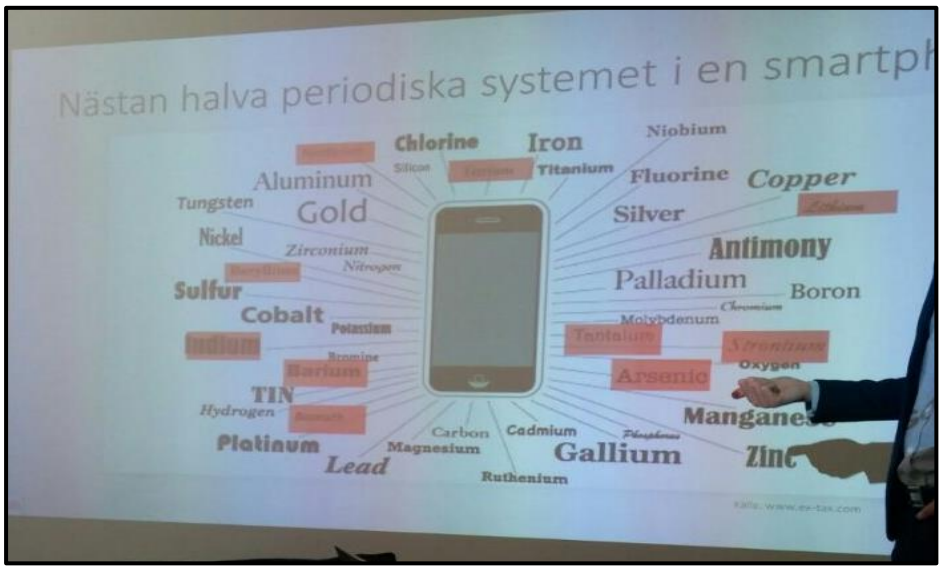


Fig. 11 - A moment taken from the presentation during which the Sustainability Manager was explaining the rare metal elements present in a smartphone and which ones are threatened with exhaustion (highlighted in red)

- Subsequently, a more specific interview of one hour with the Production Manager Andreas Ericson focused on process, business model and upgrading strategy was conducted to have a complete view of the business and deepen the upgrading activities held by the firm (Fig. 12).
- Some papers and studies available among the university written in the past years, as well as the company official web page and public reports were used as complementary sources.

INREGO production manager interview

Process questions

1. You divided the cores according to their quality in four main categories and sell the best quality ones in the Swedish market. What happen, on the other hand, to the other lower quality products?
2. Which is the step that require more time along the recovering process of products?
3. How do you handle the accessories that cannot be sold?

Business questions

1. Can you describe broadly a typical bargaining process between the sales department and a potential supplier in the B2B market?
2. Which strategies do you use to attract new and retain existing customers?
3. Do you sell also in the B2C market? If yes, which kind of product and how the relation with final consumers is managed? Which kind of services do you provide them?
4. Which are your main competitors? And how do you position your offer respect to them? What do you consider to be your main competitive advantage?

Upgrade questions

1. Which are the main reasons that pushed you to introduce upgrading for the A products?
2. Do you plan your upgrade or do simply “what is needed” in the moment?
3. Which kind of Upgrade do you usually do more often?
4. Do you need to buy extra core to do upgrade?
5. What is, according to your experience, the easiest and the most difficult product to upgrade?
6. How much the selling of upgraded products (A category) contribute to the overall revenues of the firm?

Fig. 12 - Questions asked to the production manager of INREGO during the interview

Table 4 - Activities conducted to gather information about INREGO business model and processes

Activity	Information
Visit to the company shop floor	• Process steps • Kind of products • Upgrade activities • Business model
Sustainability Manager presentation	• Company history • Company values • Company mission and objective • Environmental issues to overcome
Production Manager interview	• Business model • Process steps • Upgrades decisions and strategy
Case study paper about INREGO processes + INREGO public reports and websites	• Process steps • Company History • Company Values • Business Model

2.2.2.2 *Graphical tools and instruments*

Two visual tools were used to support graphically the description of the process and the business and give a comprehensive view of how the company work.

The first is a process map that show the flow of information and of material from the moment of recollection until the new delivery. It provides a quick and overall view of the company's operations and see how it manages the core and upgrading activities. The main symbols used are the ones shown in Fig. 13.

Fig. 13- Symbols used in the mapping of INREGO reconditioning process

The second is the Sustainable Business Model Canvas. The sustainable Business Model Canvas is a triple layered canvas built on Osterwalder and Pigneur (2010) original one. It is a tool for the description of business models that integrate to the traditional economic value, the environmental and social impacts of a business. The sustainable canvas is a practical and easy to use tool which supports creatively developing, visualizing, and communicating sustainable business model innovation (Joyce and Paquin 2016). The

traditional Canvas was conceived to give an immediate idea of how the business works and generate value leveraging on the iterations and the coherence among its sections (Fig. 14).

The Sustainable Canvas take into account not only the economic side but also the environmental and social resources and value that

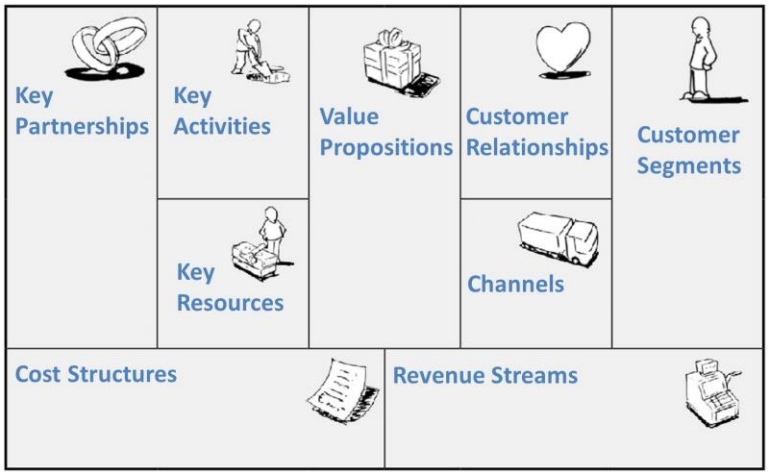


Fig. 14 - Business Model Canvas (Osterwalder, Pigneur, and Clark 2009)

the company use and create while running its business. It adds two new layers to the traditional one. The environmental layer adopts a product life cycle perspective, enlightening the impact the product/the business has on the environment. On the other hand, the social layer adopts a stakeholder perspective, enlightening the effect the product/business has on them. All the three layers must be coherent on the horizontal and vertical level to create a well performing business model(Joyce and Paquin 2016). The different categories of the three levels are shown in Fig. 15.

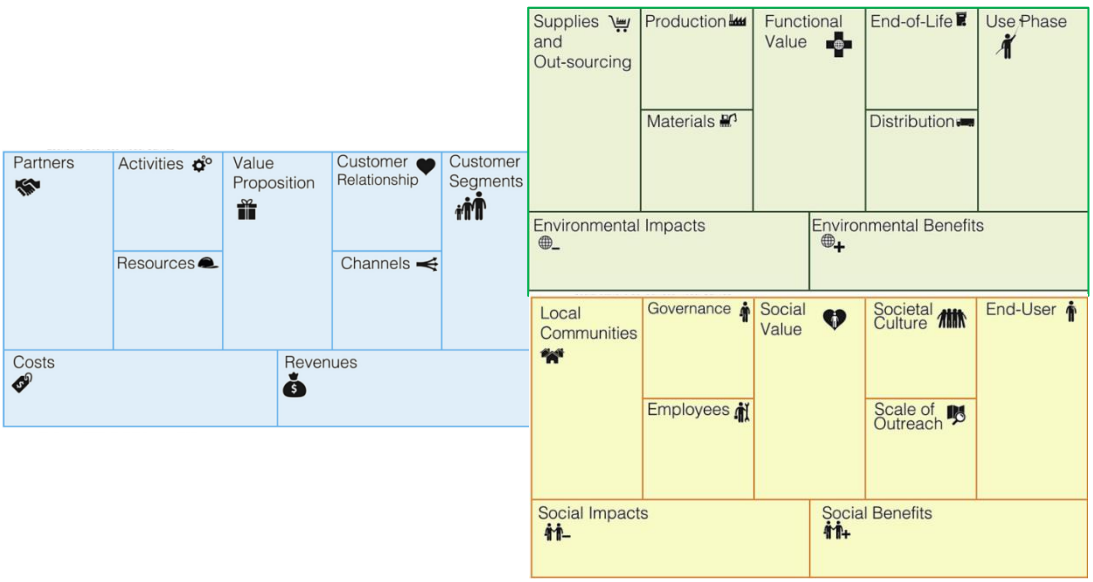


Fig. 15 - Triple layered sustainable business model canvas (Joyce and Paquin 2016)

Blue= Economic layer
Green = Environmental layer
Yellow = Social layer

Therefore, the Business Model of INREGO would comprehend the three layers described in Fig. 15 integrated in the same scheme. The layers would be distinguished thanks to the different subheadings and colours codes (Blue = Economic layer, Green=Environmental layer, Yellow= Social layer). In this way, the model would result unique, and its coherence and integration would be more explicit and easy to verify, but, at the same time, the different contributions of the three levels would be enlighten. Besides, the headings that refer directly to upgrading activities would be target and highlighted using a fourth different colour (Upgrading = dark red).

The canvas would be then discussed considering four main macrosections: the value proposition, the value network (Partnerships, Activities and Resources), the Customer Interface (Customer relation, Channels, Customer Segments) and the Economic model (Cost Structure and Revenues stream). The discussion would comprehend all the three levels. Then, a dedicated analysis about the headings regarding the upgrading would be conducted to understand how upgrading contribute and influence the running of the business and the delivering of value.

2.3 METHODS FOR THE THIRD RESEARCH QUESTION

In order to build the tool that will help firms in the transition to upgrading remanufacturing all the outputs of the previous researches were taken into account and used as input or support for the tool. The tool chosen is an iterative algorithm that works as a check list that companies should follow and verify during the implementation of upgrading remanufacturing.

The starting context of the algorithm would be the one of an Original Equipment Manufacturer that want to introduce remanufacturing and upgrading services for its products. The ideal OEM should be a medium to big size, stable company that serves B2B market. The algorithm could be used by different actors as well but its effectiveness could differ. The build of the algorithm started considering the main intervention areas identified during the research process: product knowledge, product design for remanufacturing, core management, Product Service System and key operations planning (process time, quality and efficiency). The factors were listed following a certain order. There are some factors that have the role of *gates*, thus, without them, it is useless to proceed in the implementation or checking of the other factors.

Table 5 – Main area of intervention for the introduction of upgrading services listed in order of appearance in the iterative algorithm

	Success factors
Gate 1	Product knowledge
Gate 2	Product design
Gate 3	Core management and PSS
Gate 4	Key operations planning

Subsequently some questions were formulated and, if the answer was positive the user proceed to the next step. On the other hand, a loop was designed that would help the user correcting actual conditions and proceeding to next steps. At the end of the algorithm,

if all conditions were checked and answers to questions result positive, the company should find itself in a favourable condition for implementing upgrading remanufacturing. Here are shown and explained the symbols used to build the algorithm (Fig 16)

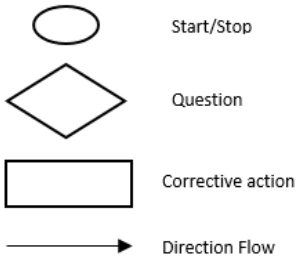


Fig 16- Key algorithm symbols

Each *box* and *loop* of the algorithm would be further deepened and commented to provide a complete explanation of the tool, how to use it and which are the main suggestions and the theoretical basics on which is built. In the end, a Business Model that summarize the main conditions the company reached and time necessary for this transition would be design.

3. THEORETICAL FRAMEWORK

3.1 CICRCULAR ECONOMY

3.1.1Introduction: the problem

In past years economy were led by culture of consumption and by linear approach take-make-dispose(Finance 2016). Industries saw consumers only as buyers and not users, and consequently used to focus mostly on the efficiency of production phase in order to produce high volumes of goods at low prices. This kind of production from industries, incepts in costumers the idea of easy replacing and waste. Firms could easily have success leveraging on efficiency of procurement, production and distribution, and consumers had the possibility to choose among a wide offer of new versions of products and buy and re-buy them at affordable prices.

The present linear economy can be explained historically. The Industrial Revolution increased prosperity substantially by radically increasing the productivity of the economy's factors of production – land, labour, and capital – through breakthrough technological advances. Incentives stimulated increasing sales and economies of scale through operational excellence, efficiency, and innovation. The fact that the stock of non-renewable resources was being depleted to keep up with the increasing consumption was not taken into account since that stock was considered to be inexhaustible. Besides, this approach, through the years, became the traditional way to do business, in a way that any other models seemed possible to apply. From one side, there was a sort of cultural inertia to change and, on the other side, all the rules, structures and business dynamics were shaped on this linear approach, making a change difficult to implement (Burrell et al. 2006).

However, some new factors and trends emerged threatening the sustainability of the linear model.
One big change regard the balance between resources' demand and availability: non-renewable resources are reaching supply limits but demand is still ever-increasing. Since now there were enough resources for any actors in the market to guarantee the progressive increases of production to satisfy an always growing demand. This abundancy reflected on resources' price development that, until 2000, was characterized by stability and low fluctuations. But the increased demand in the face of limited supply has put a strain on resource prices and increased their volatility. This leads to increased uncertainty about costs and prices, reducing economic stability.

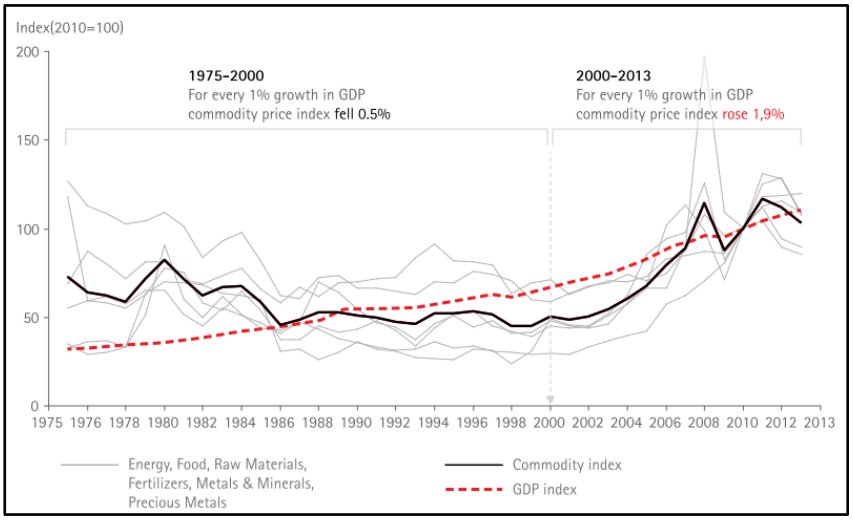


Fig. 17 - Relation between GDP growth and resources' price pattern

Besides, now that primary resources entered in a phase of scarcity, the limited availability is having negative effects on prices that started to grow with the growth of the GDP (see Fig. 17). This new pattern is having and will have consequences on traditional business.

It has been shown that the current level of consumption to support living standards in developed countries in a linear economy exceeds the carrying capacity of the earth's natural systems (Finance 2016). Using the Global Ecological Footprint, (Lacy et al. 2014) the world is already using 1.3 planets each year, that means it consumes natural resources that would need one year and four months to regenerate, and it is estimated that by 2050 the consume would be three planets.

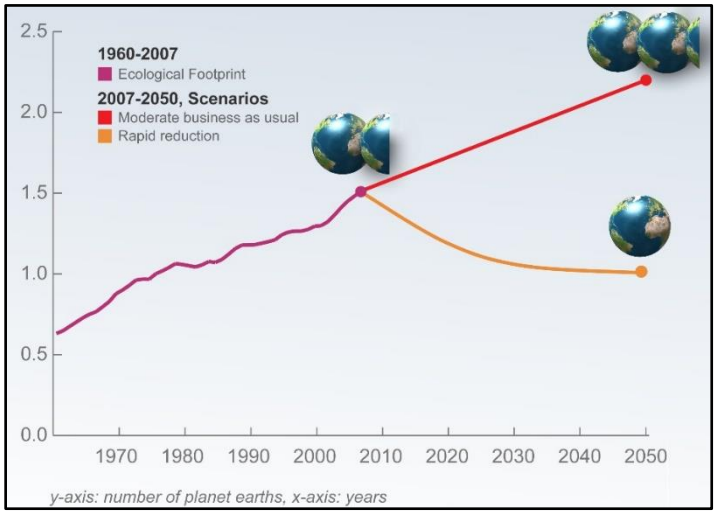


Fig. 18 - Global footprint trend

Environmental degradation is a threat for generations to come. This condition is a logical consequence of the incentives in the current economic system that does not consider the environmental cost making linear approach the most economical convenient in the short term. But not in the long one.

If linear economic principles remain the norm of business practices and consumption patterns, the outcome is likely to be shortages of certain materials, growing price volatility, and continued environmental degradation. This will bring to a decrease of the value creation of firms. From one side, there would be a revenue reduction due to the uncertainty of supply that could make necessary a production reduction. On the other side, firm would have to face a costs' increase too, caused by the unpredictability and the increase of resources' price. Last, but not less important, once the resource scarcity becomes more critical companies would be pushed to demonstrate their sustainability and the ones who could not, would lose brand value and so competitiveness in the market.

If we think that a continuous grow of population is forecasted, due to the general improving of economy and condition of population in the world (extreme poverty is decreasing - (Yoshida, Uematsu, and Sobrado 2014)), and that growing population will drive demand for resources, these trends will continue for sure and will threaten continuation of business as usual. The current situation is not sustainable anymore and there is need of a shift in industries and in mentality to continue to run sustainable and profitable business, as well as maintaining a good quality of life and have the possibility of a better future.

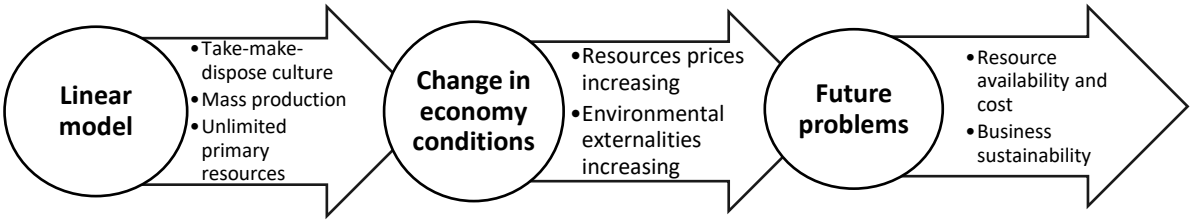


Fig. 19 - Change in the economy conditions and future scenario

3.1.2 New economy trends

In this new economic scenario, there are also other trends to take into consideration and that make even more evident that we are in a period of changes and shifting. It exists an urgency of change, of a shift in methods and strategies to guarantee, no more only a better future for next generation but also wealth and profits in the contemporary one. There are some modern uninvertible mega trends that would have the power to change the traditional definition of economic:

1- **Technological breakthrough**. The introduction of new technology can support new business model and make easier circle processes (new recycle technologies, new design technique, 3D printing, real time monitoring and so on) together with the increase of availability of them due to the commoditazion of technology phenomenon.
2- **Increase in consumption**. The poverty decrease, the rise of middle class and increasing longevity bring big change to the demographic situation. New markets with new opportunities can be explored. Products' consumption is increasing, together with the generation of waste.
3- **Demographical change**. New relationships between governments, businesses, and citizens born. Governments increasingly involve civil society in the public discourse. Some consumers turn into co-producers and some businesses redefine their core focus to that of solving societal challenges. There is more attention to the economic and world situation.
4- **New economic paradigms**. New economies are emerging and economical and political boundaries are disappearing.
5- **New societal challenges**. resource issue, health, environment, climate change and so on, push to the research of new innovative solutions.

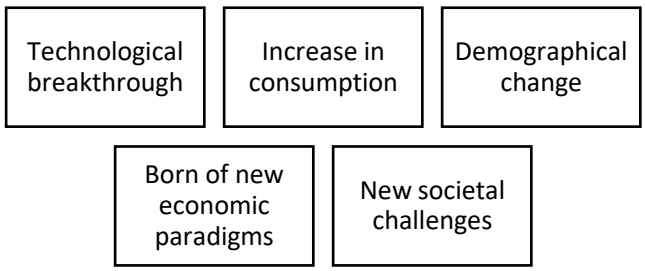


Fig. 20 - New Mega trends that can sustain a shift from traditional businesses to a more sustainable ones (Finance 2016)

3.1.3The solution: Circular Economy

The necessity to transition to an alternative economic model therefore seems evident. There is need of new models that could fit in the present situation and create long term values for customers and for firms. Recently new economic paradigms born spontaneously in the market (see Fig. 21), sometimes they are bottom driven sometimes top driven. Among them there is the concept of Circular Economy that always more companies are starting to adopt.

It is a new economic paradigm that born from the aspiration for sustainable growth in the context of the growing pressure of production and consumption on resources. It fosters reusing, repairing, refurbishing and recycling existing materials and products; what used to be regarded as 'waste' can be turned into a resource (EU).

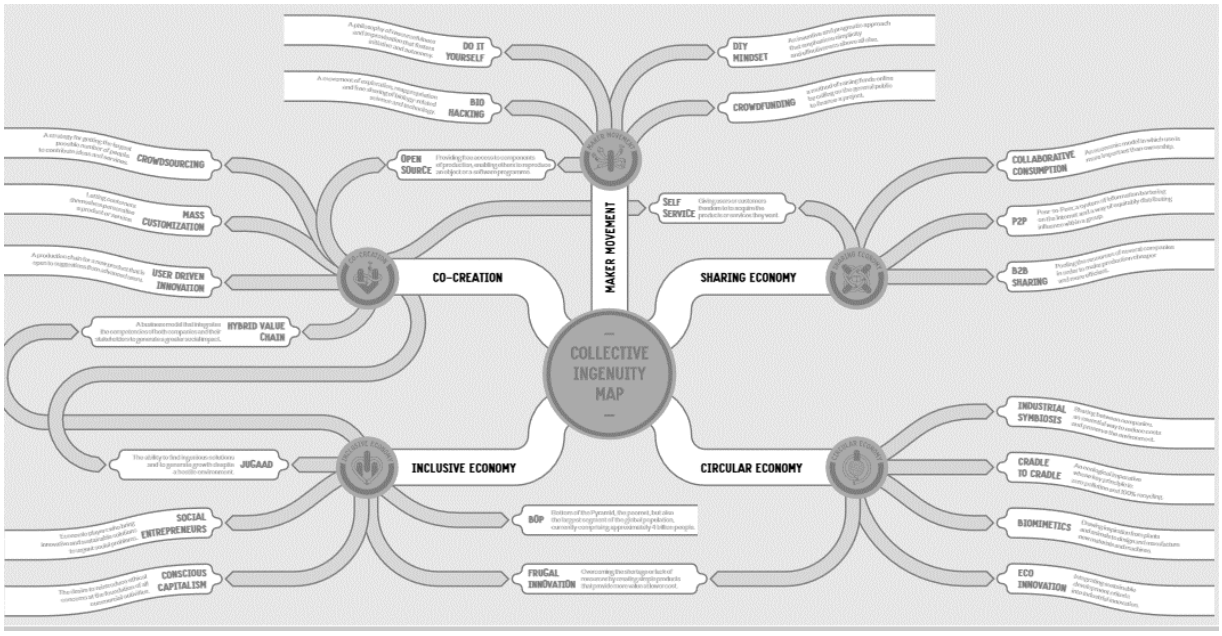


Fig. 21- New economic paradigms that appeared in the economic scenario

The main change in CE is the shift from the linear economic model to a circular economic model, where the outputs of the final stage become inputs for the same or of new processes. In CE growth is reached with scare resources and business model based on longevity, renewability, reuse, repair, upgrade and dematerialization. The idea is of a close system that is able to auto feed itself without a huge impact on the outside in terms of consume and pollution.

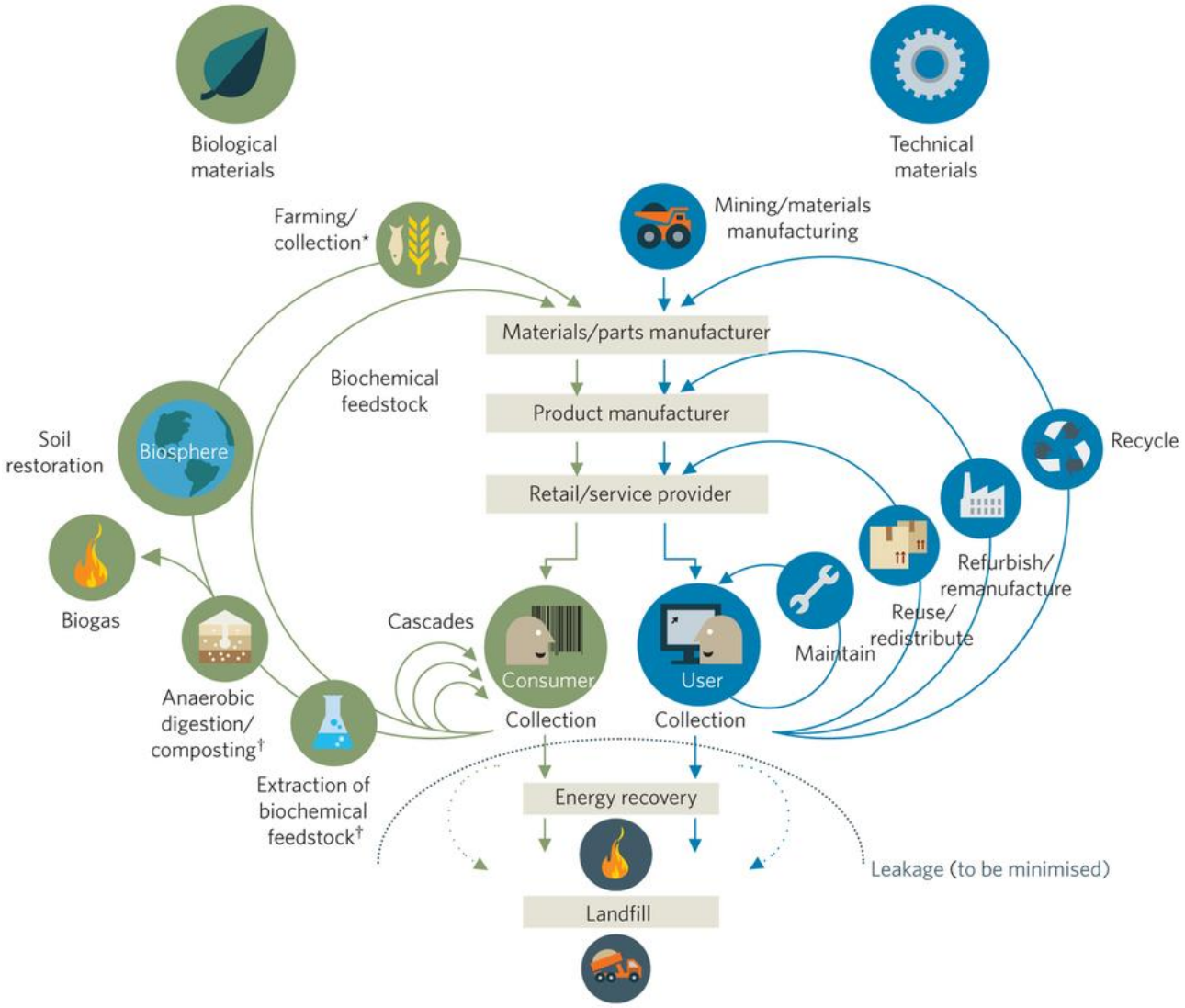


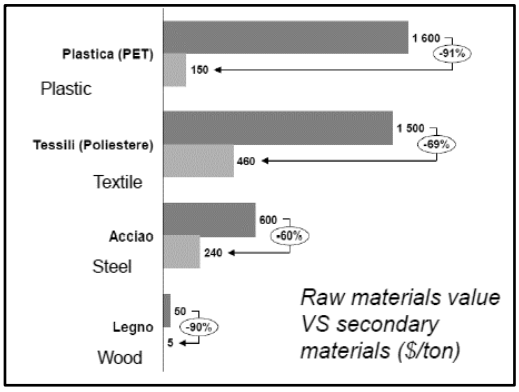
Fig. 22- Circular economy principles and techniques

A circular economy helps decouple economic growth from resource constraints. This is done by creating economic activities that make more effective use of materials, thus retaining as much of their value as possible by circulating them at their highest value at all times. The economic benefits of products and materials cycling through the system will not be coupled with the degradation of natural capital, since stocks of non-renewable resources are controlled and renewable resources are used whenever possible. A circular economy also addresses some of the externalities mentioned earlier as it reveals and designs out waste, pollution, and toxic materials. A transition to a circular economy may also generate positive externalities as it will likely spur innovative technologies and business models. Consequently, a circular economy aims at decoupling the creation of wealth and jobs from the consumption of non-renewable resources by maximising resource productivity and minimising waste generation (Fig. 22).

But, of course, a circular economy entails deep transformations of supply chains and consumption patterns so that the value of products, components, materials and resources is maintained throughout the product's useful life. Such transformations are not straightforward and switching to a waste-free economy means changes right along value chains from product design to production techniques, ownership/user-ship models and reverse logistics (Finance 2016).

3.1.4 Circular Economy benefits

The spread of Circular economy can add value to the current economy in different ways:



The first consequence would be the creation of long lasting resources that can be regenerated overtime bringing efficiency and effectiveness to industries. Resources which cost is reduced thank to the re-use. In fact, materials lose most of their value during the use phase (Fig. 23) and so acquiring secondary materials cost a lot less than the primary one. Providing an important cost savings to manufacturers (Lacy et al. 2014).

Fig. 23 - Loss in law material value from the first to the second use

If the efficiency of the economy increases because materials are not thrown away but enter new production processes, a positive effect on GDP is to be expected (Finance 2016). The increase of GDP can be pushed also by the creation of new job positions in circular economy with the enlargement of labour market. In fact, new sectors will appear, for example reverse logistics, refurbishment, remanufacturing, and recycling, and it could be anticipated that these new jobs in particular would be accessible to less-educated workers. Of course there would be also the diminishing of jobs that are now present in the linear economy but the balance seems positive (Finance 2016).

Then, market would see the commercialization of longer lifecycle products thank to the application of new circular processes or activities like remanufacturing, upgrading, recycling and refurbishing. The spread of the culture of zero waste would enlarge and change the value chain creating more collaborations and partnerships and so, fostering innovation and development (See Fig. 24).

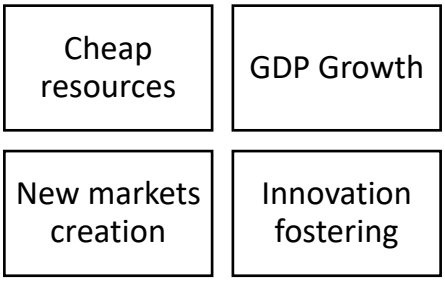


Fig. 24- Positive consequences of Circular Economy application

3.1.5 Circular Economy Barriers

There are some barriers that slow done the scale up of circular economy. First, the big change required are capital intensive, both in term of economic and intellectual capital. There is need of new structure and processes and in some cases new tools and machines for the shift. For example, the recycling technology are still not developed enough to be efficient and automated, the most part of recycling activities, especially the ones regarding the division and differentiation of different garbage are still made by human forces and this slow down the process and make it less precise and efficient. On the other hand, there is also need to create reverse logistic process and structure and product control and recovery ones. But more than ever there is need of new competences and so of training courses, updating and new hiring. Firms need to improve their knowledge about disposal, product design and new recycle methods. Besides, a change in management is needed as well, to run new business models. Businesses nowadays tend to focus on the short-term performance while circular economy look at the long run; the employees need to change their way of work and their approach too. Also outside firms' boundaries a change in customers' consumption habits is demanded. The culture of easy disposal is present in customers too that behave pushed by inertia and easy replacement habits. Concluding, there are also some product and material specifications or certificates imposed by the law that must be respected for safety reasons which make difficult for some sectors the use of second hand material (see Fig. 25).

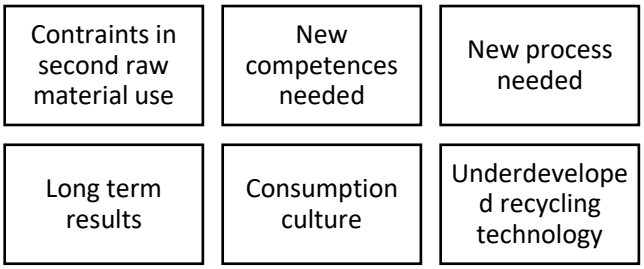


Fig. 25 - Constraints to Circular Economy implementation

3.1.6 Circular Economy Enablers

To overcome the barriers business should find a way to leverage on the enabler of circular economy. Technology, as in most cases, is the best one because it opens new possibilities and sustain, facilitate and improve new processes. Accenture identify three big set of disruptive technology that can help the transition to circular economy. The first is composed by Digital Technology (Mobile, M2M, Cloud, Social, Big Data). Digital technologies play an important role in establishing real-time information exchanges among users, machines and management systems. Such connections enhance remote visibility and control of assets, which are especially critical for the Product as a Service and Product Life Extension Business model. By altering the way businesses and consumers interact with physical and digital assets and enabling dematerialization, digital technologies can transform value chains so they are decoupled from the need for additional resources for growth. The second set is composed by Engineering Technology (modular design, advanced recycling technology). Engineering technologies enable the manufacturing of new goods from regenerated resources, as well as the actual collection, return, and processing of goods and materials and cost-efficient collection of used assets for remanufacturing.
In the end the last one that is a mix between Engineering and digital, the Hybrid Technology (Tracking system, 3D printing). It can establish a unique type of control over assets and material flows. It allows a company to digitally identify the history, location, status and application of materials and goods while, at the same time, support ways to physically collect, treat and reprocess them.

Another enabler are governments. Recently the introduction of new stricter laws about waste, recycling and emissions forced companies to change attitude and take care of their products and the end of their life. Circular economy can help them gain from

this situation and make the change convenient for every actor. Besides environmental sustainability is on the top in the list of governments concerned that discuss more often about climate change and resource consumption.

With the sustainability theme in the centre of the modern concerns and discussion even customers start to consider it a value added for products. Leveraging on this change of preferences can help boost this mentality and create new market and opportunities for circular products. A change in culture should start from basic education and supported by the context. As firms are an important and integrant part of this context they are the ones that in first place have to apply the change.

We conclude saying these new business models would change the value chain, the partnerships and add some new processes to the traditional business. Context as well as chain collaboration must always be taken into account. This is not possible without collaboration throughout the chain: designers and suppliers as well as service providers and end-of-life companies need to collaborate to reach a circular state of the economy by sharing not only materials, water, and energy, but also information and services. Furthermore, if a product is fully designed and produced according to all circular principles but the customer throws it away after use, the outcome is still linear. Hence, all parts of the supply chain need to collaborate, proving again that this change is not merely technical, but systemic (see Fig. 26).

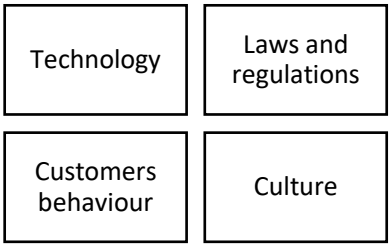


Fig. 26- Circular Economy enablers

3.1.7 Circular Economy Business Models

Clearly, the implementation of such innovation would require big changes at the strategic and operational levels. The shift from a linear approach to a circular one requires more complex and articulated business and building of large and solid networks. Some changes are more evident and explicit because are linked to technical products characteristics and new processes development, others are more hidden and regard values, cultures and new relations. Both kinds of change are necessary for a good shift and implementation of circular economy.

The technical changes regard product life, materials, transaction and ownership. In a circular economy product life is extended thank to maintenance, second uses, remanufacturing, recycle, refurbish that postpone as far as possible product disposing. The materials used need to change too, now there is more attention to use of hazardous materials and efficiency in material consumption is a design and production priority. Transaction can be more complicated. Before, the exchanges were linear and managed from top to bottom, with some firms selling products to other firms or final users. Now new possibilities arise, like customers that sell cores to firms (opposite direction) or consumers that sell products to other consumers (peer to peer transaction) and so on. Another change in the transaction regard the property's transfer. Before the transaction was considered ended when the property move from the seller to the buyers. Now there are more possibilities, like a temporary transfer of property or no transfer at all with the seller that maintain the ownership of the product and the users is allowed only to use it

The other kind of change are more behavioural and they regard values, collaboration networks and measurement scales. The value offering become more complicated because now there are more aspects to take into consideration like the environmental sustainability of a product and this affect the evaluation methods too that now include more variables that not always are exactly quantifiable and measurable but need some proxy or assumption to be included in a performance measurement system. That makes things more complicated but more complete too. A last important change regard the creation of collaborations. Since circular economy is more articulated, partnership, collaborations, and consultancies become fundamental for a performant implementation of the new economy. In the Table 6 are listed all the changes in the business models when a company moves from a linear to a circular approach.

Characteristics	Conventional business models with a linear orientation	New business models with a circular orientation
Principles for value creation	Business continuity and profit optimisation are the overriding principles.	Business continuity and profit optimisation arae the overriding principles. Value creation opportunities are sought by looking at business through a circular economy lens.
Product life	Exhaustive in nature (take, make, use and dispose).	Prolonged life through refurbishing and maintenance. Products are passed to the next user.
Materials	Merely consumed and disposed.	Resource efficiency, the quality of the product emphasize.
Ownership	Customers are buyers who own the product and dispose it after using it.	Access to a service is more important than ownership of a product that delivers the service. Customers are users in a closed loop system creating a cycle of passing on products to other users and at the end returning the used products to the production process as raw materials
Transaction	Transactions emerge in B2B or B2C markets with money as medium of exchange.	New market segments arise in which consumers interact with other consumers (C2C) and in which economic agents act both as manufacturer as well as consumer (C2B). Money is the main medium of exchange.
Collaboration	Relationships limited to the traditional buyer-seller relationships.	Supply chain collaboration creates a web of shared values. Companies in circular supply chains often cooperate beyond traditional buyer-supplier relationships that characterise linear supply chains. Instead they operate in a network of companies and institutions that often involve a strong element of collaboration and co-creation.
Success measurement	Success is measured in a financial cost benefit analysis for the parties involved in the transaction (seller and buyer).	Success is measured in a cost benefit analysis primarily based on financial value for the stakeholders involved, but which can incorporate non-financial vlaues to stakeholder and society.

Table 6 – Changes in Business models moving from a linear to a circular approach (Finance 2016)

There are three main big group of new business model identified by (Finance 2016). Of course, these business models can then acquire different operational characteristics giving born to other more specific classifications:

1. **Circular Innovation Models**: these business models focus on the development phase. Products are designed to last longer and/or be easy to maintain, repair, upgrade, refurbish, remanufacture or recycle.
    a. Product Life cycle extension

2. **Circular Use Models**: these business models focus on the use phase by optimally using the product and maintaining added value. These business models make it possible to retain ownership of the product.
    a. Product as service

b. Sharing platform

3. **Circular Output Models**: these business models focus on the output and added value of a product's after-use phase. In these business models revenue is generated through transforming after-use products into new products or useful resources in order to add value, reduce costs, or reduce waste.
    a. Resource recovery
    b. Circular supplies

These are a macroclassification of the possible application of circular business model in industry. For sure each single application would be more detailed and acquire more precise characteristics according to the technique use, the market served and the products (e.g. Industrial symbiosis, Refurbish, Remanufacturing and so far so forth).

3.2 REMANUFACTURING

3.2.1 The remanufacturing process

The urgency to change because of the changing economic balances and conditions pushed manufacturers to seek new kinds of business models for environmental and policy reasons. By keeping sustainable development in mind, manufacturing companies are forced to satisfy customer needs in a manner that leads to, from a life cycle perspective, less raw material extraction and consumption as well as energy consumption. One of the means to achieve this is to adapt the products for product recovery, where parts of the product or whole products can be reused once again after being used (Sundin 2004). One way to achieve this objective, that manufacturers all over the world are adopting quite successfully, is *Remanufacturing*.

The remanufacturing industry developed during the Second World War to respond the need of producing cheap military products in the fastest way as possible. But the concept of remanufacturing spread only during the latest decades among different industries' sectors as a new circular economy solution. Remanufacturing is defined as *the process of rebuilding a product, during which: the product is cleaned, inspected and disassembled; defective components are replaced; and the product is reassembled, tested and inspected again to ensure it meets or exceeds newly manufactured product standards* (Sundin 2004).

The remanufacturing process consists in recollecting *Cores* (i.e.used/brokendown products (or components) aimed for remanufacturing (Sundin 2004)) and reprocess them in order to restore all the original product functionalities. For a successful remanufacturing process the final quality of the product must be the same of the original one.
Usually in a traditional remanufacturing process there are some steps to follow, but they do not have a mandatory order because the way in which remanufacturing is performed depend on the kind of products and on markets. Generally, the main steps of a remanufacturing process are:

1. Inspection
2. Cleaning
3. Disassembly
4. Storage
5. Reprocess
6. Reassembly
7. Testing

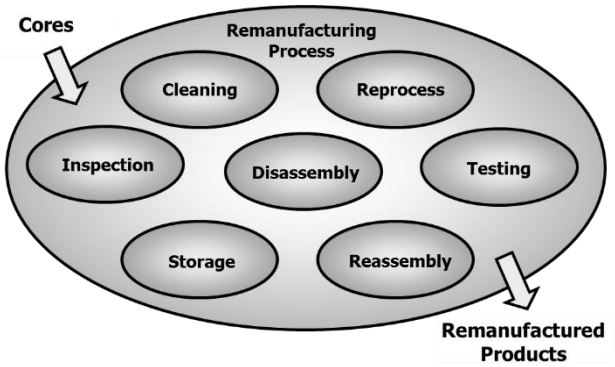


Fig. 27- Possible steps for a generic remanufacturing process (Sundin and Bras 2005)

Inspection
In this phase the core is inspected and tested to identify the possible malfunctions or errors. Usually technicians, thanks to their experience, know what kind of failures are common to products, and can estimate what it will take to remanufacture them. If the failure is not visible and targetable by human eyes a non-destructive inspection and testing methods are required (e.g. penetrating radiation, magnetic, electrical, mechanical vibration, thermal and chemical test). Another option is monitoring the product during the usage phase using a condition-monitoring device. In this way, having a product life history, it would be easier to understand which parts had been damaged (Myer Kutz 2007).

Cleaning
The cleaning phase is usually an important step for remanufacturing. In order to be able to use high quality cores they must return to the original conditions before the customers' usage. There are different cleaning methods that can be adopted. The choice of which one use depends on the kind of product, some products cannot withstand certain methods for example, on cleaning costs or on cleaning technology availability. Among the most used cleaning techniques we can find the thermal cleaning, that use heat to burn external dirt and surface contaminants; solvent-based chemical cleaning, that use chemical products to melt the dirt but recently has become the least desirable technology for cleaning because of their negative impact on the environment. Abrasive cleaning consists in brushing mechanically the cores in order to remove rust and scale, as well as to improve surface finish and appearance. The latter is indeed use by most remanufacturers to obtain like-new appearances, which is very important in this business. This is usually an expensive and time consuming phase (Myer Kutz 2007).

Disassembly
In this phase the product is disassemble in its different parts. This phase could be easy or time consuming according to the initial design the product was conceived with. If the product was meant to be disassembled the use of design for disassembled or design for remanufacturing technique could facilitate this phase. On the other hand, it could result very complex. The parts that are in good conditions are stored to be used during the remanufacturing process while the others are discarded and sent to some recycle center(Myer Kutz 2007).

Storage
In this phase products parts and/or components are stored. Warehouse costs and obsolescence costs are indicators that have to be taken into account during in this phase. As in all stock decisions(Myer Kutz 2007).

Reprocess
This phase it is not always necessary. Usually if parts need some modifications to respect new standards, need to be modified to be sell in different markets or some parts can be added, those could be some reasons for them to be reprocessed. The use of floor shop machines is usually necessary(Myer Kutz 2007).

Reassembly
In this phase the new final product is reassembled. Components are put together and if necessary new components or parts are added. If some further upgrades have to be done this is usually the phase in which new components can be added and the software are updated to the last version (Myer Kutz 2007).

Testing
This represent the final step, in which the product is tested to certificate its quality, functionalities and safety (Myer Kutz 2007).

3.2.2 Actors in the remanufacturing industries

There are different kind of company that perform remanufacturing. They can be classified according to the different relation they have with the company that had produced and market the products in the first place.

Original Equipment Manufacturers. The OEMs remanufacture their own products; In this case, it is the OEM who remanufactures its own products arriving from service centres, trade-ins from retailers or end-of-lease contracts. For these OEMs, the remanufacture of products is profitable, and they can offer their customers a wider price range of products. Furthermore, OEMs have all the needed information concerning product design, availability of spare parts and service knowledge. The remanufacturing process could be integrated with the ordinary manufacturing process or be separated from it. Also, the parts from the remanufactured products could be used in manufacturing, or the products could be entirely remanufactured (Sundin 2004).

Contracted Remanufacturer. Secondly, there are remanufacturing companies that are contracted to remanufacture products on behalf of other companies. OEM normally owns the products, but does not need to perform the actual remanufacturing of them. Still, the OEMs have their products remanufactured and can offer them to their customers once again for a lower price. For the remanufacturer, there is likely to be a fairly consistent stream of business with fewer working capital requirements (e.g. work in progress) and risks, and the company can expect to obtain assistance from the OEM in terms of replacement parts, design and testing specifications, and even tooling (Sundin 2004).

Independent Remanufacturer. Thirdly, there are many independent remanufacturers who remanufacture products with little contact with the OEM, and who need to buy or collect cores for their process. Sometimes, these companies are paid by the last owner or distributor to pick up discarded products. These independent remanufacturers also often need to buy spare parts for their products that are to be remanufactured. This type of operation is an integrated one, in that it purchases cores, remanufactures them and markets them under its own name or for the private labels of others. Generally, exchange of experience between these remanufacturers concerning reprocessing to the OEM is minimal (Sundin 2004).

3.2.3 Remanufacturing sectors

The remanufacturing industry comprises a diverse set of sectors, each with its own challenges, which share some clear underlying similarities - particularly around customer recognition of remanufactured goods, volume / quality of core, and access to core. In Table 7 are listed the biggest remanufacturing sector in Europe:

Table 7- Summary of market size of remanufacturing activities by sector Sectors(Parker et al. 2015)

Sectors	Turnover (€bn)	Firms	Employm't ('000)	Core ('000)	Intensity
Aerospace	12.4	1,000	71	5,160	11.5%
Automotive	7.4	2,363	43	27,286	1.1%
EEE	3.1	2,502	28	87,925	1.1%
Furniture	0.3	147	4	2,173	0.4%
HDOR	4.1	581	31	7,390	2.9%
Machinery	1.0	513	6	1,010	0.7%
Marine	0.1	7	1	83	0.3%
Medical equipment	1.0	60	7	1,005	2.8%
Rail	0.3	30	3	374	1.1%
Total	29.8	7,204	192	132,405	1.9%

The value for all manufactured products in the above remanufacturing-intensive sectors is €1.5 trillion. Remanufacturing makes up a small share of European manufacturing output, accounting for an estimated 1.9 % of total production value in these sectors – the remanufacturing 'intensity'. However, despite the relative small size of the activity, it is seen as a key part of company strategy and a potential differentiator for businesses (Parker et al. 2015).

3.2.3.1 *Aerospace Sector*

The European aerospace industry encompasses activities including the design, development and production of civil and military aircraft, aero engines, helicopters, unmanned aerial vehicles and their associated systems, parts and equipment. The addressable aerospace sector as mapped to Eurostat codes identified a total market value within the EU of €107.8 billion.

The role of remanufacture is to keep an aircraft airworthy. Airworthy is a legal term defined and enforced in Europe by European Air Safety Authority (EASA). Broadly, remanufacturing in the aerospace sector is any activity that keeps an aircraft airworthy and therefore effectively indistinguishable to the end consumer. This covers a wide range of services that include the maintenance, repair and overhaul of used components, the manufacture and integration of new parts, and the enhancement of performance to keep up-to-date with advances in technologies. Strictly, warranties are generally not offered but operators must nevertheless abide by strict rules governing the sector and guarantee service levels during a contract period, thus in effect providing a performance guarantee for the customer.

The growth outlook for remanufacturing in the aerospace sector over the next 5-10 years is for steady positive growth. Opportunities in this sector are driven essentially by economics: the cost of remanufactured product is around half the cost of newly manufactured, making remanufacturing the most cost-effective option in an industry characterised by the long durability of aviation components and their high capital costs. Technological advances, such as that in new composites, present cost savings that are difficult to equal on older stock, but the high cost of aircraft components and strict remanufacturing regulations mean that operators will always consider remanufactured products before a new purchase. The industry's strong remanufacturing position is reinforced by the presence of large firms on the cutting edge of aircraft technology and remanufacturing. OEMs in particular are becoming increasingly active in the sector, as the larger airlines switch to service-based purchasing agreements. Service contracts with airlines or aircraft leasing companies provide some resistance to economic downturns. Furthermore, the cost of remanufactured components is less affected than newly manufactured components by fluctuations in resource prices.

On the other hand, some barriers still need to be overcome. Legislative and trade barriers, a lack of standards across EU Member States, and relatively high European cost levels adversely affect the growth of remanufacturing in this sector. The complexity of technology make difficult for operators to intervein. Their remanufacturing activities could be limited by a lack of product knowledge and access to data such as technical documentation. A shortage of quality spare parts was also a barrier to remanufacturing activities(Parker et al. 2015).

3.2.3.2 *Automotive Sector*

The automotive sector encompasses motorised road vehicles, motorbikes and vans. The aftermarket in the automotive sector covers all repair, maintenance and servicing activities for the EU network of vehicles on the road. The European Association of Automotive Suppliers (CLEPA) estimates remanufacturing in this sector is worth €8-10 billion of retail sales, with 27 product groups able to be remanufactured.

Vehicle longevity has gradually been increasing, and the average age of vehicles on the road is now over seven years. This should provide an opportunity for the remanufacturing sector as a whole as it is likely that more spare parts will be required. The EU's End-of-Life Vehicle (ELV) legislation could buoy the remanufacturing industry in this sector. Historically, the automotive industry has demonstrated a high degree of reuse and recycling. New regulations are gradually increasing this level from 75 % 10 years ago up to a target of 95 % by 2015. Remanufacturers may be able to take advantage of this by providing alternative and superior reuse options for the industry.

On the other hand, the increase of complexity of products, in some cases potentially driven by OEMs wanting to make it harder for others to copy their products offers significant problems for remanufacture; the availability of quality core, diminished by the increase of the competition in the sector; and the speed in technological innovation, especially regarding the use of more electronic parts could refrain the spread of remanufacturing for these kinds of products (Parker et al. 2015)

3.2.3.3 *EEE Sector*

The EEE sector consist of: information and communication technologies (ICT) and consumer electronics. Based on the analysis of Eurostat the market value of this sector is €210 billion. In ICT and consumer electronics Remanufacturing consist in replacing faulty components with functioning components cannibalised from other stock or bought new. Units are then tested to ensure electrical safety. Refurbished units are also tested to ensure that they work to an as new standard, and are then sometimes resold in their original packaging. However, a significant proportion of refurbished PCs and laptops are end-of-line models, repaired warranty returns and customer returns and/or cancellations which have, effectively, never been used. ICT management companies offer complete ICT service packages including new installations, life-time upgrades and off-site backups. Reuse then forms just one part of their operation. Almost every company that operates in the ICT sector alludes to reuse as part of its green credentials. The waste generated in refurbishing ICT equipment can either be cannibalised for functioning parts or segregated and sold to authorised treatment facilities for recycling.

Requirements for the responsible disposal of consumer electronics and ICT by the public and by businesses would increase the volume, and potentially the quality, of stock for remanufacturing. Regulatory measures could be strengthened and voluntary schemes expanded to support reverse logistics for core.

The technologies used in ICT equipment and consumer electronics are changing very fast. Two to three year old units are generally considered old, five year old units out-of-date and even older units effectively obsolete. Another symptom of this fast-paced market is that the supply of certain stock and the demand for certain remanufactured products can change entirely in just a few years.

Businesses that specialised in refurbishing this type of product will not necessarily be able to switch to refurbishing the lower value, more complex netbook and tablet computers.
Some consumers are put off releasing their old computers to remanufacture due to concerns about the safety of their data. This, along with economic factors, is one reason why obtaining sufficient quantities of stock and used components is a barrier to remanufacturing in.

3.2.3.4 *Furniture*

The furniture sector can be divided into furniture for personal use and furniture for business use including offices. The remanufacturing market for furniture is estimated to be about €300 million. In order to stay competitive in the global market, European furniture manufacturers are starting to provide support services (both pre- and post-sales) and allow products to be returned. A model adopted by half of the OEMs in the furniture sector is a take-back scheme where third-party subcontractors remove, process and resell old (primarily office) furniture. OEMs also offer a refurbishment service to augment their sales of new furniture. In addition, some OEMs offer a scheme whereby an old item is traded either for a newly remanufactured product, or for the same product after a full service and warranty. For the small proportion of furniture that does get recovered at end of life, in addition to remanufacture and refurbishment strategies, reuse is also commonplace.

Given the fragmented nature of the European furniture supply chain there is an opportunity to create new products and reach new markets with remanufactured end-of-life furniture. The biggest motives for remanufacturing in the furniture sector is to secure a supply of spare parts, protect the image of the brand, adhere to government legislation and, most importantly, express responsibility to the environment. Office furniture offers a remanufacturing opportunity as it can be embedded within a number of supportive business models, such as leasing. These are more conducive to enabling recovery of quality furniture not least because the retention of ownership by the leasing company means that location is well known and the risk of investing in good product at the outset is much reduced.

A range of barriers and challenges must be addressed for remanufacturing to be adopted in an economically viable manner. The top barriers to remanufacturing in the furniture industry are customer recognition, volume and availability of furniture for remanufacturing, and legislation restrictions(Parker et al. 2015).

3.2.3.5 *Heavy Duty and Off Road equipment*

The heavy-duty and off-road (HDOR) equipment category encompasses the manufacturing, installation, maintenance and repair of a wide variety of equipment including: engines and turbines, except those used in light vehicles and aircraft; forestry and agricultural equipment, mining and quarrying equipment, lifting and handling equipment and the equipment used in the manufacture of cars and other vehicles. The European remanufacturing market is estimated to be worth €4.1 billion.
Remanufacturing activities vary according to the different products/subsectors. Remanufacturing in the lifting and handling sub-sector is not well-established. It is not a standard service provided by the OEMs, nor does there seem to be much consumer interest in taking it up. Remanufacturing in the cranes and hoists sub-sector is uncommon - though regular maintenance and refurbishment, including component replacement and reuse, is more prevalent. A moderate amount of remanufacturing of industrial handling equipment, including forklift trucks, does take place but is concentrated in a small number of OEMs that service some of their own product lines. The refurbishment and reuse of forklift trucks and other industrial handling equipment is much more common than their remanufacture. An insignificant amount of remanufacturing occurs in the lifts and escalators sub-sector, though the refurbishment and reconditioning of elevators and their mechanisms is more widespread.

3.2.3.6 *Machinery*

The machinery sector encompasses the manufacturing, installation, maintenance and repair of a wide variety of equipment including: machinery for food and beverage processing, machine tools, pumps and compressors, engines and turbines alongside the installation and repair of machinery and equipment. it is worth €138 billion as reported in the Eurostat database.

The machinery sector in the EU comprises predominantly SMEs providing equipment and services to numerous manufacturing sectors. Specialities within the European machinery sector include producing the machinery for metal product fabrication, food and beverage production and chemical industries. In the machinery sector the remanufacturing process generally involves machine disassembly, replacement of any components which are damaged, machine re-assembly and testing to the same standards required of a new product. Warranties, typically 1-12 months, are offered on remanufactured machinery though this depends on the type of product and the specifics of the remanufacturing that has been carried out. The decision by a company to carry out a specific type of repair or maintenance activity - be it remanufacture, refurbishment or other - is partly shaped by the consumer of the machinery. If a customer asks for a manufacturer to remanufacture a product, the manufacturer will carry out this service where it has the capability to do so, even if it does not necessarily make up a regular or significant part of the business.

The terminology used to describe the remanufacturing process in the machinery sector varies between companies and countries, though common phrases describing remanufacturing activities include rebuild upgrades and retrofitting. Other generic terminology used in the sector includes reconditioning and refurbishing.

Remanufacturing in the machinery sector is somewhat fragmented but widespread across Europe, with activities taking place in a variety of countries including the UK, Germany, Spain, Belgium and the Netherlands. Low value units are often not worth salvaging for economic reasons and reuse is concentrated in higher value items. If reuse is not viable the units are either scrapped or components retrieved to use as spares. In addition, remanufacturing provides the opportunity to upgrade components and install new functions such as monitoring and logging devices. Between these extremes a spectrum of reconditioning, refurbishment and other reuse type activities occur (Parker et al. 2015).

3.2.3.7 *Marine*

The remanufacturing market for marine is relatively small compared to aerospace, automotive and HDOR, estimated at €76 million. As previously highlighted, this is likely due to much of the maintenance, repair and conversion activity being more in the repair and refit domain i.e. not to the level of rigour of remanufacturing with a warranty. Remanufacturing will only be established at scale in the conservative marine industry if the economic drivers make sense. Maximising the time a ship is in active operation means reducing dry dock time as much as possible through using reliable materials and time-saving processes wherever possible. Remanufactured products need to meet these requirements if they are to be widely accepted in the marine industry(Parker et al. 2015).

3.2.3.8 *Medical Equipment*

Medical devices and equipment are items used on patients to carry out medical care, including testing, diagnosis, surgery and after-care. According to Eurostat data for 2014, the total market value of the medical device sector within the EU was €35billion. Remanufacturing in the medical device sector favours medical equipment that are designed to have a long lifespan, are non-invasive, require significant R&D investment and are capital intensive to build and buy. Remanufacture and servicing plays an important role in keeping a piece of equipment functioning for as long as it is needed or until it becomes obsolete because of technological advancements or due to functional redundancy.

The most important motives for remanufacturing are: a secure supply of spare parts; product warranties; to increase their market shares; customer pressure; government legislation; company profitability and strategic advantage. Fluctuations in raw material prices and environmental sustainability had a smaller impact on their decision to be involved in remanufacturing. Currently purchasers predominantly associate remanufacturing with the low-standard refurbishment activities used to repurpose medical equipment for

the veterinary market or export to emerging markets. Reassuring purchasers that remanufactured and reused products are not of an inferior quality to new products would be the most direct way to increase remanufacturing activity in this sector. Also because there is enormous pressure on all medical institutions to provide the best patient care at the lowest possible cost and this is an issue which can only increase in importance in the future.

3.2.3.9 *Rail*

The rail sector encompasses inter-city passenger and freight rail services as well as urban rail services, including light rail systems, trams and street cars, automatic people movers (APMs) e.g. driverless trains often used in large airports, metro train systems monorail and personal rapid transit (PRT) systems, also called podcars. The European rolling stock market had an annual value of €11.7 billion. Financial motivations rather than environmental reasons tend to drive remanufacture in the rail supply industry.

3.2.4 Drivers for remanufacturing

Thanks to the use of cores instead of raw material a consistent cost reduction in purchasing and in manufacturing process is achieved. This allow firms to sell products at lower and more affordable prices, enlarging the market and increasing the customer demand with positive consequences on profits. Secondly, remanufacturing represents a good option to comply the new laws about disposal and wastes. In fact, some firms are now required to deal personally with the disposal or recycling process of their products. And the new responsibility is resource consuming (in terms of human resources, costs and time). Therefore, remanufacturing could help them in extracting additional value from the end of life product and making the reverse logistic and the waste management profitable. As well as help in respecting the environment and running more ethical business. In the end, remanufacturing is a perfect instrument for control. It helps maintaining the control on product, customers and market with subsequent gaining of competitive advantages. Besides it can be considered a way to enlarge the company offer services and so becoming more competitive on the market (Östlin, Sundin, and Bjo 2008).

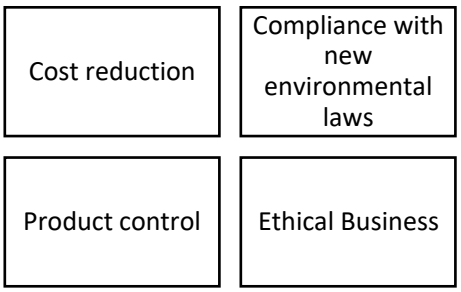


Fig. 28 - Driver for the application of remanufacturing

3.2.5 Environmental and social benefits

Remanufacturing has significant environmental benefits by averting CO2e emissions and diverting large amounts of product away from landfill. A high proportion of the worked material of a remanufactured good is retained from the original core product. This is associated with a similar retention of embedded energy and savings of emissions. Note a key distinction between recycling and remanufacturing in that the former only recovers material while the latter recovers products i.e. more value is retained (Parker et al. 2015).. Withdrawing cores from the market and fix them allow to skip some steps of the traditional production chain. Saving materials, energy and emissions. Indeed, raw materials is recovered and recycle instead of extract. In a scenario where primary resources are entering in a phase of scarcity this practice can help saving time, costs and price fluctuation. While skipping some manufacturing phases would reduce the energy consumption and pollution linked to those first phases (see Fig. 29) . In the end, using

products at the end of their life, instead of sending them to landfills, give them a second value life in the market and postpone their disposal process.

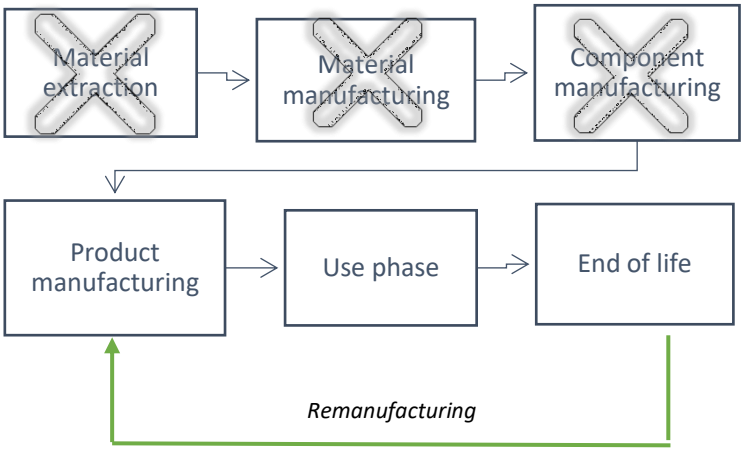


Fig. 29 - Production steps that are no more necessary thanks to remanufacturing

Remanufacturing can provide some social benefits too. Firstly, it can produce products at affordable prices, opening the possibility to sell also in secondary market. In this way, also developing countries can easily have access to those kinds of products/technologies that before were too expensive. With positive effects on local industries and people life quality (e.g. sell of remanufactured computers in schools, sell of machineries for production or agriculture and so far, so forth). Another aspect is job creations. Work requirement is higher for remanufacturing considering all the inspection, disassembly, remediation, reassembly, testing and other associated activities required (Parker et al. 2015). New process need new roles, new skills and new relations are needed and this result in the creation of new job positions to be covered.

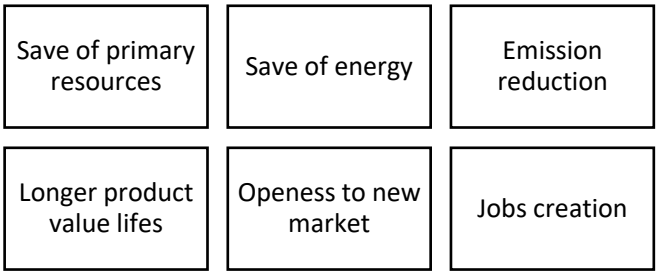


Fig. 30- Environmental and social benefits of remanufacturing

3.2.6 Challenges

On the other hand, there are still some challenges for firms who want to use remanufacturing. As we said in the previous section product control can provide important competitive advantages. But reach this kind of control is still difficult and can become time and cost consuming. Besides the unpredictability of cores return and of users' behaviour make difficult reaching a real control on products. Another issue that could represent an obstacle are the need of new skills and of new technologies. Workers need to be trained or new employees have to be hired for an effective application of the process. In the best situations remanufacturing can be performed by the already existing machines in the industry, but sometimes new technology and new tools are needed for fixing or for providing modifications to cores. These are all investment that company have to sustain, and the risk perceived could be higher

than the benefits expected. Another problem could be the customers' demand. The perception of remanufactured products is still ambiguous. Market still perceive them as lower quality products and do not give them the right value. An evidence of that kind of behaviour is they will not purchase remanufactured products unless they are sold for more than a half less of a new product price. Customers preferred remanufactured parts over new if remanufactured parts were offered at about 57% of the new part price(Myer Kutz 2007). A change in consumption behaviour is needed that will let become remanufactured products competitive as new ones.

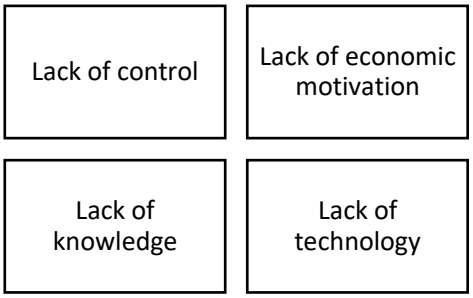


Fig. 31 – Reasons why the transition to remanufacturing could be challengeable

3.2.7 Design for remanufacturing

The emergence of WEEE (Waste Electrical and Electronic Equipment) and ELV (End of Life Vehicles) take back from de European Union pushed industries and academics to search for new design recycling methods and guidelines which are applicable to remanufacturing. The most spread techniques are:

Ease of disassembly. The products should be designed to be disassembled in little time and without damaging any product parts. Therefore, permanent fastening as welding or crimping should not be used if the product is intended to be remanufactured. Also, it is important that no part be damaged by the removal of another. This means use assembly methods based on interlocking or leverage systems. Speedy disassembly is desired, but not at the expense of damaging cores. Avoiding and preventing damage, therefore, is often the more important objective than increasing speed. An easy assemble products usually become an easy disassembled product, so usually to obtain facility in disassemble some common Design for Assembly Guidelines.

Ease of cleaning. Parts that have been use inevitably need to be cleaned. In order to design parts such that they may easily be cleaned, the designer must know what cleaning methods may be used, and design the parts such that surfaces to be cleaned are accessible, and will not collect residue from cleaning. Product parts and surfaces should be protected against corrosion and dirt. The addiction of a protections or of a protective layer for example. Then designers should avoid to use materials or parts that could be damaged during the cleaning process. The use of geometric features that could easily trap contaminations should not be used neither (small corners, cavities, rough surfaces)

Ease of part replacement. Parts must be replaceable to be able to fix the original product. So usually is better to design not too complex or customised components in order to allow the substitutability.

Ease of reassembly. It follows the same principles of ease of disassembly. Besides, where remanufactured product is assembled more than once, this become very important.

Reusable components. As more parts in a product can be reused, it becomes cost effective to remanufacture the product, especially if the parts are costly to replace.

In general, there are some guidelines or activities that could be followed or added to the remanufacturing process in order to fasten it and make it more efficient. Firstly, the product and part variety should be reduced. This would ease replacement and reusability of components. Secondly, the different groups parts should be provided with clear distinctive features for easy recognition. In this way, the processes of disassembly and reassembly are fastened. Besides, also the single parts could be provided by machine readable label to allow the automation of the part recognitions during the sorting and the replacement and reassembly. Most products and parts have labels. Those that are exposed to the environment, however, tend to wear off during life. Some companies are experimenting with radio-frequency identification (RFID) tags to facilitate the process (Myer Kutz 2007).

A new design technique that is emerging in this field is modularity. The implementation of modularity consists in dividing products in its simplest element/component as possible in order to make it easy assembled, disassembled and upgraded. Modularity allow to respect all the techniques described above. The role and the importance of modularity would be deepened in the next sections.

3.3 UPGRADING REMANUFACTURING: A LITERATURE REVIEW

In the following sections the output of the first objective of the thesis is presented. A complete and integrated literature review about upgrading remanufacturing and its sub topics is developed.

3.3.1 Upgradability strategy

Upgradability Strategy is defined as the set of decisions about upgradability of a product in terms of time, nature and steps. It's the guideline for the management of the, so called, Multiple Life Cycle Products, which will born thank to remanufacturing and upgrading (Watanabe et al. 2007). In the next sections the different decisions about upgrading are presented.

3.3.1.1 *Upgrades' classification*

Different kind of upgrades exists according to the functionality they are modifying or adding. There is the *parametric upgrade*, that consists in improving the performance of an already existing function, like for example increasing the speed of a printing machine or improving the definition of a camera; the *functional upgrade*, and so the addition of a new function, like the introduction of two sides copies always for a printing machine, or a new washing programme for a washing machine; or the *semantic upgrade*, which is the introduction of new services, like monitoring the performance of a product, put in communication machines, planning maintenance and so on. The best ones usually are the last two because they add more value to the upgrade (Olivier Pialot, Millet, and Bisiaux 2017) (Umeda et al. 2005).

3.3.1.2 *Time and content of upgrade*

For an effective upgrading strategy, there is the necessity to identify how often a product needs an upgrade. This decision can be managed thinking at the classic trade-off *First Mover/Follower,* that is always pertinent when talking about new technology introduction (Wilhelm, Damodaran, and Li 2003), but as we are talking about incremental upgrading and not breakthrough technologies this has to be only the first guess in order to understand in general the maturity of the market and how it reacts to new introductions. But then, a more specific analysis is needed: first of all the time and content of upgrade depend on the two life of a product, the physical life time (i.e. the reliability) and the value life time (i.e. the obsolescence) (Olivier Pialot, Millet, and Tchertchian 2012). A product needs an upgrade when one of these life ends. Indeed, usually customers use to substitute a good when it is broken or when a new technology enter the market making the old one useless. Which one ends first depend on kind of product and market.

Then time and content depend on operational variables too, like costs of remanufacturing and recollection, and overall environmental impact. Upgrades do not have to be too frequent or the overall costs and impacts of recollection and industrial processes would overcome the benefits of remanufacturing, and on the other hand not too seldom or it would be difficult to maintain such products on the market, because customers would prefer the classical ones. There are studies and also mathematical algorithms to help to support these decisions and help firms to define the optimal duration cycle (Olivier Pialot, Millet, and Tchertchian 2012) (Aziz et al. 2016)(Östlin, Sundin, and Björkman 2009).

3.3.2 Upgrade plan

The decisions about time and content of upgrades would become part of a plan (*Upgrade Plan*) that has to be defined along a time horizon. A well predefined plan is necessary because, in order to design an upgradable product, there is the need to know in advanced which would be the upgrades required to keep the products in the market and satisfy the demand. In order to design a reliable upgrade plan technological trends, trends of customers' need, trends of competitors, the company's policy, and so on, have to be considered during several possible generations of the target product. The plan should include functions to be upgraded, basic specification and rough price of each generation (Umeda et al. 2005) . Many variables have to be forecasted and, as always happens with planning, there would be a certain gap of uncertainty that has to be properly managed. Firms are used to deal with uncertainty and each one have its own methods, but for this specific case there are some strategies, identified by authors, that are strictly connected to the physical design of goods: maintaining a certain level of flexibility and having the possibility to adjust it during the different generations of product is possible to face the uncertainty gap. (see Design for upgradability and modularity –*3.3. Uncertainty design strategy*)

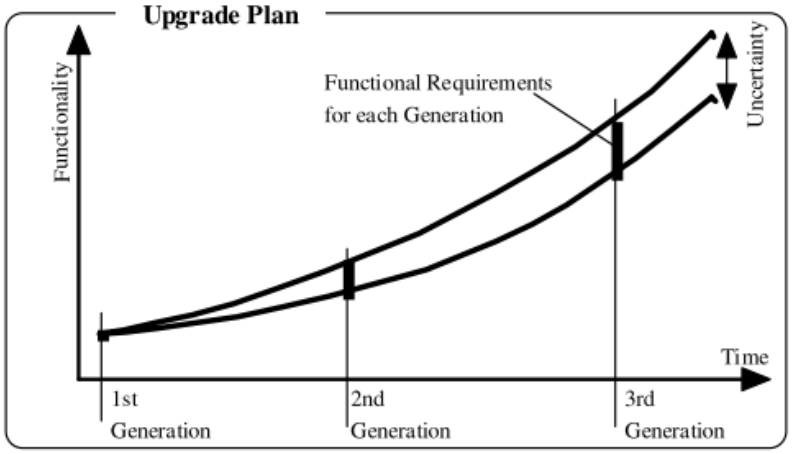


Fig. 32 Uncertainty of the upgrade plan (Umeda et al. 2005)

3.3.3 Business strategy

The last step of an upgrading strategy is the identification of a profitable market to commercialize these products, and so the management of the relation with customers and the definition of a strong value proposition and business model to sustain the activities.

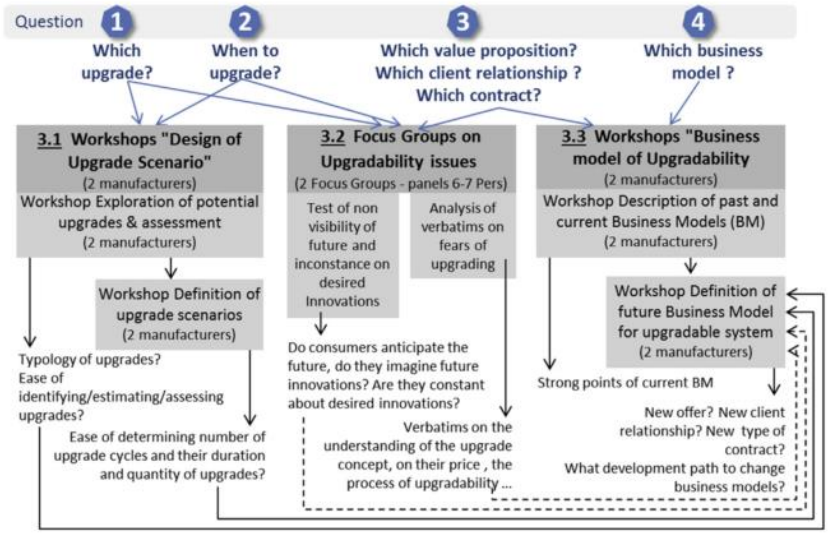


Fig. 33 - Example of upgrading strategy(Olivier Pialot, Millet, and Bisiaux 2017)

3.3.4 Management of cores

Another important topic are *cores*. A core is the used product that need to be physically withdraw from the market and remanufactured. By using cores as the main material source instead of consuming virgin materials, and conserving their physical form during reprocessing, remanufacturing captures the remaining value of cores in the forms of materials, energy, and labor (Wei, Tang, and Sundin 2015).

3.3.4.1 *Actors*

In the traditional remanufacturing process management of cores could be performed by three possible actors: OEM (Original Equipment Manufacturer, i.e. the ones who produce the product first), Contracted Remanufactured (i.e. firms that have relation with OEM and are contracted to deal with remanufacturing process) and Independent Remanufacturer (i.e. Firms that base their business exclusively or partly on the recollection of old products and their remanufacturing but do not have any relation with OEM)(Sundin 2004). For the specific case of remanufacturing with upgrade the actors are still not defined, but since the process requires long lasting relationship and a deep knowledge about the history and the structure of the products, is reasonable to assume that the OEM take the responsibility of all, at most, outsourcing some activities, but this will depend on specific cases and products.

3.3.4.2 *Management of Uncertainty*

Even though management of cores is fundamental for obtaining good results, their acquisition is often characterized by uncertainty: in volume, time and quality (Wei, Tang, and Sundin 2015). Uncertainty in volume happens because is difficult to predict the exact number of products that would be recovered from the market; the uncertainty in time exists because is not known the exact moment in which customers want to substitute the product because of obsolescence or because it is broken; the uncertainty in quality depend

on how customer behave during the usage of the product. The above uncertainties result in the unbalance of return and demand. On one hand, if there are not enough returned cores, the remanufacturers will have to use lower quality cores, convert other types of cores, or even use new products to meet the demand, and such operations can be very costly. On the other hand, if an overstock of cores occurs, it increases the holding cost and the risk of obsolescence. In addition, the above mentioned uncertainties also cause the complexities in resource planning, increase uncertainties in processing times and create difficulties in remanufacturing operations (Wei, Tang, and Sundin 2015).

3.3.4.3 *Activities of core acquisition and return strategies*

Instead of suffering from these uncertainties passively, remanufacturers can actively manage the process of core acquisition. In literature, there are studies that analyse these problems and suggest possible solutions about how to influence the return. First, forecast the return pattern is fundamental, this forecast would become more reliable once this process acquire historical data (about time, volume and quality) and remanufacturers more experience, but till now the uncertainty make it difficult.

Five main activities can be identified in the core acquisition management: acquisition control, forecasting return, return strategy, quality classification and reverse channel design, and each of them have its uncertainties to manage and influence.

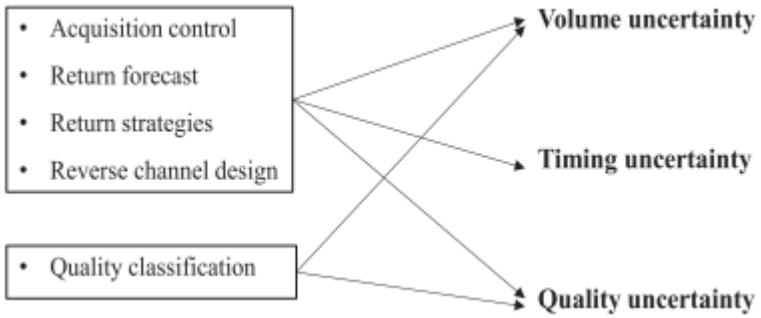


Fig. 34 - The activities in core acquisition management and their impacts on different return uncertainties (Wei, Tang, and Sundin 2015)

This is why there are some return strategies that could be adopted to maintain the control of the reverse pattern: (Wei, Tang, and Sundin 2015) suggests the use of a market driven approach based on an incentive system to push consumers to give the product back, like for example a deposit, or a buy-back price. In this way, you have more guarantees of receiving the product back and, moreover, by adjusting the buy-back price you can have more control on the quantity returned and on quality too. While (Sundin and Bras 2005) thought about the use of functional sales, that would allow the firm to maintain the ownership of goods, by selling only the use of them, and so making collection of products easier and more under control. But the most complete paper about the importance of establishing new kind of relations in order to create a closed-loop supply chain is (Östlin, Sundin, and Bjo 2008) that identified seven different return strategies: (1) Ownership-Based, (2) Service – Contract (3) Direct – Order, (4) Deposit – Based, (5) Credit – Based, (6) Buy – Back, (7) Voluntary – Based.

(1) In the Ownership – Based strategy the OEM maintain the ownership of the product and its responsible for its maintenance and its remanufacturing schedule, while customers are limited to the use and for a limited and predetermined interval of time. Usually the terms and conditions of use are specified in a contract that users sign at the beginning of the relation. Examples of this kind of relation are leasing contracts, rental contracts or product service offering[8]. The main advantage of this approach is that the linkage between the manufacturer and the users is strong and this allow manufacturers to always be informed and updated about customers' needs and products status. Indeed, since during the use phase, the seller is

[8] Commercial strategy that consist in selling only the use of a product but not the ownership, see the chapter about PSS for a deepening *(7. Product Service System*)

responsible for maintenance and repairs of the product, a relationship is established through the service/ maintenance personnel that is able to gain detailed information as to whether or not there is a need for a future remanufacturing operation. This information can make the return flow of cores easier to control and provide information on products status. Using this technique is possible to manage properly the flow input of remanufacturing by decoupling the process using cores/components buffers specifically sized, making it more efficient and reliable. This would bring positive consequences in terms of costs of, and time to process (if the buffers are optimal sized, or the effect would be negative in terms of inventories and obsolescence costs or, on the other hand, unavailability of cores). The drawback of this approach is that customers are forced to maintain the relation with the producers over time and that manufacturers, in order to operate product-service offers, need to make a transition from traditional manufacturing to also becoming a service provider, something which affects the entire structure of a company and increases requirements for administration.

(2) Service – Contract relationship has a high degree of similarity with the ownership-based relationship. The main difference is that in this case the ownership goes over to the customer, the level of control over the products is reduced. This decrease the power of remanufacturers which have less information and less degree of control over the usage phase.

(3) In a Direct – Order relation is the customer that owns the product and decides when remanufacturing it. One advantage of this approach is that, as customers provide the cores, there is no need to have any inventory and this results in a reduction of costs. But the uncertainty of return remains quite high because it is not possible to forecast customers' decisions about time of remanufacturing and the quality of cores provided. Another problem is product will be non-usable for the time when the component is being remanufactured. So this kind of relation is suitable only in the case in which is feasible to not use this product for a certain period of time.

(4) In the Deposit – Based situation the customer is obligated to return the core when buying a new remanufactured product. The retailer paid a deposit that would receive back once the product is returned, resulting in a one for one take back relationship where customers always have the product available without waiting for remanufacturing. The advantage of this technique is that remanufacturer always know the number of cores there would be returned and this reduce the uncertainty of volume since a theoretical match between supply of cores and demand for remanufactured products is achieved. The reality is a bit different, because, as it is plausible, sometimes cores are too damaged to be remanufactured or customers can decide to sell them to remanufacturers that are willing to pay a higher price than the initial deposit (so price decision is not trivial too). The result of this mismatch is that the company must use alternative systems to gather the lacking cores.

(5) The Credit – Based is similar to the Deposit ones, with the difference that customers do not pay a deposit in advanced but receive credits to buy new remanufactured products once they have returned cores. The number of credits the customers gain from the supplied cores depends on the state of the core. In this way, the remanufacturer gets a high variety of cores and can practice some level of control by the credit system, while the customer can return cores for credits. This type of system enables the remanufacturer to some extent control the balance been supply and demand. Of course, this make return flow less predictable than the Deposit system and add some administrative costs to the process of recollection.

(6) In Buy – Back system remanufacturers simply pay for cores. Any retailers that are willing to sell cores can do it freely and the price of cores would be set according to their quality. The cores flow can be managed and influences by adjusting the buy-back price. Usually this method is used when there is need to have "hard to find" or particular cores from the market.

(7) In Voluntary – Based relation is based on the idea that the customer will voluntary give back the cores, sometimes pushed by the existence of some government directives. In this case the uncertainty is not reduced and firms have to be prepared to high return flow fluctuation, always monitoring the level of inventorying and the demand. The supply of cores depends basically on the kind of relationship the remanufacturer can establish with customers.

It should be taken into account that usually these strategies are not used alone but a combination of them is the most suitable options to reduce uncertainty, obtain good quality cores and establishing strong relations with customers. By the way, authors

identified the Owned - Based strategy and the Service one as the best options because allow remanufacturers to maintain control on products and have visibility on the market.

3.3.5 Customers' relation

As it has to be clear at this point remanufacturing for upgradability need the involvement of business at many levels, and one important part is the relation with customers. Customers are highly involved in this process. Products must be customized according to their needs and taste. There is need to maintain a constant communication with them by monitoring the products in order to be able to deliver the right services, and they are an important factor to achieve a successful reverse logistic: *reverse logistics and remanufacturing are a customer relationship management challenge* (Östlin, Sundin, and Bjo 2008).

3.3.5.1 *Importance of upgrading*

As remanufacturing for upgrading is still rarely applied customers are not used to the idea of *upgraded remanufactured products*, on the contrary their consumption behaviour is still pull by the idea of easy replace and substitution. Usually the motivations that induct people to replace a product are: the high cost and risk to repair the old one, the need of always new functionalities and connections, and the desire of "something new" (O. Pialot and Millet 2014). Upgradability would solve all these three incentives to substitution creating products with always new functionalities, easy and cheap to repair and "not boring". But in order to commercialize successfully upgraded goods upgradability alone is not sufficient. What is necessary is understand what customers expect from an upgraded remanufactured product and, on one hand, leverage on good expectations and, on the other hand, try to change or defuse the wrong ones.

3.3.5.2 *Quality & Price*

According to (El Korchi and Millet 2014) and (Hazen et al. 2012), consumers typically value remanufactured products less than the corresponding new products and therefore they are not willing to pay the same price for the remanufactured because they perceive they have lower quality than classic ones. According to (Hazen et al. 2012) this happens because remanufacturers feel ambiguity too, especially about the remanufacturing process: the process is not fix, the quality of outputs is not always guaranteed and there isn't, until today, any effort to spread awareness about the existence and the benefits of these products from anyone but academics. This ambiguity perceived by industries is transmitted to customers that do not trust completely the products and this is reflected on their perceived quality and consequently on their willingness to pay. What has to be done is try to reduce the perceived ambiguity starting from manufacturers, that are the first that have to become confident of remanufacturing process and be ambassador of their products in first place transmitting confidence to people. It is necessary to define a trustworthy and winning strategy and reliable operations and then using marketing and transparency to spread awareness among people about it.

3.3.5.3 *Environmental impact*

In the end the most obvious: customers expect remanufactured product to have a lower environmental impact than traditional ones.

So in order to ensure customer purchase of remanufactured products, the following needs should be satisfied: upgradability to new product technology level, a lower price than the new product, a quality equal to that of the new product, a lower environmental impact than the new product (El Korchi and Millet 2014).

What is missing in literature is the definition of a target customer that would be more willing to buy these kinds of products, from the definition of the target would follow then the definition of price, channel, product's characteristics and marketing actions.

3.3.6 Design for upgradability and modularity

Design for Upgradability is a design approach for products intended to be easily upgraded with the addition or the exchange of one or more modules. Modules are the simplest parts of a system (in this case a good) characterized by independency (from other modules) and substitutability (with other modules). Design for Upgradability uses modularity to conceive products that are thought to be remanufactured and upgraded.

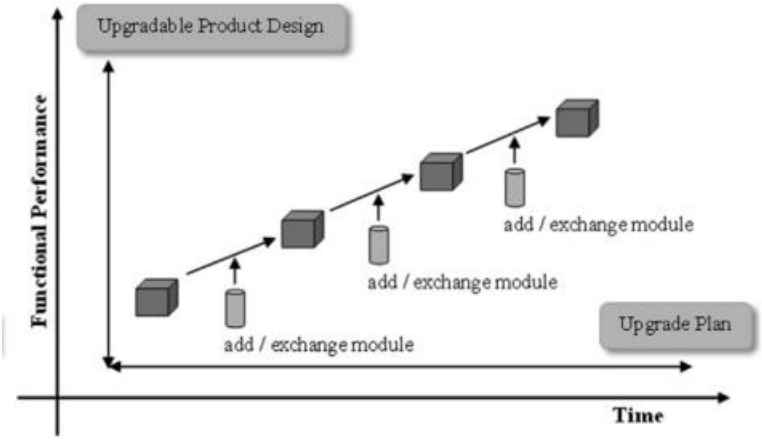


Fig. 35 Design for upgradability concept (Aziz et al. 2016)

Practically speaking, this means designs them to be easily cleaned, disassembled, repaired (through the substitution of broken modules) and upgraded (through new modules). By repair, substitution or addition of modules is possible to produce and commerce new versions of product that have the same quality of classic manufactured products, but saving materials and resources.

3.3.6.1 *Modular design*

The term *Modularity* means a design method that use modules to create different variants of products. It's a concept that exists in industries since 1965 when *Star* proposed the use of modular products in production as a new concept to develop variety(Jose and Tollenaere 2005).

The variants are created thank to the different possible combinations of modules. Of course, combinations are not infinite, but there are some constraints due to the technical and intrinsic characteristic of modules (modules' interfaces). The number of products that

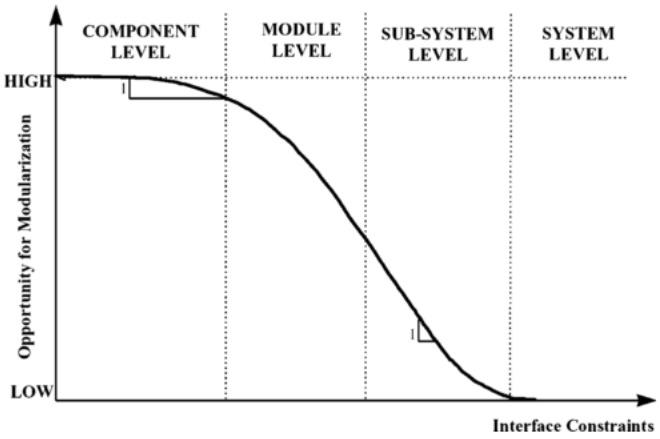


Fig. 36- Modularity and Interfaces constraints relation at design level (Jose and Tollenaere 2005)

can be developed depends on the number of module versions and variants and their physical coupling characteristics (interfaces) which allow the possibility of combining them (Jose and Tollenaere 2005). Interfaces limits the degree of combination of different modules: more the structure of a piece is articulated (because is already built with other sub modules or because has specific technical characteristics) more is difficult to apply modularization. This is why usually modularization exists at the single pieces' level (components) or simple modules (simple combination of components). After that the interfaces become too structured to allow modularization.

A set of modules that are used to create different variants of products is known as *platform*. A platform comprehends the basic components needed at the first stages of production of a products' family. These products, at the beginning, share the same components and technological process, then, they are differentiated in the final stages by adding customised modules (outside the platform) for each specific version. A platform gives the possibility to use common manufacture process, technology, knowledge which are shared by multiple products in a family. The decision of which modules and assets are going to be unique or standard between products needs a complex costs analysis. This because standardization of modules bring efficiency but allows a low variety of production, on the other hand too many customised modules add complexity to the process and increase production costs. Each industry has to identify the optimal combination between standardisation and specific modules. The Modularity Cost Matrix show the cost - diversity trade-off between standard and customized modules.

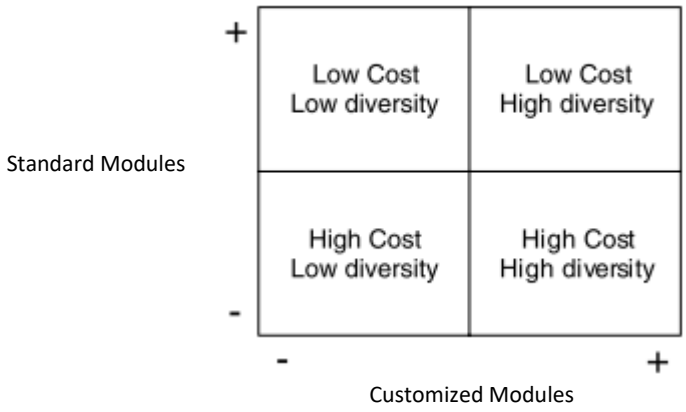


Fig. 37 - Modularity Cost Matrix (Jose and Tollenaere 2005)

When the product is complete we can talk about *Product Architecture*. Product architecture is the scheme where the physical components are associated to functional elements to form different products. In fact, there are two dimensions of architecture: the

functional one, which is the group of operations and transformations that contributes to the general functionality of the product, and the physical one, which refers to the group of physical components and assemblies that enables a function. The architecture could be considered as a configuration between components of the product and the tasks that each component should do(Jose and Tollenaere 2005).

A better and easier adaptation of the product portfolio to the market segments is derived by using product architecture principles based on modularity. It is possible to identify three principal competitive advantages in the use of a modular architecture into a product portfolio structure or manufacturing system; the first, variation of capability, that means the possibility to have different performances for the same function; the second, functional variety, that means different functionalities for the same system or product; and the third, operational robustness and other life cycle requirements, in the sense that all the operations related to the product can be done more easily (Mesa et al. 2015)

Jose and Tollenaere 2005 identified these are the main advantages using a modularity design:

- Increased number of product variants
- Economies of scale in component commonality
- Costs savings in inventory and logistics
- Lower life cycle costs through easy maintenance
- Shorter product life cycle through incremental improvements such as upgrade, add-on and adaptations
- Flexibility in component reuse
- Outsourcing d System reliability due to high production volume and experience curve
- Faster assembly and less production time
- Postponement of operations of differentiation for fast reaction of the market.
- Parallel manufacture of modules
- Fast development of products

And described generically the process the designers should adopt to conceive a modular architecture:

Fig. 38- Modularity design process

3.3.6.2 *Modularity and its effects on industry*

Modularity arises from the division of a product into independent components. This independence increases the use of standardized components and allows designers to more easily create a wide variety of products using a much smaller set of components. The physical and functional interfaces between the components are the same. The result is that any combination of components can be assembled into the different versions of the same product, or even a different product, with minor modifications(Gershenson and Prasad 1997).

But it has to be taken into account that modularity affects industry at different level. It is a big change and require a reorganization of operations and a shift in firms' culture too. First of all, as was mentioned above, it affects the architecture and the way to conceive products, but also technically there would be some modifications. Bills of materials will become narrower and deeper, since the producer would buy a smaller number of components of greater complexity. Deepening the bill of materials has the potential to

reduce the complexity of assembly operations, but increases the problems related to manufacturing management, especially when products need to be adapted to suit customer needs. Modular products will also reshape manufacturing facilities. With products being assembled by a limited number of rather complex modules, assembly lines will probably assume a fishbone structure. This line will be fed by rather long assembly lines producing each of the modules. And so there would be need of a structural change too, that result in a big investment for the firm. Moreover, if we think that creating different modules, that incorporate different functionalities and technologies, for the same products will require a certain level of coordination between the suppliers of that modules and the final assembler, it follows that the development and manufacturing of modules will not be carried out by an individual organizational entity. Such operations will generally be performed by temporary associations of suppliers acting as a consortium or as *Virtual Enterprise*[9]. In the end, modular products will affect product development too, as there would be need of a strong communication, involvement of customers and reliable prediction of product and technological trends. The managing of innovation would become fundamental (Cantamessa and Rafele 2002). Modularity also influence the strategic level. The flexibility that this structural change brings to the system will be useful in the management and commercialization of upgradable products and become a good enabler for the implementation of a Product-service-system.

3.3.6.3 *Upgradability design process*

As is mentioned at the beginning upgradability is a process that starts since the very first steps of product conceiving. In this paragraph the process designers must follow to design a good upgradable product is outlined. Always taking into account the upgradability strategy, what change is the perspective they must use to think products. In order to design a good upgradable product, the view that must be adopted is the functional view. An optimal base is the FBS model (*Function-Behaviour-Structure* model), that conceptualizes design objects in three ontological categories: function (F), behaviour (B), and structure (S). Functions are meant as the purpose of a product, Behaviour as the attributes associable to the function and Structure as present components and their relationship. Functions are univocally connected to Behaviours and Behaviours are univocally connected to Structure. Using this view makes easier to think at products as a composition of functions that would be more easily transformed in physical modules. So usually this is the starting point of a good design process for this purpose.

Dividing a product into functions is only the first step, then there is the necessity to classify the different functions, and so modules, making them independent from each other (the base of modularity) and insensitive, which means that a change in functions do not require a structural change (Umeda et al. 2005). After that step the literature divided itself into a numerous of different mathematical algorithms to identify the optimal modular structure according to different variables (economical and environmental) and always taking into account the upgrade plan (and so forecasted variables), for a deepening see (Olivier Pialot, Millet, and Tchertchian 2012)(Aziz et al. 2016)(Shimomura, Umeda, and Tomiyama 1999)(Smith and Yen 2010)(Kristianto and Helo 2015) (Xing et al. 2007)(Yi Li, Deyi Xue, and Peihua Gu 2008)(Cantamessa and Rafele 2002).

[9] A **virtual enterprise** (VE) is an alliance of businesses that come together to share skills or core competencies and resources in order to better respond to business opportunities, and whose cooperation is supported by computer networks

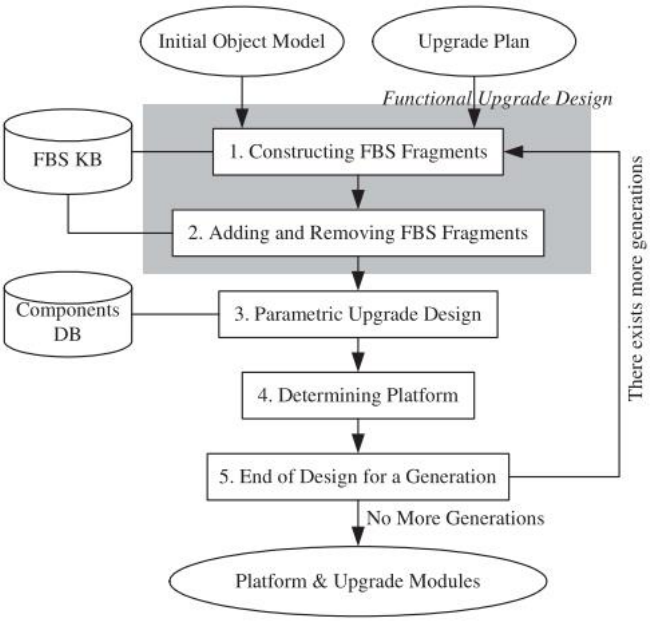


Fig. 39 Upgradability design process (Umeda et al. 2005)
FBS= Function Behaviour State model
DB = Database

3.3.6.4 *Uncertainty design strategy*

Without entering in the detail of the single algorithms that can be used to support the technical phases of design process, what is important, more strategically speaking, is the adoption of different strategies to maintain the design flexible and adaptable to market trends and changes. As is mentioned above, the design process has as input the upgrade plan that bring with it self a certain level of

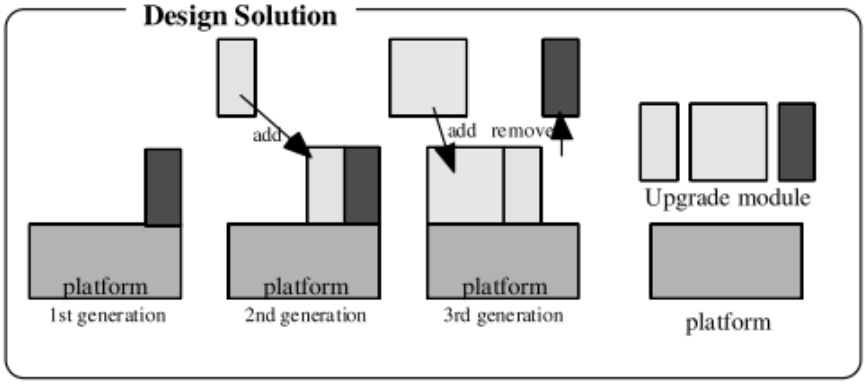


Fig. 40- The framework of design of upgradability – Platform approach (Umeda et al. 2005)

uncertainty. (Umeda et al. 2005) suggests two approaches: in order to manage the uncertainties tight to functional upgrade designers should fix a platform made of components that with a high level of plausibility would be required by the markets and, on the other hand, prepare modules of components with a lower level of plausibility. So components that perform upgrading functions with high plausibility should be integrated into the platform as much as possible, to ease upgrading operation. On the other hand, components for functions with low plausibility should be isolated from the platform as upgrade modules, in order to avoid the risk that those functions are not required in subsequent generations. Then in order to manage parametric upgrades the author suggests to identify a range of possible requires performances and prepare modules to cover this range and add them at the right moment (Delayed selection of component).

3.3.7 Sustainable product service system

3.3.7.1 *Business model*

A *business model* is a framework that describes how a firm creates value. The value creation is reached through the definition of a strategy, a value proposition and a coherent operations' design. The value is meant as value for customers or social and environmental value according to the different business taken into consideration.

A BM usually are described graphically with some frameworks that tend to underline the different aspects of the business and the dynamic of creation of value. The idea is try to summarize all the business in a scheme, in order to make it simple, visible, immediate understandable and so improvable. There are different kinds of BM frameworks, each one more focused on one aspect than others. But they generally include:

- The strategy definition – This is the starting point of each business model, it's impossible to build a business without the guidance of a clear strategy
- The value proposition – The value the firm want to provide to customers that will buy its product
- The value network description - The description of the network that the firm need and use to make business, usually here there is the description of stakeholders, resources (inputs) and operations
- The customer interface – this section represents the receivers of the value and include the description of how to reach them, the segment target and which is the reason why customers choose the firms products
- The economic model - as the base of all the description of cost model and revenue model of the firm.

A good business model framework not limited itself to the description of these aspects apart, but enlighten the connection among them in order to visualize how they influence the creation of value. A good BM framework is not static but dynamic. Another important characteristic is simplicity, a BM framework must be intuitive and easy to understand at a first sight. Then it must be complete and coherent with the strategy and value proposition set at the beginning.

3.3.7.2 *PSS classification*

Generally, is shared the idea that a suitable business model for the production and commercialisation of upgraded goods is the Product Service System. PSS is a service based business model thought to sell services and not products, where costumers pay to use a good, instead of own it.

This intrinsic characteristic of services[10] make them develop and structure differently from the traditional system. Firstly, they can be considered open system: selling of services means maintain closer relations with business stakeholders. Indeed, usually PSSs are based on strong collaboration with supplier and customers and on partnerships with other firms, in order to be able to provide different services (like monitoring, maintenance, delivery and so on) and to create an efficient information flow. Information is fundamental in this case because firms need to stay close to the market to adapt their product-service provision. Secondly, due to its dematerialization principles PSS is an excellent vehicle to enhance competitiveness and foster sustainability simultaneously, this is why they are spreading recently in the economic scenario (Ren G. 2007).

There are three level of degrees of PSS that are *Product oriented* (i.e. the addiction of services to the simple selling of a product), *service oriented* (i.e. the sale of the use and not of ownership), *result oriented* (i.e. the sale of an output without any use or ownership).

[10] High Degree of customer contact, Uniformity of input, Labor intensiveness of jobs, Variance of output, Measurement of productivity, Coincidence of production and delivery, Quality assurance, Low Amount of inventory, Evaluation of intangible work, Ability to patent design lower (Introduction to Operations Management McGraw-Hill/Irwin Copyright © 2012 by The McGraw-Hill Companies)

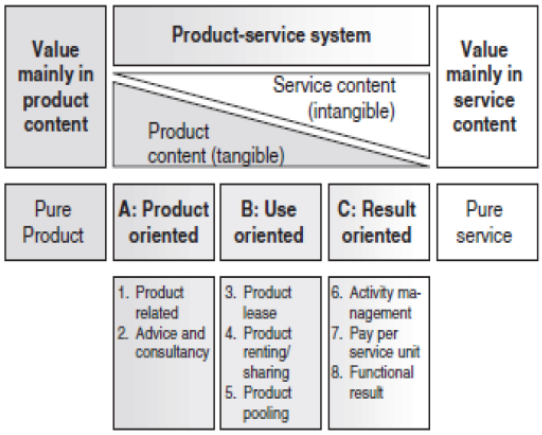


Fig. 41 – Categories of PSS (Tukker 2015)

A variant of this system is the *Sustainable Product Service System (SPSS)*, which (Vezzoli, Kohtala, and Srinivasan 2014) define as *products and services that are together able to fulfil a particular customer demand based on innovative interactions between the stakeholders of the value production system, where the economic and competitive interest of the providers continuously seeks environmentally and socio-ethically beneficial new solutions.* In other words, compared to a traditional product sales offer, in an SPSS approach it is in the economic and competitive interest of the producer to foster continuous innovation in reducing the environmental impacts and improving social equity and cohesion. What change, from the traditional one, is the explicit intentionality to create a positive impact.

In the next paragraphs the focus would be on the latter, because, in the application of upgrading remanufacturing, the intentionality to achieve a good impact it is an important value added.

3.3.7.3 *Advantages*

The first advantage related to the application of SPSS is cost savings for manufacturers that results from the incentive to resource savings and the extension of product and materials life. In fact, as the ownership remain to the producer, first of all the total production result lower than in traditional selling business, then., during the use phase, the producer has an economic interest to reduce the amount of resources consumed, because profit is dependent on the cost per unit of service provided to the customer. While at the end of the end of product's life it will be incentive to find new way to extract new value from its components and materials through the application of reuse, remanufacturing and recycling in order to postpone the disposal and landfill costs.

On the other hand, also on the customer side there is a gain in term of costs, since they are not supposed to pay for the ownership, maintenance and disposal but only for the use of it, there is not a necessary "initial investment" to access the product. Besides, it exists a social gain too, as PSS broaden access to useful goods. Furthermore, PSSs are able to provide customers high quality and customised product/service with a consequent improve of satisfaction.

Then, as SPSS offers are more focused on the context of use, they create relationships with the end user. This means greater involvement of local stakeholders that have a good knowledge about local market and structures, thus fostering and facilitating a potential reinforcement and prosperity of the local economy(Vezzoli et al. 2015).

3.3.7.4 *Limitations*

There are some disadvantages and barriers to take into consideration when talking about PSS. First of all, PSS need specific structure and new processes like reverse logistic and maintenance deliveries that need to be design well or they would result expensive and not environmental sustainable.

Besides, companies require new competences, skills and experiences, in relation to both management and design activities. This means there is the need to: structure the organisation in a way to be competent in designing, making, and delivering PSS offers. For these reasons company personnel need to be trained and additional personnel may be needed. In general, this kind of system are more difficult to manage than the traditional one. Usually change in culture of firm before its application is needed. And a change in culture is not trivial.

Then, PSS business models require medium to long-term investments compared to the short-term profits generated by traditional selling system. Consequently, SPSSs are connected with uncertainties about cash flows, which may cause producers to perceive SPSS businesses as riskier than product-based ones. In addition, Small and Medium-sized Enterprises (SMEs) are often unable to finance these kinds of business models, given their usually limited financial resources.

From the customer sides it exists a lack of knowledge and understanding about the SPSS concept. This generates uncertainties related to unclear risks, costs and responsibilities and can lead customers to underestimate the benefits of an SPSS offer. Besides, the strong relations between producers and customers, that comprehend the access to customers' utilities and some personal information about their habit, necessary for the monitoring of the use of the product, can be perceived as an invasion and become a privacy issue. Usually, this strongly depend on the culture existing where SPSS are applied. For instance SPSSs have been more readily accepted in communal societies like Scandinavia, the Netherlands and Switzerland than in many other countries (Vezzoli et al. 2015).

3.3.7.5 *Design for SPSS*

The *servitization* trend foster the creation of Business Model that are sustainable due to service nature that push to a more responsible consume and production. But the introduction of product - service in business alone is not sufficient alone to achieve a change. Industries and customers create barriers in response to the big change needed in business strategy and culture consumption for the application of SPSS. Therefore, there is the necessity to support the change process through other smaller and practical changes starting from the new product-service design. Changing visible characteristic and usage techniques can help accepting more intangible changes (De los Ríos and Charnley 2015).

So the design process of product - services must be integrated in the process of modelling of the system, always taking into consideration the impact in term of sustainability. There are different frameworks in literature for the design of SPSS and according to the specific context one can result better than others. In general, these frameworks have in common these three main steps:

(1) PSS requirements identification and analysis
(2) PSS Modularization
(3) PSS configuration and Monitoring

The first step consists in the context analysis in terms of economic condition and actors involved (stakeholders) and of product and services' requirements. (2) It follows the step of Modularization, that is specific for PSS, in which all the related PSS components are identified. Modified service blueprint is used to identify all the related PSS components and their interdependences including service processes, service objects and service resources. At the end components are clustered into PSS modules. (3) In the last step the system is built choosing among modules the ones that are going to compose the system and others that remain optional for possible future inclusion taking into account sustainability and market trends.

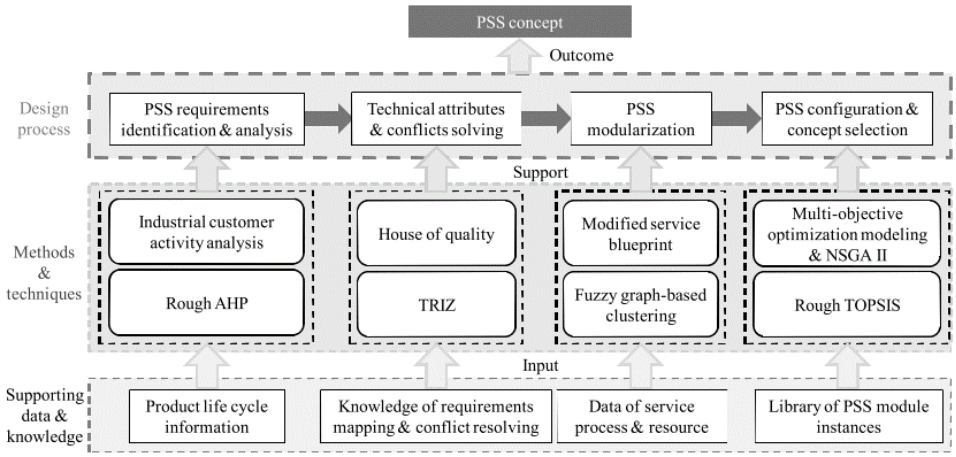


Fig. 42 A design framework for sustainable Product/Service System(Song and Sakao 2017)

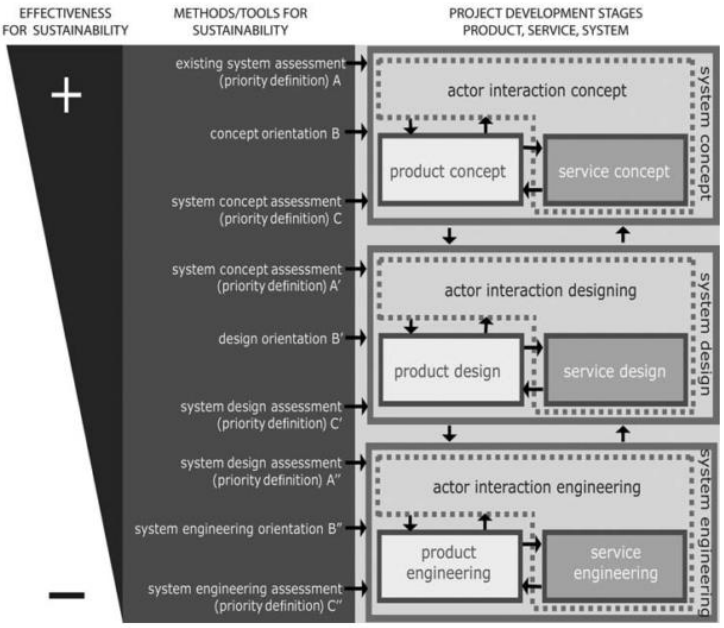


Fig. 43 General action plan for the designing process of a product- service system, where sustainability-orienting tools can be integrated into the various stages of the design process (Vezzoli, Kohtala, and Srinivasan 2014)

To support the process some tools and practices may be required. The creation of a database that can support designers during the design of modular products for service system showing al the interdependences between products components and service requirements would be effective (Nemoto, Akasaka, and Shimomura 2015); the creation and maintenance of strong stakeholders' relationships would result fundamental in this kind of context. Besides the implementation of a Monitoring system that constantly show the results or report some problems would help a continuous improvement.

The main change from traditional design process is services and business are designed with the same concept of modularity that is applied when physical products are designed. This would help designers and managers, administrators and other workers to be aligned under the same *way of thinking,* making culture and work practices more homogeneous and coherent, and it results in a better application of SPSS.

3.3.7.6 *Why is the best choice for upgrading remanufacturing?*

Selling Upgraded Products would require upgrading and maintenance services along their life cycle, the use of a service oriented system seems a suitable option to manage the offer (O. Pialot and Millet 2014). Then, a modularity structure promotes interchangeability and gives designers more flexibility that is becoming increasingly important as uncertainty in service requirements, due to new diagnostic and repair technology and ever changing warranty agreements, increase. This flexibility allows some design decisions to be delayed because they have a lower impact on the total product. A flexible product can more readily adapt to a late influx of service technology or a late change in service strategy (Gershenson and Prasad 1997). Modularity and services fit good together. But the most important benefits of service can be seen looking at customer side: selling only the use of a product make customers more responsible, as paying for what they use push them to a more efficient and careful usage of the resource, that can result in a better quality of cores (Chierici and Copani 2016) and foster sustainability. It also makes companies closer to their customers and products, as the provision of a service need monitoring and quick intervention in case of problems, establishing a performant information flow. So, the proximity to the market guarantee companies to be always updated about customers' behaviour and market trends, helping in future forecasting. Besides, the retaining of product ownership, make them easier the delivery of maintenance, the recollection and remanufacturing, knowing exactly the position and the story of the product (Sundin and Bras 2005).

But, even if the almost totality of articles agree about it, the business model is not discussed deeply but only generic hints are given to provide an idea of the changes and principles to implement it.

3.3.8 Key success factors

Literature provides fragmented but complete view about what is remanufacturing and what it implies for firms. There are some topics that are treated often in papers and researches that can help listing the first main critical factors to take into consideration and to evaluate when talking about upgrading.

First, all literature agrees that the most suitable business model for providing upgrading services is the Product Service System. Upgrading is a service that requires proximity to the market, long lasting relations with consumers and easy core recollection. The use of a model that is based, indeed, on services facilitates all these three characteristics thank to the continuous contact with the users and, in some case, with the retention of the ownership of the physical product. In the papers related to upgrading many references were found about the design of products as well. A modular design is an enabler of remanufacturing as well and become more important when talking about upgrading because it provides flexibility to changes to the product, it helps managing the uncertainty linked to the forecasting of possible upgrades, and, above all, makes the product easily disassembled, repaired and updated thanks to the easy access to the different products parts. The importance of planning emerged too. Knowing which kind of upgrades and when the market asks for them, and so being able to forecast the different life cycles of the products, help in the implementation of upgrading services making them more effective and efficient. Many algorithms were design for specific firms or products to help them manage multiple life cycles products.

Some critical points were discussed as well. The relation with customers is not always positive, there is still lack of awareness from their side and a linear consumption culture that is difficult to overcome. But, theoretically, upgrading is a good solution for their needs. More analysis is needed to understand the role of customers in upgrading remanufacturing. Subsequently emerged core management represents an issue for remanufacturer. There are many core collection strategies but any of which emerged as the winning one. The core withdrawal is still characterized by high uncertainty in terms of volume, time and quality.

What is missing are some real examples of how companies can manage all these new variables and process to provide upgrading services and which are the main reasons that pushed them to include this service in the remanufacturing offer. Which kind of

upgrades are more required and in which sector this technique is more spread. Besides, some factors still have to be deepen and confirmed.

3.3.9 Conclusions

What emerged from literature are some first preliminary ideas of what is important to consider and what implies for companies the introduction of products remanufacturing and upgrading processes. The use of Product Service System business model and Design for Remanufacturing techniques as well as the importance of Planning of the upgrading interventions were discussed as pillars for a successful implementation of the upgrading management. On the other hand, Core management and Customers relation resulted two main big issues for remanufacturers. Moreover, no real market studies focused on companies that offer upgrades were found in literature and so there is still lack of a favourable or typical context description in which upgrading is part of the remanufacturing offer. The kinds of upgrades required, the type of products, the market and the benefits sought by potential consumers were treated superficially or not treated at all by literature.

In the next sections of the research other different analysis based on real case studies would be presented. The focus would remain on the variables that emerged from literature and on finding some common context characteristics that could have push companies to introduce upgrades.

4. REAL CASE STUDIES FRAMEWORK

In this section are shown the results of the research described in 2.2. Real case studies in the world of companies that perform upgrading remanufacturing were collected and classified under a common framework in order to identify some common characteristics and derive proper conclusions.

4.1 Results

4.1.1 Framework

Table 8 - Upgrading Remanufacturing industries mapping

FIRM ***COUNTRY (YEAR)***	**SECTOR** ***PRODUCT***	**B2B/B2C**	**CUSTOMER TARGET**	**OER/CR/IR**	**CORE STRATEGY**	**KIND OF UPGRADE**	**DFREM**	**PSS**	**CIRCULARITY**	**UPGRADING**
NEXTANT **USA (2007)**	**Aerospace** *Jet*	B2C	Private users	OER	Voluntary	M+E			X	
FAIRPHONE ***NED (2013)***	**EEE** *Smartphone*	B2B+C	End consumers	OER	Voluntary	H+S	X	X	X	
INREGO ***SWE (1995)***	**EEE** *IT devices*	B2B+C	Private firms, municipalities, private costumers	IR	Buy-Back	M+S		X	X	X
RE-TEK ***UK (1996)***	**EEE** *IT devices*	B2C	Low income people/charity organization	IR	Buy-Back	S			X	
PHILIPS-LIGHT ***NED (1891)***	**EEE** *Lighting System*	B2B	Companies (private or public)	OER	Service-contract	H	X	X	X	X
KYOCERA ***JPN (1959)***	**EEE** *Printers*	B2B	Firms	OER	Service-contract	M	X	X		
NEOPOST ***FRA (1924)***	**EEE** *Mailing equipment*	B2B	SME	OER	Ownership	E	X	X		
XEROX ***USA (1960)***	**EEE** *Photocopiers*	B2B	Public and private offices	OER	Ownership	M	X	X		
MARTELA ***FIN (1945)***	**Furniture** *Furniture*	B2B	Workplace, schools, welfare environment	OER	Credit	M	X	X		
AGCO POWER ***FIN (1990)***	**Machinery** *Agriculture eq.*	B2B	Farmers	OER	Deposit	M+E	X	X		
CATERPILLAR INC ***USA (1965)***	**Machinery** *Construction eq.*	B2B	Constructor	OER	Deposit	M	X	X	X	
SIEMENS ***USA (1960)***	**Machinery** *Gas turbine*	B2B	Manufacturers	OER	Service-contract	M	X	X	X	
STÅTHÖGA MA ***SWE (1988)***	**Machinery** *Pumps*	B2B	Manufacturers	CR	Direct-Order	M		X	X	
STOREBRO ***SWE (1991)***	**Machinery** *Milling eq.*	B2B	Manufacturers	CR	Direct-Order	E		X		
PERKINS ENGINE ***UK (1932)***	**Machinery** *Engines*	B2B	Manufacturers	IR	Buy-back	E		X		

BLACKHILL ***UK (1950)***	**Machinery** *Quarrying eq.*	B2B	Extraction companies	OER	Service-contract	M	X	X		
WEALDSTONE ***UK (1965)***	**Machinery** *Car engines*	B2B	Cars manufacturer	CR+OER	Service-contract	M	X	X	?	?
PHILIPS HELATHCARE ***NED (1981)***	**Medical equipment** *Healthcare eq.*	B2B	Hospitals	OER	Ownership	M	X	X	X	
TOSHIBA MEDICAL ***JPN (1950)***	**Medical equipment** *Image eq.*	B2B	Hospital	OER	Buy-Back	S				
ROETZ BIKES ***NED (2014)***	**Transports** *Bikes*	B2B+C	Rental company (NS -Dutch Railways) and final users	CR	Service-contract	M+E	X	X	X	

4.1.2 Location

Most case studies came from the north of Europe (Fig. 44). Probably this is due to a cultural matter. Northern countries often show more interest in sustainability issues and have a longer history in applying and developing circular economy among industries. That allows them to optimize their operations, building solid networks and so improve the traditional remanufacturing process, like introducing upgrading services (Parker et al. 2015). In addition, also the data sources used influenced this result. The databases used were from Europe and USA, and so of course it was more likely to find case studies coming from these areas. In the end, as the research were developed during a stay in Sweden, the research context had some influence too. For example the database ERN is one which Swedish academics contribute to build bringing local examples.

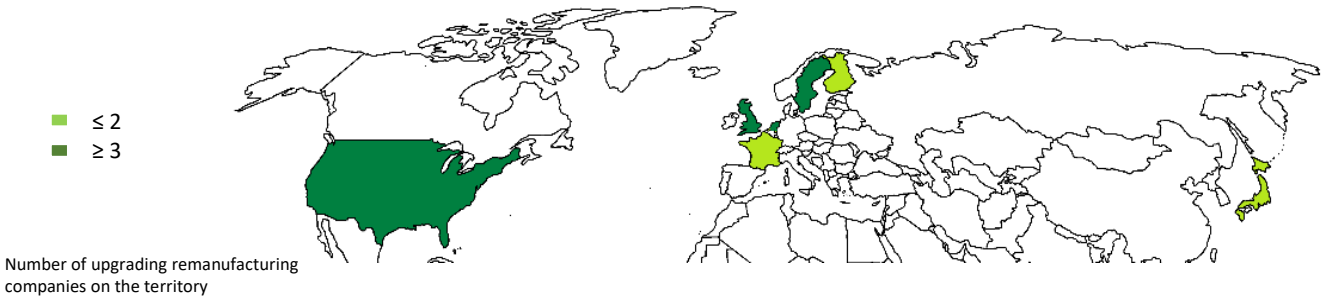


Fig. 44- Countries where case companies performing upgrade remanufacturing are located

4.1.3 Sector

The sector division was done following the classification of the ERN project that identify nine sectors, in which remanufacturing is usually performed, aggregating different kinds of products (Table 9).

Table 9 - Sectors division and related products considered during the case study mapping

SECTOR	PRODUCTS
AEROSPACE	Civil and Militar Aircraft, Aero Engines, Helicopters, unmanned aerial vehicles and their associated systems, parts and equipment
AUTOMOTIVE	Motorised road vehicles, motorbikes and vans
EEE	information and communication technologies (ICT), consumer electronics, Office Imaging Equipment, White Goods, Cartridges
FURNITURE	Furniture for personal and Business use
HDOR (HEAVY-DUTY AND OFF-ROAD)	Cranes and hoists, forklift, trucks, lifts and escalators, mining, quarrying, forestry and agricultural vehicles and equipment
MACHINERY	machinery processing, machine tools, pumps and compressors, engines and turbines
MARINE	Transports by sea and related equipment
MEDICAL EQUIPMENT	Anaesthesia, Endoscopy/laparoscopy, Hearing aids & audiometry Hospital capital fixed plant Hospital supplies & disposables Implantable devices, In-vitro diagnostics & kits, Infusion & inhalation therapies Invasive surgery, Prosthetics and artificial joints Ultrasound
RAIL	Raction units (providing motive power to pull passenger and freight trains), passenger carriages, self- propelled passenger vehicles, freight wagons and infrastructure maintenance vehicles

The sector in which upgrading remanufacturing is more applied is the machinery one (See Fig. 45). This sector has a high potentiality for the application of the process, because of its dimension and the kind of customers. The reasons why machineries seem the most suitable for the application of upgrading remanufacturing are clarified and deepen by the next results. The EEE sector see a good number of application as well. But, this result is influenced by the definition of EEE sector given by the ERN project that includes in

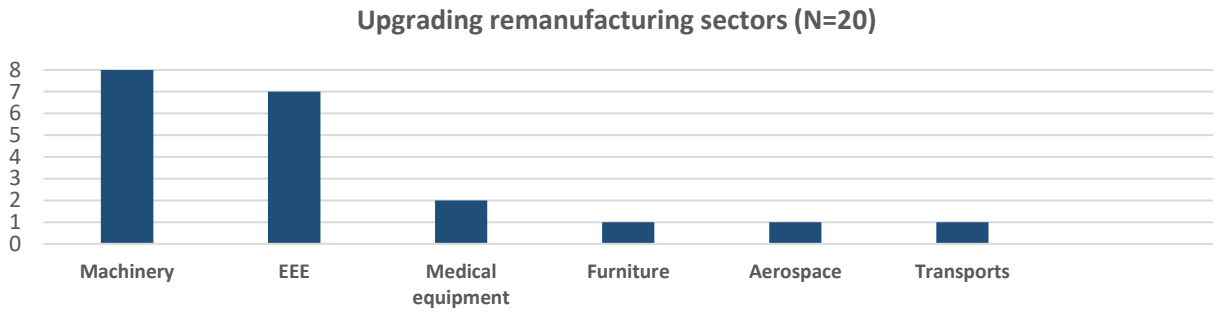


Fig. 45- Graph that describes in which sectors case companies operate

the EEE a high variety of products (from the IT to Office Equipment). Disaggregating the EEE in smaller subsectors we see that 3 out of 8 are IT devices (Laptop and Smartphones), 3 out of 8 are technological equipment used especially in the offices (copiers and printers) and 1 regard the lightening. These three subsectors have different market and business dynamics and so the aggregated result cannot be valued as the one of the machinery that is, on the other hand, more homogenous and internally coherent.

Even if machinery is the one in which is easier to find upgrading activities, it is not the biggest sectors in which remanufacturing is applied. According to a remanufacturing market study within the ERN project by (Parker et al. 2015), the biggest sectors are Aerospace and Automotive. However, during the case study research none of these sectors show any application of upgrading activities.

Table 10-Summary of market size of remanufacturing activities by sector (Parker et al. 2015)

Sectors	Turnover (€bn)	Firms	Employm't ('000)	Core ('000)	Intensity
Aerospace	12.4	1,000	71	5,160	11.5%
Automotive	7.4	2,363	43	27,286	1.1%
EEE	3.1	2,502	28	87,925	1.1%
Furniture	0.3	147	4	2,173	0.4%
HDOR	4.1	581	31	7,390	2.9%
Machinery	1.0	513	6	1,010	0.7%
Marine	0.1	7	1	83	0.3%
Medical equipment	1.0	60	7	1,005	2.8%
Rail	0.3	30	3	374	1.1%
Total	29.8	7,204	192	132,405	1.9%

The possible reasons of the misalignment were discussed during a group meeting and, thanks to the experience of the members, some hypothesis were suggested. The conclusions were in the automotive sectors upgrades are difficult because they concern very small parts or, they are so simple, that are performed by mechanical intervention or reparation that are not even notify to customers. Consequently, there is no trace or sufficient material to study them. There is lack of official data to analyse. Regarding the aerospace sector the reasons are different. Aerospace can be considered a sector apart, with very different rules than the others because of the high investment in time and capital and because of the high risk of failure that can also bring to human losses. For these reasons,

there are very strict specifications about the nature of material and the production process, thus make difficult the use of recycled cores or recycling process. Besides the very long life of these products often make useless the idea of remanufacturing and recycling.

4.1.4 Products

Looking at the list of products remanufactured and upgraded by firms, the analysis aim at discovering possible groups to identify some common characteristics that, clearly, make them more suitable for upgrading. Products belonged to different sectors but industries, that produce them, seem to have something in common. For example, even with a very preliminary analysis it was possible to state they operate especially in the Business to Business market. Then, they seem to deal with mechanical products with a medium high complexity that need maintenance activities (in the most of case studies companies confirm they provide maintenance services). A first indication was they were all big heavy machines. In order to verify the two hypotheses a map of the products was drawn using these two variables: on the horizontal axis, there are the two possible markets: on the left the business to consumers market and on the right the business to business one; on the vertical axis, on the upper side there are the light products (i.e. small no particularly complex products) while in the lower side the heavy ones (i.e. big and complex products). In the graphs are positioned some tags of the most common sectors[11] in which remanufacturing is performed to better orientate the reader and make the framework clearer. If in these sectors some products were interested by upgrading activities the image of the product was inserted (see Fig. 46)

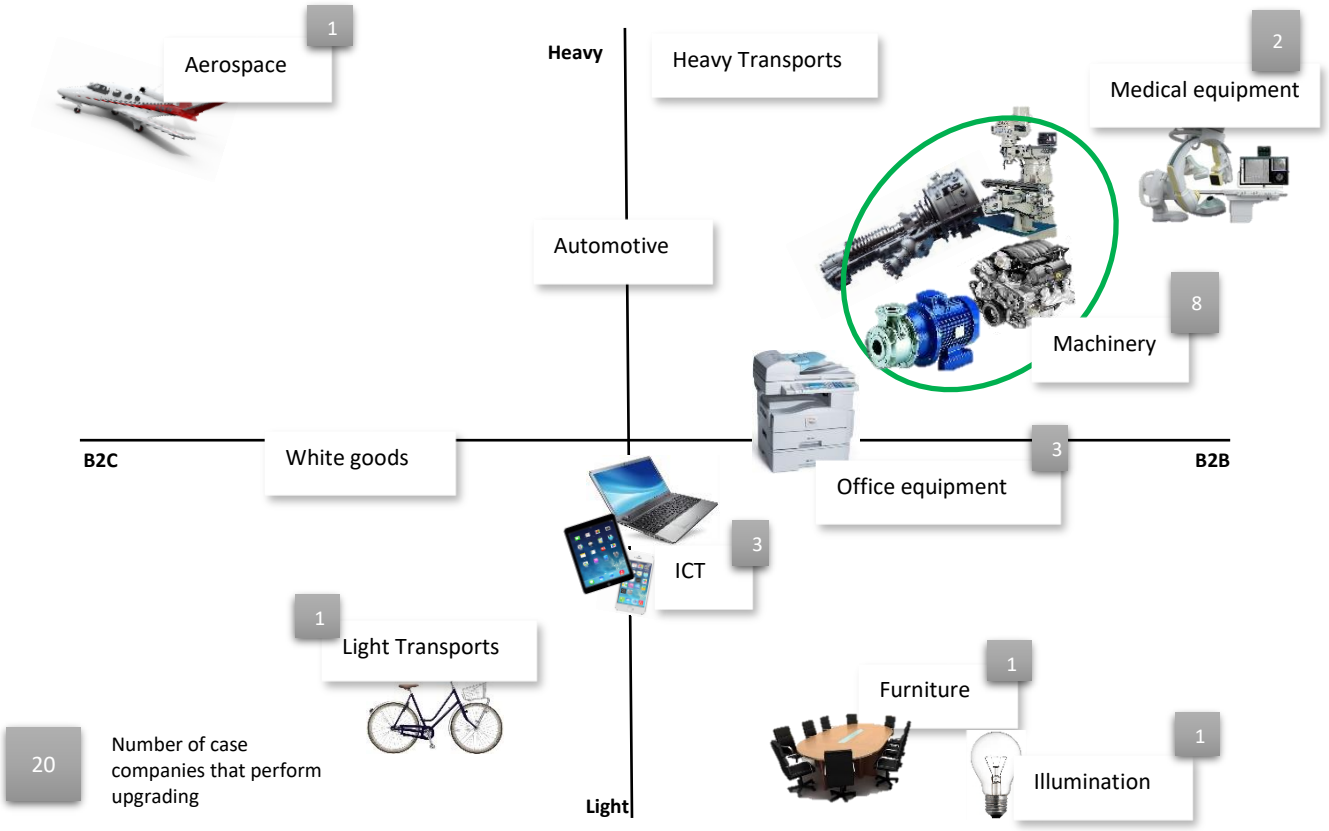


Fig. 46- Map of remanufactured and upgraded products that appear in the case studies

[11] The sectors used are taken from the ERN project Market study (Table 9) but the EEE sectors were disaggregated to provide a more specific view of the kind of products and the transport sector was added as the Market study did not include these types of products.

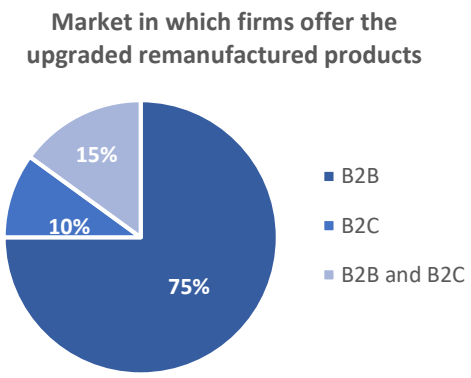
Positioning the products in the diagram it was possible to identify a cluster in the up-right side of it (B2B and heavy products). The cluster is largely composed of machines for industrial production. It is so possible to deduct that products that are remanufactured and upgraded pertain to the set of *Machineries.* Machineries, that are defined by the European commission as *an assembly of components, at least one of which moves, joined together for a specific application. The drive system of machinery is powered by energy*[12].

The common characteristics, that make them suitable for upgrading, are they are highly componentized products and so easy to disassembled to reach critic parts and, therefore, easy to upgrade through the substitution of components. Modularization work well with these kinds of product too. Besides, is easy to create standardized modules platforms because of their mechanical nature and the fact their design do not change radically in the last years (Parker et al. 2015). Standardization of platforms help in the remanufacturing and upgrading process and in the cores recollection, making the flow of return more stable in terms of quality and quantity. In the end, they are all products with medium-long life cycle. This help in the planning and forecasting of possible upgrading and make worth the upgrading intervention because they can extend the value life of a relevant period (*see* Fig. 47)

Machineries	Highly componetized products
	Possible Platform Standardization: stable design
	Long value life cycles
	High initial investment (price)

Fig. 47 - Reasons why Machineries are suitable products for Upgrading Manufacturing

4.1.5 Market (B2B/B2C)



The **75%** of cases confirm the most used market is the Business to Business market. The possible reasons why are because it is easier to establish relationship between industries than between an industry and more final users: the relation between industries is regulated by contracts or partnerships and this make more structured and so controllable the process of recollection, remanufacturing and new delivery. Besides, the cores return is more predictable and stable since the needs of firms are driven by objective and rational reasons while the final consumers can change their behaviour because of more emotional and so unpredictable factors (see Fig. 48)

[12] http://ec.europa.eu/growth/sectors/mechanical-engineering/machinery_it

B2B	Regulated relations (e.g. contracts)
	Flow cores return more predictable
	Rational and more constant in time needs
	Longer products life

Fig. 48 - Reasons why B2B is a suitable market for upgrading remanufacturing

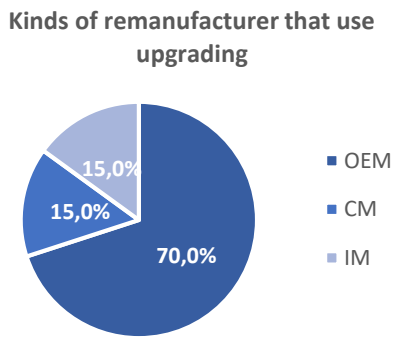
4.1.6 Customer target

In the almost totality of case studies it was clarified that the main advantage in buying remanufactured and upgraded products was cost saving. The remanufacturing process can produce products with the same quality, performance and reliability of the new ones but saving costs and resources. Moreover, with the introduction of upgrading the value life is further extended. Another important factor is the product availability. Indeed the target consumers of remanufacturers are usually big companies that work with heavy machineries and that want to save money in the maintenance and repair/substitution of shop floor machines but that cannot afford too long production stop, so the maintenance and substitution services must be performed quickly (see Fig. 49)

Target	Heavy machineries users
	Cost saving
	High quality and performance
	Product life extension
	Quick intervention

Fig. 49 - Needs and preferences of users of remanufactured and upgraded products

4.1.7 Kind of remanufacturer

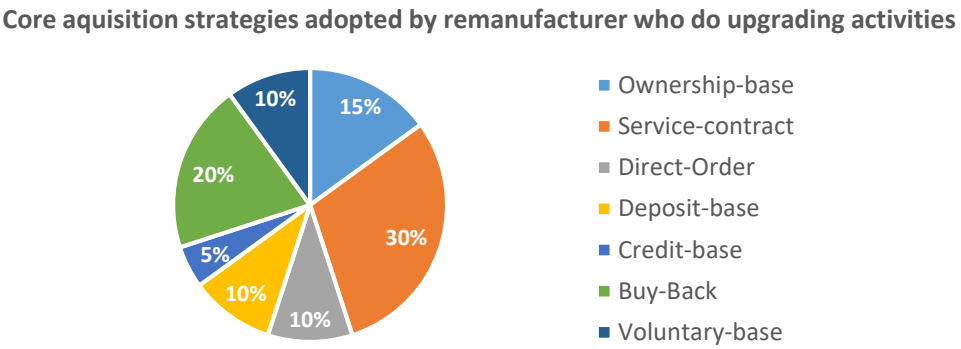


The actors that use more upgrading in the remanufacturing process are the Original Equipment Manufacturer. Due to their experience in their sector they have a great knowledge of the market and its dynamics, its trends, and its customers. Besides they already built, through years, solid networks and a strong reputation that make them trustworthy and efficient. The high knowledge they have of their products make them able to manage and change the design and production process easier than other remanufacturers. Besides, the close relation they can establish with their customers, together with all the other factor, facilitate the application of cores return strategies (see Fig. 50).

OEM	Experience of the market
	Products know-how
	Solid Network
	Close relation with customers

Fig. 50 - Reasons why OEM have better possibilities in the application of Upgrading Remanufacturing

4.1.8Core acquisition strategy



According to the case studies the most two adopted return strategies are the Service-contract, buy back and ownership-based. But in general, the distribution of strategies is quite homogenous and there is not one that beat the others. Probably they depend more on specific reasons like the single product, market or remanufacturer business structure too.

As OEM are the ones that apply upgrading remanufacturing the most their strategies were studied apart: OEM have the tendency to use more the service-contract ones and the ownership-based. And this is in line with this kind of actor that can easily maintain the ownership and the control of the good they produce in the first place or set formal contracts to manage the selling (Fig. 51).

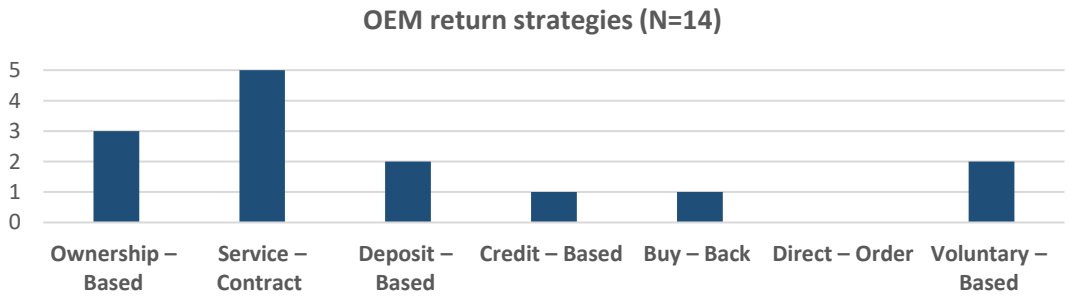


Fig. 51 - Graph that describes the most adopted return strategies adopted by Original Equipment Manufacturer of the case studies

4.1.9 Kind of Upgrade

Three main kinds of upgrades performed by firms could be identified: the mechanical or hardware upgrade, the electronic upgrade and the software upgrade.

- **Mechanical or Hardware Upgrade**: consists in the substitution or addition of a physical part (a module) to the system. It is a *radical* upgrade because it changes the physical design of the product. It could add new functionalities. It also increases the product potentiality to be upgraded electronically or at software level. Indeed, the new hardware would be able to sustain new and more upgrades. Due to its complexity, it is expensive and time consuming. E.g. Change Graphic card in a phone (*Fairphone*), change the engine of a machine (Caterpillar), change the processor of a computer (*Re-Tek*).
- **Electronic Upgrade:** consists in the change of the electrical parts of a product. It increases the product electric capacity and performance. Products can load more energy or make the same performance but consuming less energy. This upgrade open the way for new possible software upgrading. It is less complex and time consuming of Hardware upgrading but still more demanding than the software ones. E.g. change of circuits in a machinery *(Storebro industrier AB*) or the electrical equipment of an engine (Perkins engine).
- **Software Upgrade:** consists in updating the software versions installed on a product**.** It adds new small functionalities, improve the performance of the existing ones and correct possible old software errors. It is easy, cheap and usually quick. E.g. update the operative system of a phone or of a computer (*Fairphone* and *Re-tek*), update the software that a machinery use to work (*Toshiba* and *Inrego*).

What companies usually do is launch new product and then release several software upgrading options over time. This is the faster and cheaper way to remain competitive and up to date in the market. But software upgrading cannot be run endlessly. They are limited by the electronical capacity of the product. At a certain point, it would not be more possible upgrading the software, because the system could not support these upgrades anymore. Further upgrading of that kind would affect the performance and the functionalities of the product, making them decrease instead of increase. If the hypothetical firm want to continue the upgrading process, it would have to move to an electronic one. Only in this way it would be possible to improve the capacity of the product and make it capable to support a new software. But electronic upgrades have a constraint too, that is the hardware. It is not possible to make an infinite number of electronic upgrades because the physical system would not allow it beyond a certain level. A change in hardware would be needed to support them and continue the upgrading process. Of course, this is not a mandatory path to follow. There are firms that perform directly mechanical upgrades or others that stop at the software or electrical ones. The decisions about how and what to upgrade, depends on other variables like the firm strategy, costs, availability of cores, market needs or possible technical constraints. If we want to represent this situation using an analytic language the result would be approximately like the one represented in Fig. 52.

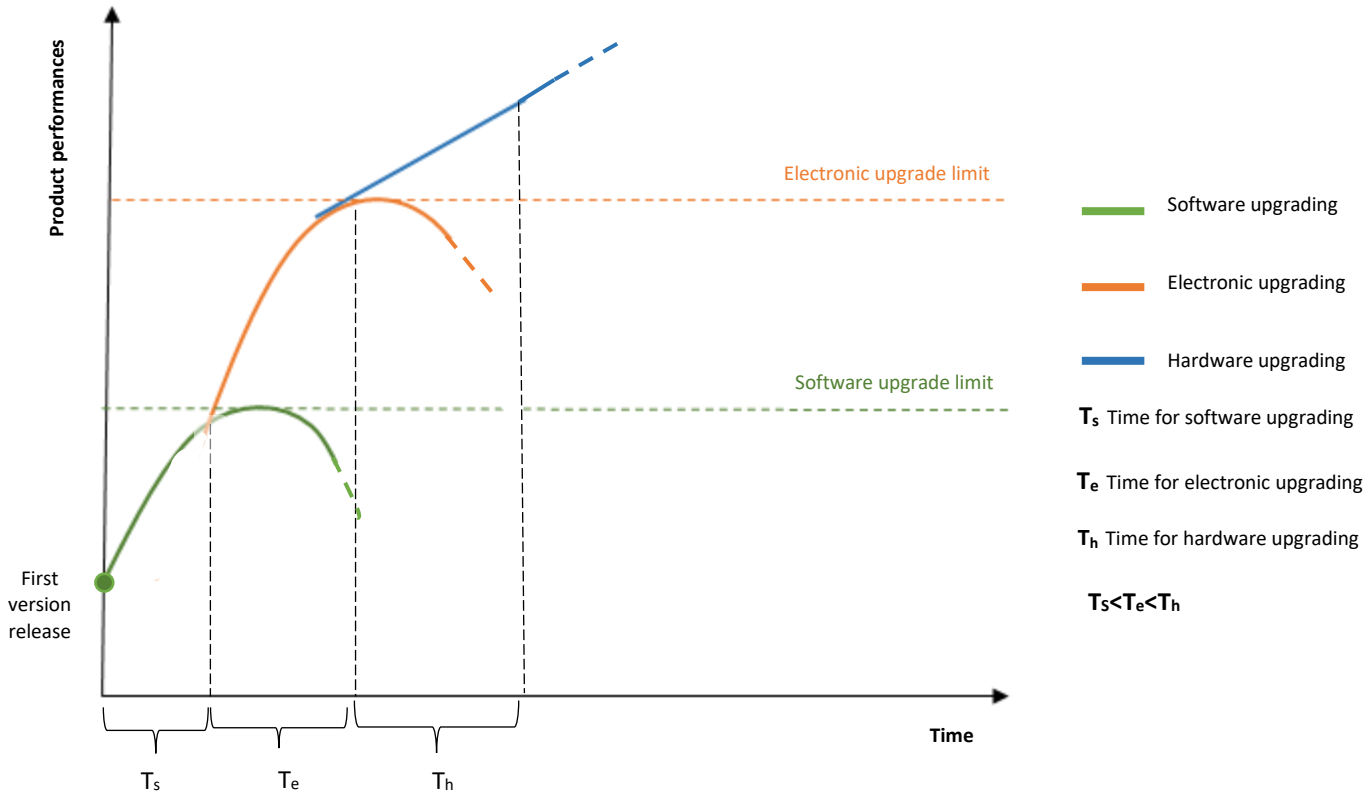


Fig. 52- Pattern of different kinds of upgrades applicable to a product

4.1.10 Design for remanufacturing

13 out of 20 companies use modular design for remanufacturing techniques, confirming that a successful upgrading process starts since the design phase. Design technique like design for remanufacturing or modularity can help in the subsequent steps needed for a good application of remanufacturing. Indeed, they make the process of disassembly and repairing easier and faster and so more cost efficient. It is possible to broad the upgrading options creating more flexible and customized offers providing different functionalities and configuration using the same modules platform. The main advantages of modular design are treated in the literature part.

4.1.11 PSS

17 out of 20 companies add some services to their offer or they maintain the property of the product. And so, they apply, at different level, a Product Service System. Services are indeed considered good enabler for upgrading activities because of how they intrinsic nature. This idea is shared and agreed among academics and companies too. Services indeed allow company to have more product control and give them the possibility to establish long lasting relations with their customers. Two characteristics that become fundamental when dealing with long term offer like upgrading remanufacturing. For a deepening see the upgrading literature.

4.1.12 Value proposition

The meaning of the latter variable need further explanations. The decision to study the value proposition of the companies is related the fact that sometimes companies prefer not to promote their remanufacturing activities because they are afraid to influence negatively the perceived quality of their customers, that often associate remanufactured products to second-hand ones and so to lower quality and performances. As the Product Manager of Caterpillar (one of the company studied) share:

"People think it means washed, painted, repaired, second hand and so on. It's a challenge to convince and educate the consumer that they're getting the same performance at 50-60% of the cost of new" – Matt Bulley (EAME Product Manager of Caterpillar)

Usually companies that have this belief tend to talk about upgrading remanufacturing only in some hidden parts of their reports or have website managed apart from the main one (one example is Toshiba). So, a company that, on the other hand, talk about remanufacturing and circular economy in its principal page or, better, insert this word in its value proposition sentences demonstrate to have the maturity to understand the competitive advantage of the application of remanufacturing. This is an important cultural characteristic that can promote the change to an always greater use of circular economy and give more chances to the business to spread and so influence customers' opinion. The purpose of the *Value Proposition* variable was to verify if among the companies that perform upgrading remanufacturing this attitude was present.

The result is that half of companies included the concept of remanufacturing and/circular economy in their value proposition or in their main values.

About considering upgrading as an important value to offer to customers, almost the totality of firms (17 out of 20**)** does not mention it in their value proposition or mission. Is evident that firms consider upgrading only a surplus activity and not part of their core offer. Upgrading is not a concept that marketing use to sell its product, it is not a fashion or a trend as can be considered recycling, sustainability and circularity. Firms do not have any incentives to insert it in their value proposition.

4.2 Results discussion

A discussion of the main results is conducted focusing specifically on the upgrading decisions and activities. The data that were collected from companies' cases are now classified in function of the three kinds of upgrades identified*:* software upgrading, electrical upgrading and mechanical upgrading. This classification allow to read the data in the light of the physical interventions and changes a product is subjected to. Since some companies run different kind of upgrades the single upgrading interventions were counted: there are five software upgrading, seven electrical upgrading and fifteen mechanical upgrading interventions run by 20 companies. The aim was identifying some reasons for the different upgrading decisions and patterns. The single column would be commented and deepen in the next sections.

Table 11 - Classification of the context/firm's characteristics that appear more often for the different kind of upgrades in order to target the existence of some majority that could have played the role of influencer in the upgrading decision

UPGRADING **(N= UPGRADING INTERVENTIONS PRESENT AMONG THE COMPANIES STUDIED)**	**MARKET**	**PRODUCTS AND SECTORS**	**COMPANY IDENTITY**	**PSS**
SOFTWARE (N=5)	3/5 B2C	3/5 EEE	No relevant majority	3/5
ELECTRONIC (N=7)	6 /7 B2B	4/7 Machinery	No relevant majority	5/7
MECHANICAL (N=15)	11/15 B2B	No relevant majority	No relevant majority	10/15

4.2.1 Upgrading

The first result that emerged is that often **companies use combined upgrading strategies** and so they offer a mix of the three kind of upgrading interventions, as can be seen looking at the total number of companies and the total number of upgrading interventions (20 companies running 27 upgrading interventions). Therefore, some companies use to provide a mix offer of upgrading to their customers. This is due to different possible reasons: the most evident one are the technological constraints that the different kind of upgrades have and that are described by the upgrading function in Fig. 52. Sometimes to be able to provide a complete service more kind of upgrades are necessary. Usually the combined strategies are, indeed, mechanical plus electronic (AGCO Power, Nextant Aerospace, Roetz Bike, Ståthöga MA Teknik AB) but also mechanical plus software in case of necessary reparation (Inrego and Fairphone). The decision on how much the extend of upgrade is extendable depend on the market needs, the product design (if it was designed to be remanufactured and upgraded), the company know how and the technology available to provide this kind of interventions. Therefore, are more linked to the single cases and it is difficult to derive some common rule and law.

4.2.2 Market

As it was already commented the market served is most B2B market. **In two kinds of upgrading activities the largest market served is the Business to Business one, while for the B2C, if upgrading exists, it exists at software level**. Software upgrades are quick, cheap and easily spreading among final consumers than the mechanical and electrical ones that require more structured and complex processes. **The same approaches and strategies used in B2B market are not valid for the B2C ones**. The high products change rate in B2C make difficult for remanufacturers to establish steady relationship and provide upgrading services. In this market, tastes develop and change quickly. The demand for customized product is higher and variable due to personal preferences and temporary fashions. Besides, the prices of technology devices drop in the last ten years due to the commoditization of technology phenomenon. The quick spread and the high competitiveness bring to a price war that start the commoditization in the B2C technology market. This make for customers easier to replace a technological product than repair it. A clear example is the market of white goods, that even if it has the right dimension and potentiality for the application of remanufacturing with upgrading, see a very seldom application of remanufacturing (Parker et al. 2015).

But even if remanufacturing of short-life products is still difficult, some successful examples exists: *Inrego* and *Fairphone* for example can manage remanufacturing and upgrading in a B2C market in the EEE sector. They common characteristic: are online selling, a system based on voluntary or buy back return strategy and a strong presence on social network and internet (especially for Fairphone that make a massive use of online marketing). They try to reach the maximum number of customers and cores possible and then adjust the price of selling and buying to balance demand and supply. Besides, they leverage on an easy withdraw/delivery system that are well explained in their websites and that do not put many responsibilities or extra costs on users. There are also some initial attempts in white sector (one of the biggest B2C market). *Gorenje's goRENT project* for the selling of use of household appliances and *Miele&Boundle* for washing machines are two examples of pilot projects that want to try to sell customers only the use of household appliances. They leverage on offering medium price products but assuring a significant longer life of appliances and constant performances. By monitoring the usage of the products, they are able to intervene quickly in maintenance, reparation and substitution. The projects are still new and so there were no reliable data or evidence of their effectiveness. The consuming culture, the higher prices and some privacy issues could represent big obstacles for them. But they are good examples of the intentionality of some company to change the way end users approach to this kind of products.

These first attempts are due also to a new trend that is sustainability that influence consumers' behaviour too. Now final consumers tend to have more attention and give more importance to companies' culture and products sustainability. The value added that is given to new "green products" can help in overcoming some possible obstacles that still make difficult the selling of remanufactured products in the B2C market. Besides the institution of different strategy based on this new trend can help fastening this process.

Fig. 53 – Examples of companies that sell upgradable products in the B2C Market

What emerge from these examples is this system would not work if the users do not decide on a voluntary base to return their products or allow firms to control their consuming behaviour. Until the culture of no waste would not be present in the large users' markets and more specific laws and facilities to recycle old equipment would be implemented, B2C would remain more challengeable than the B2B market.

Then, considering also the results sections, it is now possible to give a complete description of the target segment that is more attracted by upgrading services (Table 12).

Table 12 - Target segment in the B2B market for upgraded products

	VARIABLES	**DESCRIPTION**
CUSTOMER CHARACTERISTIC	*Socio-demographic*	Big-medium manufacturing companies
	Geographic	Local markets are usually served (north of Europe, USA, Japan) according to the remanufacturer location
CUSTOMER BEHAVIOUR	*Product usage*	Usage in their own production processes
	Buying process	Direct contact; long lasting contracts; services like maintenance, withdraw and deliver are included
CUSTOMER NEED	*Benefits sought*	Cost saving for equal quality

Upgrading is a service that is provided only to those companies that want to maintain and need always the best performances from their products. They look for cost savings of course but they required high quality too. Therefore, usually the market in which upgrades activities are provided are developed first markets. While for the traditional remanufacturing is quite common to sell to secondary ones. Besides the necessity to provide quick and customized services make necessary the proximity between providers and customers.

4.2.3 Products and Sectors

The kinds of upgrades are influenced by the kind of products. The software upgrades are more likely to be performed in the EEE sectors probably due to the nature of the products present in this sector. IT products are easily upgraded through the release of new software versions and the upgrading process result cheap and quick. Besides for these kinds of products the software are often subjected to updating and correction and so there is often need to upgrade them. Regarding the electrical upgrade there is a majority for the machinery sector but this is probably since machineries are the most upgraded products in the sample studied. While, concerning the mechanical ones, it is the upgrade intervention that is run the most and it is seem to be provided in all sectors. Probably because, as shown in Fig. 52, in order to upgrade a product is necessary to provide some hardware change in order to be able to provide some electronic and software ones and so in order to upgrade a product software or energy capacity they need to combined them with some change or substitution of parts at mechanical level.

Even if the single upgrading interventions are well distributed among the different products, practical results showed a relevant preference for the machinery sector for the application of upgrading strategy. So why upgrading is only partially or not present in other sectors than machinery? The reason is that, probably, there is no, or no enough, demand for this kind of service for other products. Customers still do not require it or are not aware of this possibility. The reasons why this happens could be more and different. Companies that are dealing with machineries have a high interest in enlarging their product life as the investment required to buy new ones could be very high (so product life play an important role). In other sectors, the investments are not so high and even if a remanufactured and upgraded products could represent a cheaper option there is no urgency to ask for it. The efforts to change the traditional way of practice result higher than the potential cost savings. Another reason could be they are not aware of this possibility, and so in that case are companies that should apply pressure on them but this means investing in communication and engagement and probably the perceived risk is too high from the companies' side to take the initiative.

4.2.4 Company identity

This variable was introduced due to the presence of very different companies that were doing upgrading (some are consolidated companies other are very new ones). It would had been interesting to see specifically if the different company stories, experience and identity had an influence on the different kinds of upgrades decision.

The companies were divided in three sets according to their *year of foundation*, to the *size* of the company and to their *brand value* (how much they are known by customers but also people). Three main kinds of company were identified: very young company that were founded specifically with the purpose to market remanufactured and upgraded products (Type A); medium sized old company (20-30 years) that use it as a complementary activity but serve local market and which brand is only partially known (Type B); and then big multinational company with strong presences on the market (Type C).

Table 13- Classification of the different kind of case companies according to Year of foundation, Size and Brand value

CRITERIA	KIND	COMPANIES	
• **YEAR** • **SIZE** • **BRAND VALUE**	**A**	Fairphone, Roetz Bike, Nextant Aerospace	3
	B	Inrego, Re-tek, Storebro AB, BlackHill, Ståthöga MA Teknik AB, AGCO Power, Wealdstone engineer	7
	C	Phiips (x2), Caterpillar, Perkins, Xerox, Toshiba,Siemens, Martela, Kyocera, Neopost	10

But as shown in Table 11 there is no evidence that the identity of company influence the decision on which kind of upgrade perform. The results showed that it is unlikely they had strong influences on the single upgrading decisions.

But what is evident in Table 13 , on the other hand, is that the third set is bigger than the other two. Considering that the actors that are more likely to apply upgrading remanufacturing are the Original Equipment Remanufacturer (saw the result about *Kind of remanufacturer*). We can affirm that no, **company identity** does not seem to influence the decision on the single upgrading intervention (that depends more on kind of sector, product or market) but, of course, **have an influence in the decision of introducing upgrading in the first place**: big multinational company with strong market and product experience are more likely to perform upgrading activities.

4.2.5 PSS

In the most totality of upgrading cases companies adopt a Product Service System. This adoption seems independent from the kind of upgrade as it appears in all three solutions, but it is a constant in firms that provide this kind of service. Services, as was already

underlined in the literature, are good enabler for upgrading. They allow firms to maintain product and so core control, high process and product knowledge and enhance customer loyalty.

4.3 Common difficulties to overcome

Beyond the achievements that these firms share there are also some common difficulties and constraints they still have to overcome:

- **Core management**: core acquisition remains an issue. Since it is not a common practice it needs to be improved. For example, there are still few studies about the sustainability of reverse logistic or winning reverse supply chain strategy.
- **Perception from the market**: there is still a low awareness about remanufacturing in general. It is well known in the Nordic countries but others geographical markets never heard about it or, if they do, they have the tendency to associate it to "recycling" and "second use". Besides, as there is still ambiguity about remanufacturing there is no attention for upgrading. Market still not seem to ask for it.
- **Uncertainty about processing time**: The process is still affected by high uncertainty because of the fluctuations of cores quality and availability, and because of the introduction of always new different products in the market.

4.4 Favourable Scenario for the application of Upgrading Remanufacturing

After the results analysis and discussion now it is possible to describe the best scenario in which all the conditions that favoured the application of upgrading are satisfied. Firms that share these or part of these characteristics are optimal candidate for the introduction of upgrading in their remanufacturing processes. Since upgrading remanufacturing is an extension of the traditional remanufacturing it is likely that these conclusions can be applied to it too. But it has to be taken into account that this analysis was focus exclusively on firms that include upgrading activities, and so the conclusions are specific for that purpose, even if, for sure, they represent good conditions for remanufacturing too.

4.4.1 Company identity

The macro socio-demographic characteristics these firms share are they are big solid enterprise known by the market and with already built infrastructures and facilities. Most of them are leaders in their sectors and serve large and loyal market. Usually these markets are Business to Business Market because the relation with customers is more regulated and stable. The majority are Original Equipment Manufacturer with an intensive and deep knowledge of their products, that, in most of cases, belong to the set of machineries. As always, experience and knowledge play an important role in upgrading and remanufacturing. In the end, they already have experience in Design for Remanufacturing techniques and they usually add some services to their offers.

4.4.2 Context and market conditions

From this profile, we can then identify some main practical framework conditions that is necessary to have and/or create in case a firm want to adopt upgrading remanufacturing: product control (especially during the design and the use phases) help in the production process and cores recollection; the product life market by the firm should be medium-long in order to make the intervention worth; Customers' loyalty became fundamental, the return of cores is always an issue, a big loyal segment could represent a stable cores source.

4.4.3 Operational variables

Once those conditions exist there are some key operations that firms should learn to apply in their business. What emerged from literature and was confirmed by this analysis, is that there are three main variables to take into consideration and manage well in the application of upgrading remanufacturing: Process Costs, Process Time and Product Quality. They have a great influence on processes, services and upgrading decisions and the final users seek for lower costs, high quality and quick services. The firms that succeed in the application of upgrading remanufacturing act on these variables and can manage them good:

- **Minimize upgrading and intervention costs**: maintaining the cost of intervention low is fundamental to deliver a product-service sustainable and worth from an economic point of view. Create efficient process of recollection and production, leveraging on products standardisation and taking right decisions about time and content of upgrading, are some activities that should be thought and planned well. The use of algorithms, partnerships and R&D became important and firms should invest time and resources in them.

- **Minimize upgrading and intervention process time**: process time and customers waiting time are important too. To maintain a high level of services firms should try to short the time for maintenance, remanufacturing and upgrading. In some cases, for example, maintenance and some related services are performed directly at the client plant. In others, firms already have as stocks some remanufactured and upgraded products and deliver them directly to their customers and then take their time to process the returned cores.

- **Improve product control and quality**: make reliable prediction and manage cores return have always been an issue also for traditional remanufacturing and it became more important with the introduction of upgrading. What firms do, usually, is maintaining a close relation with their customers, provide services and not only products, sometimes selling only the use but maintaining the ownership and leverage on technology introducing digital tracking to maintain better control of cores quality and return.

Company socio-demographic characteristics, the achievement of certain context and market conditions in which they operate and the good management of some relevant operational variables create a hypothetical scenario where upgrading remanufacturing has good potentiality to be applied successfully (Fig. 54)

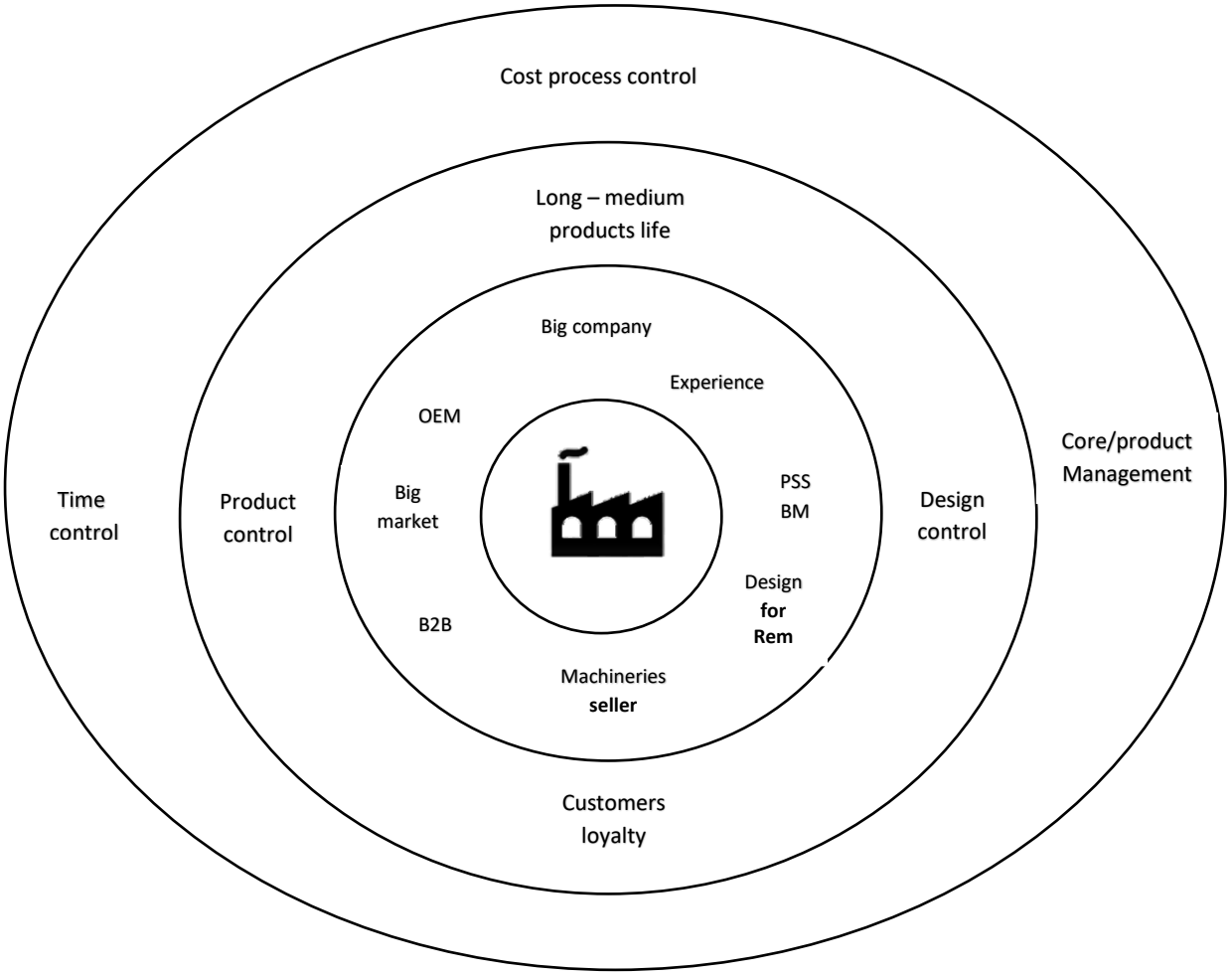


Fig. 54 - Scenario that encourages the application of Upgrading Remanufacturing

4.5 Research answers

Thanks to the brief analysis we are able to give more precise answers to the research questions number two and three.

4.5.1 Kinds of upgrade, Type of products and Market

There are three main kinds of upgrades: mechanical, electrical and software upgrades. Each kind of upgrades can improve existing functionalities or add new ones. Often companies used upgrading combined strategies and so one product can be subjected to more than one kind of upgrade.

The market in which upgrades are offered the most is the B2B one. While the B2C still presents some limitations for upgrading introduction. The B2C allows only software upgrading that are the cheaper and easier kind of upgrade. This is due to the intrinsic differences between the customers of B2C and B2B market. Therefore, the practices that make upgrading works in the business to business are difficult to replicate with final consumers. New strategies should be designed and business to consumers' market still need to become more mature to accept this kind of change.

The sector that present the highest number of upgrading intervention is the machinery one. All the three kind of upgrading activities are present in very different products. But the results about the most upgraded product category shown Fig. 46 indicated the machineries as the most upgraded ones, while the others are still a great minority. This is due to the intrinsic characteristic of

machinery products that make easier the application of upgrading strategy. However, some successful examples of upgrading are present for other products or sectors even if they are not so spread. Probably there are more complicated reasons that go beyond the simple technical characteristics of the products. The data hide some deepen reasons and open new research questions. What we can hypothesis is that if a service that has no big evident constraint to be provided is not, it is because the market still not ask for it. So, it is a problem of lack of demand that do not make companies think about its introduction.

4.5.2 Key Success Factors

The company identity does not influence the kind of upgrading provided but influence the decision of introducing upgrading in the first place. The experience, the availability of intellectual and financial capital and the deep knowledge of the product and the market push company to improve their offers and find new market opportunity. Therefore, big multinational company with strong market and product experience are more likely to perform upgrading activities.
The use of Product Service System as the best model to manage the remanufacturing with upgrades offer is confirmed, seen the higher percentage of adoption among the case companies. Upgrading is sold as a service using combined upgrading offers. The importance of adopting Design for Remanufacturing was confirmed too; most companies confirm the importance of having easily disassembled products for their easy repairing and upgrading. Highly componentized products like machineries result to be the best option. Then, the result that show how the actor that most applies upgrading are OEM and the result discussion about the company identity that indicate that usually big companies are more luckily to provide upgrading services, indicate that Knowledge about the product technologies and developed competences in the sector, market and process influence the decision of introducing upgrading. Another important result regards the management of some critical operational variables: quick intervention and product delivery are essential and high valued by customers, so a good manage of process time result successful; then the main reasons why customers are attracted by upgraded products are because of the lower prices for the same product quality, so access to quality core and the ability to be efficient in the reconditioning process are another two key success factors for upgrading remanufacturing.

The role of customers remains ambiguous. The benefits were clarified but its active role in asking for upgraded products still need more deepen research. The lack of awareness and the consumption culture still limit their role in this phenomenon.

On the other hand, Core Management still result the most critical part to manage and very demanding conditions, like big loyal market, existing logistic structures and fast core evaluation are required to maintain it effective. But no specific strategy emerged from the analysis.

4.6 Conclusions

At this point some reflections and comparison with the main results found in literature con be conducted. In literature, the most spread classification of upgrading was based on the change (improvement or addition) of products' functionalities: parametric upgrades (improvement of an existing function), functional upgrades (addition of a new function) or semantic upgrades (addition of auxiliary services); while during the case studies the classification that emerged was focus more on how a change or addition is achieved, and therefore we saw mechanical, electronical or software changes or update. The different classification can be easily correlated as upgrades interventions found in the case studies classification, would in some way have as result a change in functionalities as described in literature classification. Therefore, they can coexist. However, we preferred to use the one directly derived from real case studies because it is more in line with the thesis objective and focus.

The concept of Product service and the Design for Remanufacturing that emerged from literature were confirmed as the most od case companies study adopt them. On the other hand, the role of customers remain ambiguous and Core Management was confirmed to be a big issue to manage for remanufacturers.

In the end, some more qualitative reflections about the possible changes and future development of upgrading remanufacturing are discussed:

The offer of remanufactured products is still almost completely based on cost saving. The focus is on price because is a winning strategy to use to attract customers that have to choose between two similar alternatives: buy a new product or remanufacture and upgrade the old one. But there are other strong points to leverage on for remanufacturing and upgrading. The potentiality to establish a long-lasting relation with quick and customised services, or the good effect on the image for recycling and reducing environmental impact. Enlarge the reasons and the value added of remanufactured products respect to the traditional ones can help to spread the culture of circular economy and improve the market perception about remanufacturing and upgrading. While focusing only on the cheap price can mine the quality perception of users, as is already happening in some cases.

Companies should not underestimate the upgrading concept. To spread the new technique, is important to add it in the remanufacturing offer. It could also help in improving the distort perception of “second hand” or “used product” that some companies or customers still have. By underlining that there is the possibility to produce new versions of products, the concept of remanufacturing could change from simple “recycle” to what it is: a technique that allow to produce highly performant product saving money and resources.

5. INREGO: A REAL BUSINESS MODEL CASE STUDY ANALYSIS

5.1 Company presentation

History[13]. INREGO is a Swedish IT reconditioning company that recollect, repair and resell old computers, smartphones and tablet. It was founded in Lund by two university students, Henrik Nilsson and Rickard Hannerell, that wanted to offer more affordable computers to other students of the university. The company is nowadays one of the biggest in the sector of IT reconditioning.
The company started with a small shop located in Lund, where the twenty-five years old students used to work. The demand for used and cheap computer was incredibly high and soon they opened another shop in Uppsala in 1998. Since then the company have always been able to follow and adapt to market changes. Varying the offer, customers and services provided. They started acquiring and selling from traffic schools, regular schools, municipalities and always more companies. The demand for second-hand IT products was always greater than the supply, and therefore INREGO begins buying equipment from other countries. Over time they built a large network of hundreds of suppliers and retailers in Europe and the US. This makes it easier to both buy and sell products at the right price. In parallel, services are developed to help organisations to reuse their old IT equipment in a safe, sustainable and cost effective manner.
The company is now headquartered in Stockholm where all handling and logistics are managed. It collects core from 30 countries and resell them to local and international market. The last turnover register (2016) was of 27 million Euro.

Current Values. The company believes and applies the circular economy principle fostering the sustainable production and consumption behaviour, thus *Sustainability* can be considered one of their first value. *Adaptability* and *flexibility* to changes are fundamental. As it is stated in their official website: - The philosophy is written in stone at INREGO or as one employee puts it: *"a major part of working here is to question old truths and to come up with improvements. Nothing is sacred*."[14] -. Being *Ethical* in business governance and operations is another company pillar. Beyond the circular economy ethical value INREGO commits itself in not selling products or sending recyclable parts to those countries which disposal laws are not clear or unsustainable. In the end, *transparency* is another core value. The quality, the classification methods and the way the company operates are public and clearly stated in the official page. Besides the customers are always invited to contact directly the firm to have more information.

5.2 The process

The main macro activities INREGO conducts to transform old core in new fully functional IT devices(Fig 55), can be summarized in the following seven steps:

1. **Trading process:** The sales department contact and manage the bargaining process between INREGO and possible suppliers. Most of the time this process take place using a *proactive approach*: the company contacts directly possible candidates and offer them their services. There is a database in which are listed the most suitable suppliers. Different departments can be contacted before convincing them to give their old cores back. INREGO usually act on all department underlying the financial advantages, the sustainability and the gain in terms of product life to convince companies to accept their offers. The dealing usually take a long time to be processed. On the other hand, companies can contact INREGO using the official webpage and wait to be re-contacted back from the company to arrange the deal. But this happen less often than the proactive approach. Another option is that some other Swedish reconditioning companies contact INREGO to sell

[13,2] http://www.inrego.com/en-en/about-inrego/history

some leftover IT devices that they were not able to allocate in the market, which INREGO instead can easily process and sell thank to its wide national and international network. Excluding the latter one, suppliers can choose to give INREGO their old IT devices or substitute the old core with new ones as well. The company offers to the potential suppliers some standard packages that comprehend different kind of services:

- **Logistic services**: Core recollection and, in case of product substitution, new delivery;
- **New equipment preparing:** always in case of products substitution, IINREGO prepare the new IT devices to be delivered (new software installation, packaging, and so on)
- **Data Wiping**: INREGO use a certified software, BLANCOO, to wipe all the data stored on the IT devices. This is one of the main competitive service offered to suppliers that, in this way, can be sure that any sensitive data would be cancelled avoiding the possible spreading of sensitive information. In fact the phenomenon of stealing data from IT wasted is growing, but end users and company still underestimate this risk (Larsson 2017).
- **Financial Services**: in case the supplier could not afford to pay INREGO the total service amount immediately

According to the kind of service required by the supplier and the actual value of the core offered to INREGO a price is set as the difference between the price for the services and the value of the core.

2. **Reception process:** within this step the company register the delivered cores providing them with an individual ID number and initiates product information collection process.

3. **First sorting process:** in the sorting of cores step a visual quality control for each core is performed while certain core carrying lower value are removed directly from the main flow to the waste. Additionally, accessories are separated from the main flow too. This because usually finally consumers ask for the main product but no for the accessories related. The leftover would be sent to some recycle centres or given as gift to consumers that ask for them. Registration process of the cores are accomplished by uploading the core information on the intra-net database displaying the core availability in the inventory stock.

4. **Test and wiping process:** within these steps the company run some tests to ensure the functionalities of the core and then use the software (BLANCCO) to wipe all the data on them.

5. **Second sorting process**: Simultaneously the cores are classified into four quality categories:

A – Top quality product, fully functional with zero o insignificant cosmetic faults
B - A product that have some minor functional problems and minor cosmetic false
C – A product that have significant functional problems and substantial cosmetic faults
D – Waste

The B and C category, if it is economically worth it, are repaired. Some of the B product can be moved to the A category, but it happens in few cases. Most of them are sold in the international market (Western Europe or US). If they are too ruined and it is no more possible to resell them as functioning product, thing that happen especially for the C category, the operators disassemble the device and store some parts that could be useful for the repairing of others damaged core. The surplus parts are sent to some recycle centres for their recycling or disposition.

6. **Reconditioning process:** The A category is composed by the set of products that have a very high quality and that are worth upgrades for the selling on the Swedish market. According to the production manager there is a further distinction in this set of products. There are some items that after the upgrade can be classified as A+. This is this category that is easily sold in the Swedish market with good margins. While the A category is sold always in Sweden or, sometimes, in other international market, always gaining good margins. The kind of upgrades conducted during this phase are mostly a change in the hard drives, an upgrade of memory (mechanical upgrades) and, if required and necessary, a change in the keyboard layout to adapt to the market standards. Besides, before the selling, all products are provided with the software versions required by the costumers (software upgrade).

7. **Selling process:** Customers use the webpage to consult the category and kind of product available and then buy them online (if they are end users) or contact directly the firm to arrange the selling details (if they are public or private companies).

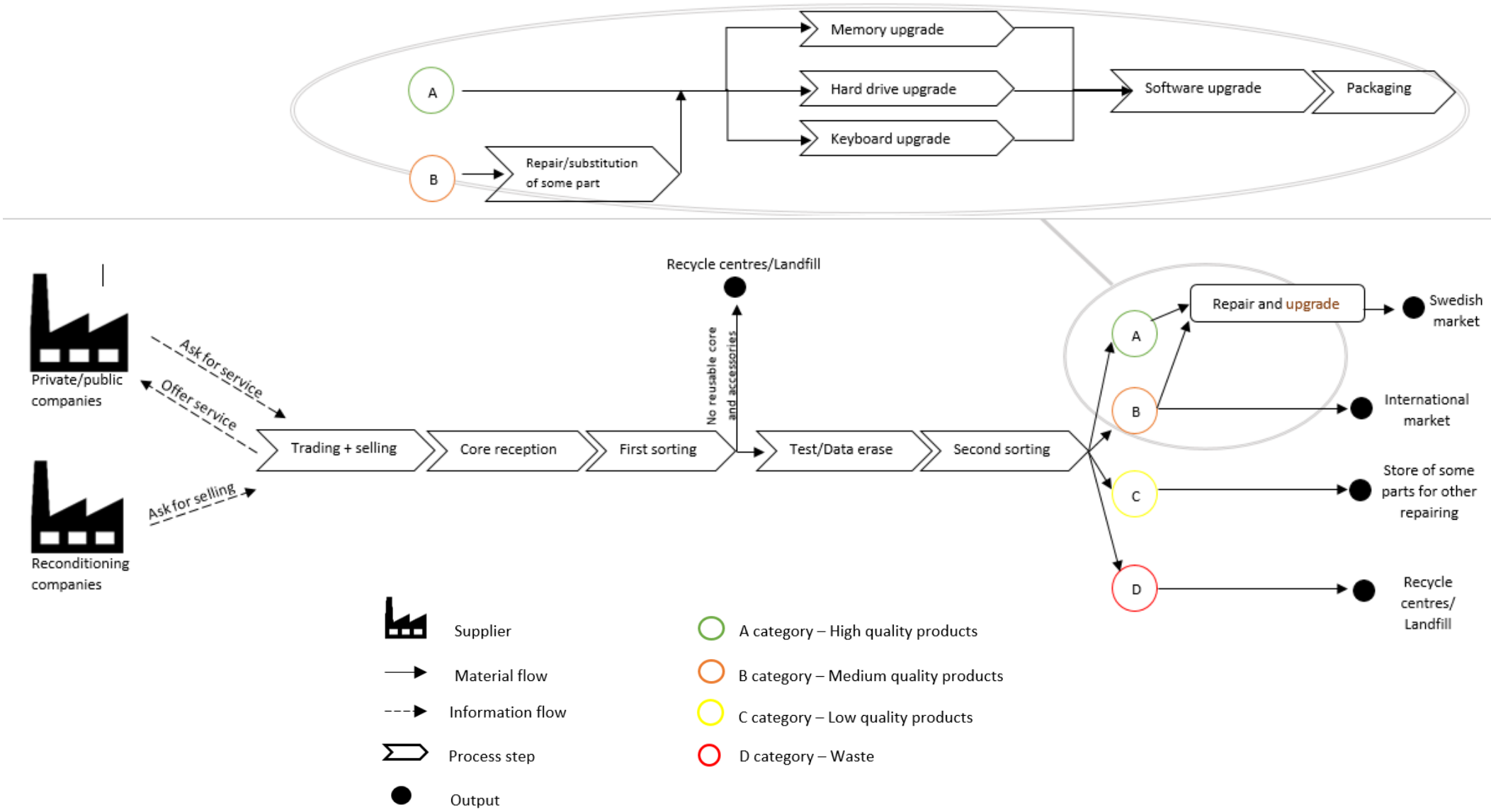


Fig 55 - Reconditioning process of INREGO for the remanufacturing and upgrading of IT devices

5.3 Upgrading activities and strategy

As was already specified in the previous section most of upgrades are provided to the A category (A and A+) and sometimes to the B product to make them pass to the A category as well.
The kind of upgrades that are performed the most are the change of the hard drive and the memory expansions. Besides, all software are updated to the versions required by the final customers. Thus, the firm conduct mechanical and software upgrading. Sometimes there is the need to buy extra parts to perform the upgrading and this influence the final price of the product and increase the time for processing the core.

According to the Production Manager, the main reasons why INREGO decides it was worth to upgrade some core are that, on one hand, thanks to the higher quality and modern functionalities of the upgraded product, it is possible to allocate them on markets that have the willingness to pay more; on the other hand, it also happens the company needs to do upgrades to convince customers to accept their offer in first place. So, as stated in the interview, not always the upgrading activities are profitable but they are an important value added of the service they offer and are important to attract and retain potential and existing customers.

Regarding the difficulty and limitations of upgrades. The manager explained how the kind of device does not influence the complexity of upgrading process. Upgrading a smartphone or a computer can present the same level of complexity. What influences the most upgrading is the initial design through which the product was conceived. This strictly depends on Original Equipment Manufacturers (and so the Brand) of the products. Companies that design their products to make them easy reparable or disassembled make them easier to be upgraded too. Also, because the availability of spare parts in the market is higher thanks to the easy disassemble and extractions of valuable parts. While, products that are not modular and that were assembled with no reversible technique (e.g. use of glue or welding) are more difficult to disassemble and repair. Some parts result inaccessible without compromising other parts of the product, and the availability of substitutive parts is limited. Often the OEM that decide to use no repair friendly design technique do this as a “protective strategy” for the brand in order to maintain it exclusive and characterized by originality. But, in this way, they prevent the possibility of an easy access to the core parts and the availability of substitutional fitting components to repair or upgrade.

From a more strategic point of view, INREGO still does not use any specific upgrading strategy or planning. Most upgrading activities are planned and conducted “on order” and so when and in the way the customers ask for. Of course, thanks to their experience and the efforts to remain updated about the development of the IT products on the market, they usually purchase some spare parts in order to answer quickly to the possible requests.

5.4 The Sustainable Business Model Canvas

The Business model detailed in (Fig 56) represents how INREGO act on the market. The model pertains to the category of Product Service System Model as the value provided is a mix of products and services and, in addition, is described on three level: economic, environmental and social. The headings interested by upgrading are enlighten in red.

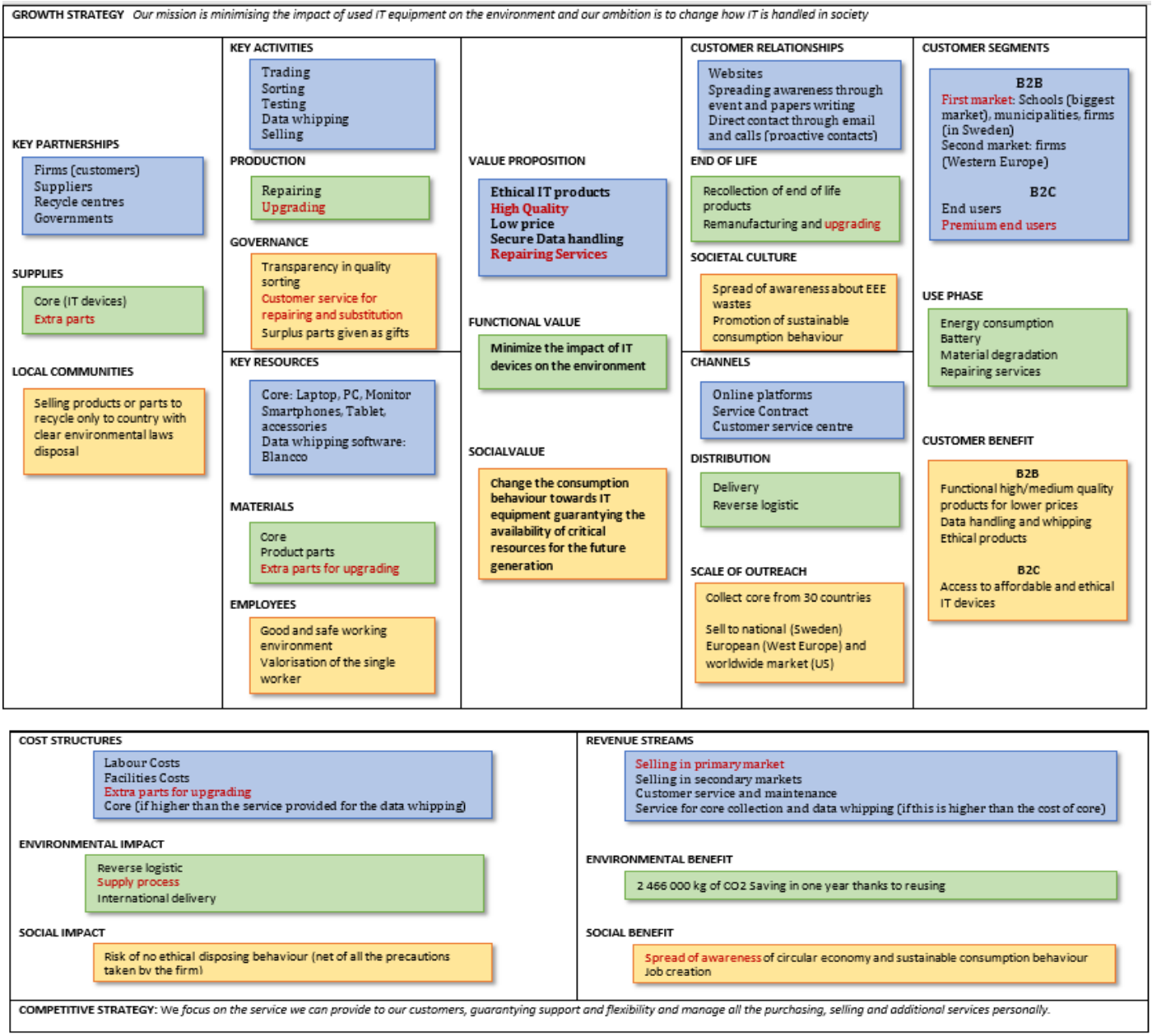


Fig 56 - Three Layered Sustainable Business Model Canvas of INREGO for the remanufacturing and upgrading of IT products

5.4.1 Value proposition

INREGO is able to sell high quality products at lower prices thanks to the recollection of core and reconditioning process. It does that considering social and environmental sustainability and transparency. The products are classified according to their quality and modification and upgrading services are conducted as an additional value if required by the customers.

Besides, it distinguishes itself from other companies for the kind of services it is able to provide. Data protection and whipping, logistic services and customers' assistance. All is handle using personal contact, that give the service more flexibility, and provide quick solutions.

5.4.2 Value network

There are three main kind of suppliers: big brand companies, medium sized company, similar IT refurbishing companies.
Big brand companies. If the company are big brand ones, the contract could be more tailor made and the price and services discussed more in details to reach the expectation and the extra measured required by them.
Medium sized. If the company are medium sized and have no strong bargaining power or legal issues the contract are standards.
The refurbishing companies sell their repaired product to INREGO to take advantages from its market contacts. In fact, INREGO has a large international market that other similar firms still do not have the time and the experience to develop and so, in order to sell all their core, they need to rely on INREGO's market connections.

INREGO use transparency in all its activities and follow precise rules for not selling products to countries in which the disposal laws are not sustainable. The network of the firm is aligned with the company main values. The environmental benefits generate is a direct consequence of the remanufacturing activities themselves and of its governance.

5.4.3 Customers interface

The primary contact between any possible consumers and the firm is usually the INREGO official websites. In the web page, there are two sections, one dedicated to the B2B customers and another one to the end consumers (Fig 57)

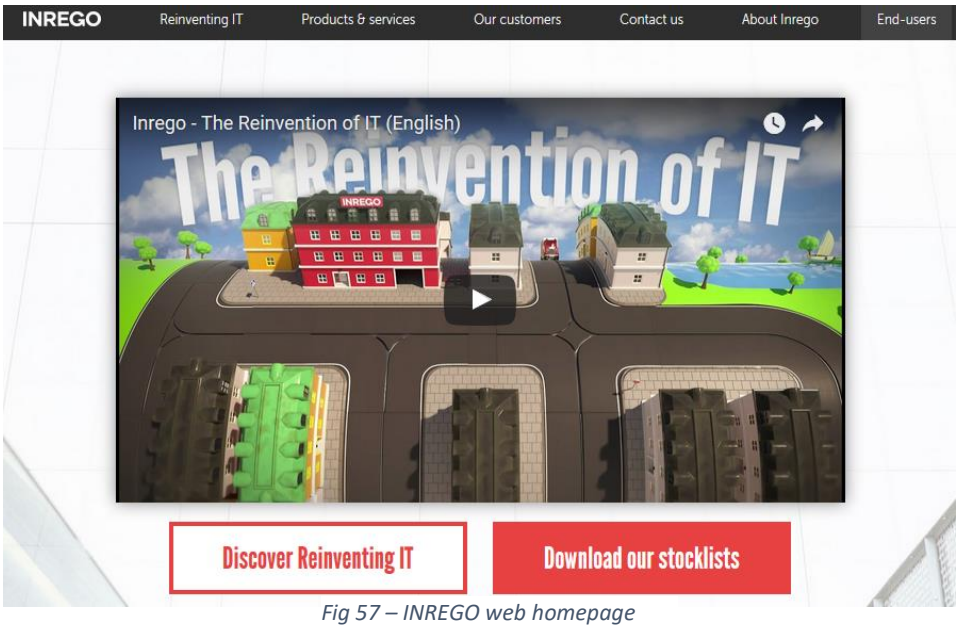


Fig 57 – INREGO web homepage

The stocklist is meant for the B2B market. But it is accessible by everybody and it comprehends the list of the products available and the related characteristics. The products are purchasable in big stock and the customer need to contact directly the firm to arrange the sale. The stocklist comprehends laptops, monitors, PC, mobiles, tablet, parts and accessories, network, servers and storage.
On the other hand through the section *End-users* it is possible to access to the Webshop where end consumers can buy online single IT devices. The offer comprehends as well laptops, PC, monitors, smartphones, accessories and some premium products (new, high quality ones). The end users can also access to the *Asset Recovery* section through which they can contact the firm in case they are having problems with their devices. In fact, for the B2C market there is a dedicated customer service centre. They can ask for a substitution or a repairing or upgrading too. Sometimes INREGO prefers to provide the end users with a new and equivalent IT product and retain the broken one that would be subsequently insert into the traditional processes as a core input. In this way, INREGO minimizes the time needed for assistance and maintains a high-quality level of service. In both cases consumers are encouraged to contact directly the firm to have more information and arrange the selling. A lot of importance is given to customer relation and services.
According to the production manager, there is always demand for their products and it happens rarely or never that some products remain unsold. The demand is still not saturate and this allow the company to make new investments and keep growing. Thus, the positive impact keep spreading thank to the increasing of awareness about remanufactured products, creating value for the social level. More people and companies adopt remanufactured products easier would be change the linear consumption behaviour. On the other hand, the positive impact on the environment is given by the possibility to re-use a product at the end of its life instead of disposing it, saving materials and industrial processes.

5.4.4 Economic model

The products are placed in two kind of markets. The primary market is the Swedish one. In this market the best quality and upgraded products are sold. The share for this market is not high. Only the 20-30% of product are sold there, but the margins, thanks to the quality of products, are high (25-30%). On the other hand, the secondary market is the international one, where medium/low quality products are sold. This market represents the 70-80% of the company total market but, due to the product conditions and the higher costs of delivery, the margins are lower.
The environmental impact, on the other hand, seems positive. Further more precise calculations would be needed but, given the high market served by the firms and the fact the core are collected in big batches, the save in CO2 should overcome the emissions for the recollection.
The social impact, measured in spreading of awareness, is positive and the firm is dedicated in putting more efforts in that and so it is forecasted to grow.

5.5 Upgrading in Business Model headings

The entries of the Business Model that regard directly or indirectly upgrading activities were enlighten using a different colour. Leveraging on the overall view that the canvas tool is able to provide, it was possible to see immediately which part of the business where interested by upgrading and which and how the three levels were influenced by it. It would follow now a discussion about what upgrading add or remove to the quality of the business in terms of economic and sustainable performances net of the economic, environmental and social contribution that traditional remanufacturing and reconditioning is able to provide alone. In a nutshell, what is the differential contribution provided by upgrading to the business model.

Starting from the Value Proposition, upgrading contributes in increasing the quality of the products in terms of functionalities and design. INREGO uses it as an additional service for customers who required modern and updated products. It is a distinctive characteristic the company use to shape its proposition of value and satisfy and retain customers with higher purchasing power.

To support this part of the value proposition a solid Value Network become fundamental. In fact, the section in which upgrading is more present is the one that comprehend partners, activities and resources. To be able to perform upgrading there is the need of extra supplies, and so partners that are able to provide new bulk parts or components to be added to the core; extra production steps would be needed as well for the inclusion of the new parts in the core; and, as a consequence of both, extra materials would be used. Since we are talking about extra parts that are necessary for upgrading, the level that is affected the most is the environmental one. The inclusion of upgrading, differently from the traditional remanufacturing, make necessary the use of new "inputs" and this affect the environmental side of the model.

On the other hand, the delivery of value proposition see the upgrading in the customer segment section. Being able to provide updated product give the possibility to sell to more demanding customers (big brand company or technological demanding end users). Besides, upgrading services are a way to attract and retain customers and so it appears also in the customer relation headings. Therefore, on the customer relation side upgrading influences positively the economic level of the business opening new market opportunities.

The upgrading influence on the Value Network and on the Customers Relation is reflected in the economic model. In fact, from one side there are the extra cost and environmental input of the extra parts; but on the other side upgrading influence positively the revenues and contribute also in the spreading of awareness about remanufacturing and sustainable consumption behaviour thanks to the attraction and retain of new consumers.

Upgrading is an investment and the company need to be able to evaluate it and calculate its return (always using a triple bottom line view that comprehend the three level of sustainability). Regarding the specific case of INREGO, as already specified in previous section, upgrading is not always a rewarding activity. Only the 10% of revenues are related to the selling of upgrading products. The extra work and the extra parts needed to perform it contribute in reducing the selling margin. But the company is still oriented in putting effort in this technique. This means that the value added in terms of competitive advantage and attraction of new consumers (and so spread of awareness) compensate the extra efforts.

5.6 Challenges of INREGO business model and process

There are still some challenges that INREGO needs to manage. From the interview and from paper analysis about its process it emerged that the purchasing process is still an issue. It requires long time and it is still characterized by high uncertainties. Sometimes core supplier companies are not able to give detailed information about the IT devices in their possession and this make difficult for INREGO to predict the quality of core. Besides, as the supplier contacts are still managed in a proactive way, often the sales department need long time to convince a potential supplier to accept the recollection service. This is due to lack of awareness and popularity of these kinds of services.

Always regarding the purchasing of core, the company still not withdraw from the single end users. The logistic process and the trading process are resource and time consuming if compared to the small volume the end consumers can provide to the firm. In order to remain efficient INREGO still need to process big batches of core and the end users are not able to provide the same number of products at the same time as firms do. Besides, end users have the tendency to use their IT products for longer time than companies, because they need less updated ones and do not have warranty limitations. A longer product adoption means also an older core and a lower quality. Less value can be extracted from an end consumer IT device. In the end, also the use phase influence the quality of cores. Office environment is different from a private house and also the use in terms of movement, contact with other objects, position of the device and so on, affect the final condition of the product over time.

INREGO is putting some efforts to enlarge the supply market to the B2C and spread good consumption behaviour. Some experimental initiatives would be put into practice (e.g. the inclusion of some flyers in the product package that promote the possibility to send the product back at the end of its use). But they still leverage on the good will and the efforts of the final consumers that has to take care of the product delivery.

In the end, as underlined in the previous section, upgrading is not always a profitable activity for the company and it still consist on a small percentage of gain and of market share.

5.7 Results discussion

Seeing the results and the two visualisation tools that describe the business, it is now possible to identify some practical key success factors that INREGO use/have that result fundamental for a good manage of the remanufacturing with upgrades process.

Upgrading is integrated in the offer of the firm as a value-added service. In this case, it is necessary for selling, because customers ask for it. In this case are customers that pull the offer asking remanufacturing companies improvements of the remanufactured products.

A good network of core and extra parts suppliers is necessary to provide quick and high quality upgrades. Upgrading needs extra bulk components and in order to be able to perform it quickly reliable suppliers are necessary. The time to process remain an important operational variable, as underlined in the results of the case studies framework discussion. Especially in this case in which upgrades are performed on order and there is no structure planning procedure, the suppliers acquire even more importance.

INREGO still not have a structured planning strategy for upgrading. Having an upgrade plan or simply forecasting the possible upgrading activities can help in improving the process time and quality. In this case the number of upgrades are still limited and the company manage them easily “on order” and thank to its supply networks. But, with a view to grow, planning the purchase of extra parts would result rewarding.

In the end, another peculiar characteristic of INREGO is that they are Independent Remanufacturer and not OEM. As underlined by the results of case studies framework usually are OEM the ones that easier apply remanufacturing and upgrading because they have easier access to core and have a higher knowledge of their own product technology and structure. INREGO represents an exception in this case because it is able to process different products of different brands. This is achievable thanks to the expertise of the technicians that are able to deal with different devices. Therefore, the main rule (OEM are the ones that best succeed in upgrading remanufacturing) and the exception to the rule confirm that, in any case and for any actors, knowledge and competences is another important key success factors for the implementation of upgrading remanufacturing.
But what are the strategy and the offer characteristics that make INREGO outperform the remanufacturing activities of the Original Equipment Manufacturer? First of all, INREGO and the OEM have two different customer relation. OEMs withdraw only their own brand products from final users or companies that exclusively adopt their devices, while INREGO offer to withdraw any kind and brands of IT products that small, medium or large companies do not use anymore (and that in the most of cases had put in the “basement”). So, the flexibility and the working capacity of INREGO is broader than the one of the OEM and the core market result larger. Moreover, INREGO is fully dedicated to the reconditioning and selling of remanufactured products while OEM only partly remanufacture, and above all upgrade, their brands because they are still producing and selling new product versions and want to avoid the risk of a cannibalization phenomenon (Parker et al. 2015). In the end, the INREGO offer is not limited to the simple withdrawing and remanufacturing but it comprehends also the data wiping certification, a very attractive service for public and

private companies and end users. We can further support this thesis reporting that the production manager did not identify the OEMs as their directly competitors but only other similar reconditioning companies.
On the other hand, in a possible scenario in which Original Equipment Manufacturers decide to move to an almost complete offer of remanufactured and upgraded products the role in the market could change and the OEMs could find themselves in an advantaged position. In a context in which the environmental issues and the scarcity of raw material is becoming always more real, this possibility should be taken into consideration and deepen in terms of changes, consequences and market balance.

5.8 Key success factors

In this section, thanks to the analysis of a near company reality, it was possible to enlarge and deep the list of success factors for the application of upgrading remanufacturing. Company should have: a good supplier network for the purchasing of good extra parts for upgrading; extra value services that can be used strategically with product cleaning and upgrading to attract and retain customers; the ability to always extract extra value from cores in a smart way and the ability to repair any kind of products pertaining to that specific sector and, therefore, the competences of the technicians that work on the shop floor is an important factor; flexibility in the service offer, like the division in different products' categories according to final reconditioned product quality or the upload of a specific software; loyal business core providers and loyal reconditioned products buyers.

5.9 Conclusions

Within this step, it was possible to confirm some previous results and conclusions derived from literature and the case studies searching. Another time the use of an offer that comprehend both physical products and intangible ones result the best options for the application of Upgrading Remanufacturing. Moreover, upgrading itslef result to be part of this service offer as an extra value-added activity to attract and retain customers. The use of a Product Service System Business model is still the most popular options among remanufacturers. Also the importance of applying some Design for Remanufacturing technique was definitely confirmed as the production manager of INREGO stated that the complexity of reconditioning and upgrading strictly depend on that. The necessity of Planning was not confirmed by INREGO example as they are able to manage upgrading without any structured plan. But this is due to the low competition, good supply network and the availability of spare parts on the market. The three main key operations were confirmed by INREGO business: they sell high quality products and give importance to the time needed to provide its services (e.g. a good supplier network or the immediate substitution of a broken products in the B2C instead of repairing it), always maintaining low prices. The need of skills and knowledge of the products were confirmed as well. The technicians at INREGO are flexible and can handle different devices and brands thanks to their experience inside the company.
Then, the role of customers in the whole business was further clarified but there are still some open questions about them. Besides, other constraints about the serving of B2C market arose or were confirmed. The B2C is still not a suitable source for core. The withdrawal would require too many efforts and would not be efficient due to the small batch. The willingness to give a core back still rely on the willingness of the single end users. While the firm manage well the selling to end users through the web shop portal, demonstrating that selling of remanufactured upgraded products in the B2C is possible for the EEE sector.
On the other hand, core management was confirmed as the biggest issue to manage. Literature, most companies and INREGO itself show problems in managing the purchasing of core. The flow remains still unpredictable in terms of quality and time. But still the companies succeed in manage it thank to the high availability of core in market. But new reverse logistic strategies should be implemented.

6. STRATEGIC TOOL FOR UPGRADING REMANUFACTURING

6.1 Introduction

Seeing the results of the research is now possible to have a complete proof list of key success factors, limitations and favourable scenarios for implementation of upgrading remanufacturing. These conditions would be used to build an *iterative algorithm* that would support Original Equipment Manufacturers and Remanufacturers in the process of introduction of upgrading. The algorithm would work as a check list that companies should follow for a successful introduction of upgrading. In the following section the algorithm is built and commented. The objective is providing companies with a useful tool that help them in the first introduction of upgrading. Providing a structured tool would help promoting circular economy practices and at the same time creating more profitable circular factories.

6.2 Strategic transition tool

Fig 58- Iterative algorithm to support industries during the shift to upgrading remanufacturing

6.3 Discussion

6.3.1 Starting conditions

The algorithm is thought to be used by Original Equipment Manufacturers that have the willingness to introduce remanufacturing and upgrading services in their value proposition. The tool was designed considering a situation in which no remanufacturing activities are held. The tool checks all the conditions necessary for the introduction of remanufacturing but already considering the possibility to do upgrading. Upgrading and remanufacturing are embedded and are meant to be introduced at the same time. Upgrading is a process that start since the first steps of product conceiving, thus it is often necessary to check some upgrading conditions even before the ones necessary for the simple remanufacturing process. The idea is to help manufacturers in the introduction of the two techniques in order to implement a remanufacturing process that already consider the possibility of upgrading. For sure, also manufacturers that already provide simple remanufacturing services can use it to add upgrading.

6.3.2 Product knowledge

Product knowledge is one of the success factors identified during the research. Knowing the technology of the product is fundamental in order to be able to repair and update it. The know-how of the technicians in the INREGO case was the reason that make the firm able to perform products reconditioning efficiently and successfully. Also from the case studies analysis emerged how, usually, OEM were more performant in the implementation of upgrading, thanks to the control they have on product technology. Thus, if companies want to implement upgrading remanufacturing one necessary condition is having good knowledge of their products. To verify if this condition exists a good proxy companies should use is their ability to repair their own products. If they can intervene in this sense the know-how will be sufficient to manage upgrading services.

In order to verify the level of know-how firms should measure its knowledge and test the skills of its employees using the method that best fit with its operations. Here we provide a check list that should be useful as a starting point for this measurement:

Table 14- Existing conditions that allow firms to have control on product technology

QUESTIONS	EXAMPLES	CORRECTIVE ACTIONS
IS THERE CONTROL ON THE PRODUCTION PROCESS?	A- The product production is managed internally the firm B- The firm outsources the production of the product but has a strong partnership with the products supplier C- The firm outsources the production and have poor knowledge of the supplier production process	Bring the production internally Establish good relation with production partner
ARE THERE ANY DOCUMENTS THAT DESCRIBE THE PRODUCT STRUCTURE?	Availability of bill of materials or product blueprint	Build them using an internal team Acquire them from external market actors
ARE TECHNICIANS ABLE TO REPAIR A BROKEN PRODUCT?	Test their skills and knowledge	Training course Hire skilled people
IS THERE ANY DEPARTMENT THAT IS ABLE TO REMAIN UPDATE ABOUT MARKET TRENDS?	Sales department, R&D, Production, Design department	Introduce Market analysis Implement PSS

Companies could find themselves in different starting conditions that might influence the knowledge they have of their products. We considered three main big scenarios:

If the production is managed and controlled directly from the firm is more likely to have the sufficient know-how on product technology; as well as if the company outsource the production but cooperate with the supplier, keeping itself updated about technology production steps, developments and trends; on the other hand, if the firm does not have any control or knowledge on

the production process (C scenario) it might be difficult having the right competences to manage an hypothetical reconditioning process. Therefore, it is advisable to create the A or at least the B scenario.

The availability of updated and completed documentation about the product structure, design and technology is a fundamental source because it helps on one hand in having a written and structured know-how and on the other hand it provides a tool for the spreading of this know-how. Companies can create a team to collect all the no-structured know-how inside the company in order to write these papers or on the other hand acquire them from other companies (partners, universities, consultancy companies and so on).

Subsequently, the human force that directly work in the reconditioning process should has the right skill to be able to repair and upgrade the processing core. High skilled people are flexible and are able to manage the variability that is likely to characterized this kind of process. Not all cores have the same quality, conditions and timing. Therefore, companies can act in two ways, after testing technicians it can offer training course to a group of people that then can take supervision of the reconditioning process, or it can hire skilled people from outside the company in order to lead the reconditioning operations.

In the end, companies should be able to remain update about market trends and technology development in order to be able to maintain an always updated know-how and so remain competitive in the market. Working to maintain strong relations with the customers (e.g. implementing a Product Service System) and making frequent market analysis could be a good strategy to maintain the product know-how and development.

6.3.3 Product design

Product design is another fundamental factor for a successful implementation of upgrading services. Since the first literature research it emerged as a fundamental characteristic for product that are meant to be upgraded. It was confirmed by the statistics of the case studies analysis and INREGO identified the design of a product as the factor that influence the complexity of repairing and upgrading. Saw the effectiveness of modular design, the algorithm suggests to use modularity as best option to adopt. A modular product is composed by independent and interchangeable components that make the repairing and upgrading of products easier. Adopting a modular design helps not only in the reconditioning process but it influences also the availability of spare and compatible parts that can be used for repairing and upgrading. If the product is conceived as modular more parts could be substituted with other different products components and more components can be saved and use as spare parts for the same or different products. The components' specificity is lower and this increase the probability to find compatible parts on the market (from other similar products or from the same products core) to be used in the reconditioning process.

Therefore, there are two questions companies should solve in this section, one regard the modularity of the product and the other one regard the availability of spare parts. Using modularity can create a virtuous circle in which from one side there is an easy reparable product and from the other side a high availability of spare compatible parts for repairing and upgrading. (E.g. if a *Dell* computer is designed using modular technique it would be easier both finding spare compatible parts coming from other computer brands, and obtaining good condition spare parts from old Dell core to repair and upgrade it).

Changing the design of a product is not trivial. This can influence the design of production process and machines, the supply networks and the skills required on the shop floor. This is why the change should be implemented with cautions and with the collaboration of all department of the organizations and also external partners. There are in literature algorithms specifically design to support this change. Companies can refer to them and target the most suitable one for their business. Besides, also in this case the design should be managed internally or from a partner with whom exists a strong collaboration relation, to maintain knowledge and control.

6.3.4 Core management

Core management is the biggest issue for remanufacturers. It is characterized by uncertainty in time, volume and quality. Firms should elect one or more core collection strategies to manage the core supply that fit best its business and customers. According to research result, Product Service system emerged as the best and most adopted solution. In fact, is another success factor for the implementation of Upgrading Remanufacturing. The use of functional sales help firms maintaining the control of product also during

the use phase and so making easier its maintenance and its collection, which means having higher quality core at the end of product life and at more control on time and volume of withdrawal. Besides, the relation with customers would be improved by the delivering of timing and tailor made services, creating loyal markets which are good core source. The switch from product offer to service-product offer should not be difficult as this practice is spreading and has been accepted positively by markets in recent years.

6.3.5 Operations planning

The last section of the algorithm regard the control of the activities necessary for the reconditioning and upgrading of products. In fact, time, costs and quality of the final product are others success factors that emerged from the analysis. Customers choose remanufactured and upgraded products because they can access faster to low cost but high quality products. The ability of remanufacturers to provide quick maintenance services or product substitutions are clearly competitive advantages that maintain the business profitable. In order to improve the process the first intervention should be put the process under control and measure some process performances with the help of some indicators. However, the use of Product Service System help in maintaining the product under control making the core flow back prediction easier. On the other hand, acquiring experience and good practice, it would become always more reliable and help in the management of the core and reconditioning process.

6.4 OEM VS OER: main differences in the algorithm use

The algorithm can be used by remanufacturers as well, and so by those firms that already run traditional remanufacturing processes and operations but do not upgrade their products. In this case the introduction of upgrading should be easier. Remanufacturers start with an advantaged position due to the remanufacturing processes already ongoing. The product knowledge is already sufficient or, in any case, would need little deepens to reach the sufficient level for the implementation of upgrading. In that case, would be more important to develop the know-how related to market trends and technology development that, on the other hand, could be underdeveloped because not fundamental for the implementation of the classic remanufacturing processes. Besides, remanufacturers should be familiar with core management as well, that is one of the most problematic aspect for reconditioning process. Another advantage of remanufacturers is the relation they have with the market. Their customers are already used to the idea of remanufactured product and so it is easier to introduce upgrading as an extra service. The response is more likely to be positive. Therefore, the two factors remanufacturers should focus on are product design and planning. The design of product for upgrading could differ from the one for remanufacturing. A product that is meant to be upgraded need more specific modular design and compatible parts than the ones that only need to be repair. Besides, the upgrading and the maintenance intervention should be planned. In any case, the shift would be softer. For remanufacturers, adding upgrading would be considered an incremental change while for manufacturer a radical one. Incremental changes are faster and less difficult while the radical one are difficult also because they require a change in culture and basic operations.

6.5 Business model

If firms succeed in applying all the corrective actions to make the business ready for the introduction of upgrading remanufacturing they would have some business characteristics in common in their business model (Fig 59). In the next paragraphs these conditions are summarized and discussed.

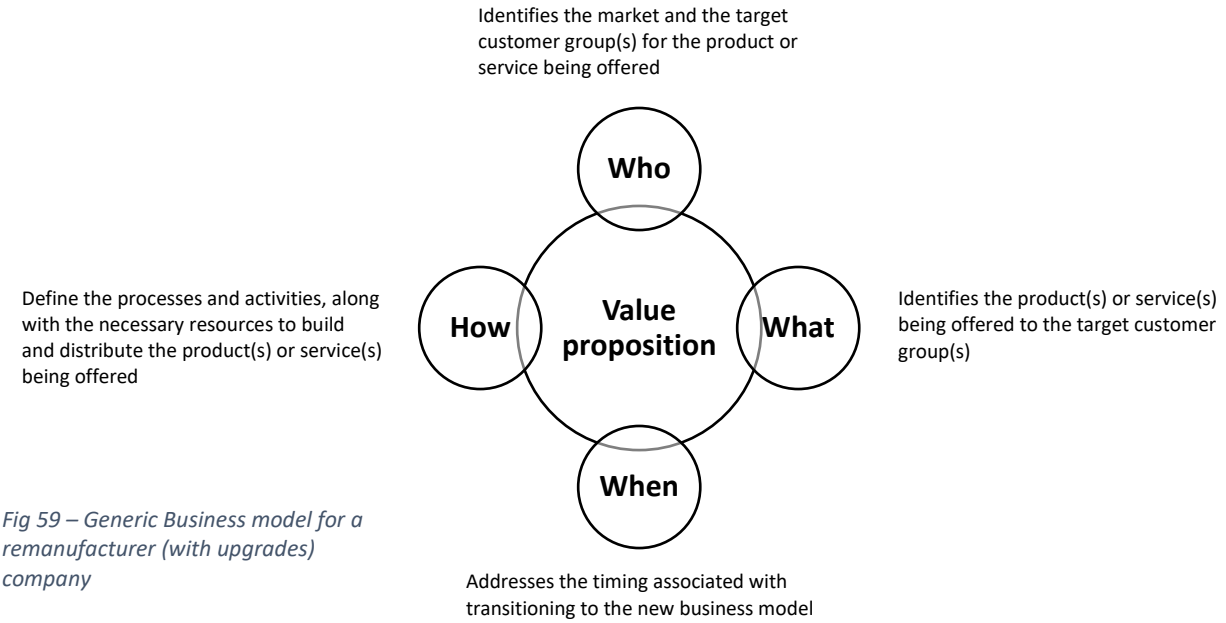


Fig 59 – Generic Business model for a remanufacturer (with upgrades) company

6.5.1 Value proposition

The business value offer would be composed by high quality remanufactured product and related services for their maintenance, control, withdrawal, repairing, upgrading and substitution. The firm through the application of a circular service oriented business model aim at creating strong relationships with their customers providing them with sustainable and smart products, always taking into account customers, environment and society's needs and benefits.

6.5.2 Who

The target market served would be, more likely, composed by other manufacturing companies or private/public firms that need performant and always updated products (machines or IT devices) to run their own businesses. They would value product quality and cost, as well as quick intervention services. The possibility of serving final consumers exists, but still present more constraints than the B2B one. Constraints that are not taken into consideration in the iterative algorithm and that still need more analysis to be managed.

6.5.3 What

The product is a remanufactured and upgraded product accompanied by several services: maintenance, withdrawal, upgrading and new delivery. The kind of product would be more likely to be a machine or an IT device, conceived with a modular design and with recyclable and substitutable parts.

6.5.4 How

Using the tool is possible to implement or improve all the activities necessary for the implementation of the upgrading services. The macro activities are: product design, production, delivery, maintenance services, core collection, remanufacturing, upgrading, new delivery. The product would be sold using functional sale (PSS). The degree of functional sale would be decided by firms according to the kind of market they are serving. It could be sold the propriety together with the related upgrading and maintenance service or it could be sold only the use of product. In each case the selling of products would include a strong relationship with the final consumers in order to assist him during the product use.

6.5.5 When

The time for transition depends on the starting condition of the company. Assuming the best starting condition is the one of an Original Equipment Remanufacturer, that is already familiar with some operations needed for a circular business model, and the worst condition is the one of an Original Equipment Manufacturer, that is shifting from a linear model to a circular one for the first time, it is fair to assume a minimum period of six month and a maximum of 1 year and three months. In Fig. 60 the transition time is presented.

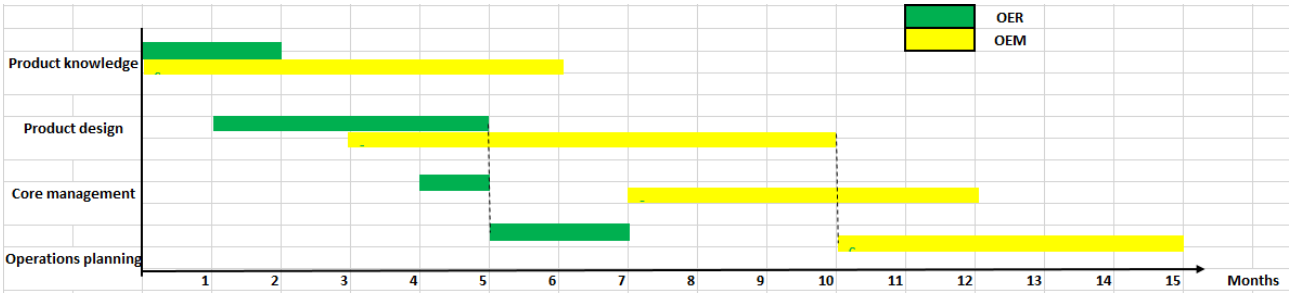


Fig. 60 - Transition time needed for OEM and OER for the implementation of upgrading remanufacturing

In the case of an Original Equipment Remanufacturer the transition time would be shorter because the time needed to gain product knowledge and implement a core collection strategy are minimum, as they are already present in the business thank to the traditional remanufacturing. Two months are allocated to product knowledge to deepen the upgradability potentiality of the product and one month to find the best way to introduce the extra service in the core management strategy. On the other hand, product design would need more attention and only when the design decisions would be settled the operations planning sequence can start. On the other hand, OEM would need more time to go through each step of the algorithm. However, the longer time would be useful to face the change and give the possibility to managers, employees and customers to get used to the idea of a radical changing in strategy and operations. Six months are allocated to reach the necessary know how and seven months to changing the design of products. As it happens for OER also in this case the design need to be fix before starting to plan the basic operations for the upgrading of the product. On the other hand, company would risk to make some mistake in the planning of new interventions on the product, undermining the transition process.

7. CONCLUSIONS

The aim of the research was to study the favourable conditions and the potentiality of upgrading remanufacturing as a new sustainable service-based circular economic model solution for companies that have the willingness to include it in their businesses. Four research questions were used to go through the research, mapping the European situation and arrive to proper conclusions. Different analysis were conducted and different outputs were reached. Each output (the literature review, the companies' framework and the case study) contributed in shaping final answers to the research questions and in building the iterative algorithm that would support firms in this transition.

A complete description of upgrading remanufacturing is provided. Upgrading is a circular economy solution that aim at producing new technologically updated products thanks to core collection, remanufacturing and upgrading. Dealing with upgrading implies managing upgrading planning, design for upgradability (modularity), core collection and Product Service System business models (QUESTION 1). The favourable context for its application saw big companies with good knowledge and control of their products. The market served is most likely the Business to Business one. The offer is composed by modular long-life products (machineries) and maintenance, collection and combined upgrading services (QUESTION 2). The key factors that influence the success of its implementation are the use of functional sales (PSS) to maintain product control and provide quicker maintenance and upgrading services; the use of design for remanufacturing technique to make products easily fixable and upgradable; the use of planning, to forecast the upgrading intervention, and the use of control on operations, to have efficient and effective upgrading services; in the end, the reaching of a satisfying internal know-how, to be able to intervene on products. On the other hand, there are some challenges to overcome. Customers' quality perception and possible issues that could arise from a closer control of products still need to be managed and solved. Together with limitations in serving B2C markets and high uncertainties in predicting core flow (QUESTION 3). This new structured knowledge about upgrading was used to build the iterative algorithm to provide industries with a tool to support them in the introduction of and transition to upgrading remanufacturing (QUESTION 4). It was not possible to address properly QUESTION 5 and 6 due to time constraints. The relevance of upgrading remanufacturing emerges from the numerous result discussions and the clear urgency to find new practice to substitute the traditional linear approach. However, more structured research and analysis regarding its future potentiality to spread are needed. Besides, a methodical evaluation to prove the sustainability of remanufactured and upgraded products against the traditional one is still missing. PLCA methods or environmental foot print are some possible suggestions.

In the end, also new open questions arose. Customers' role remains ambiguous. What is their influence in the introduction of upgrading remanufacturing? Are they pulling the offer of remanufactured and upgraded products or companies still need to push them? And then, why companies find difficult to sell and withdraw products in the B2C market? Privacy issues, easy replacement culture, small batches and poor core quality could be some possible reasons. Also, future roles of different actors dealing with remanufacturing would be an interesting topic to deepen. How the competitive scenario among OEM, IR and CR would develop in future years? Who has the main competitive advantage? In the end, how new technologies can help in sustaining this transition? New wave of Industry 4.0, Internet of Things and digital applications can help in creating more reliable and sustainable core collection and upgrading intervention?

Upgrading remanufacturing is still a new topic but with the right researches and tools it has the potentiality to spread among future industries as a new long term oriented circular solution.

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9. APPENDIX

Remanufacturing with upgrades case studies

Storebro

Firm information
Storebro, sweden
Since 1991
www.storebro-service.se
Product
Lathes, milling and grinding machines.
Value proposition
Today the main focus has turned to the advanced machine reconditioning and servicing of small as well as larger machines of any brand or type. We have the skills and resources to prolong the life and increase the productivity of your machine tools.
Core Sourcing
Storebro Industrier (Storebro) is performing remanufacturing on latches, milling and grinding machines as a service for their customers. This means that the customers own the machine during remanufacturing and placed back when remanufacturing is finished.
Business description
Storebro has a close collaboration with their customers in order to provide them with a good remanufacturing service of their customers' machines. In general, the remanufacturing process is including the steps; 1) Inspection and test run at customer; 2) Transport to Storebro; 3) Disassembly; 4) Cleaning of parts; 5) Part reprocessing or replacing; 7) Reassembly; 8) Testing; 9) Transport to customer; 10) Installation at customer.
During the first step, the machine goes through a status review, a test run and a final check. Secondly, the machine is disassembled. All parts will be washed and thoroughly cleansed. The machine bed and chest will be reground as well as saddles, cross slides etc. Milling machine tables will be planed. Gibbs, headstocks, tailstocks and slides will be scrapped. Teflon or Turcite linings will be relined and scraped. Headstocks, Norton gearboxes and aprons will be overhauled and equipped with new bearings, bushings and gaskets. Damaged gear wheels or axles as well as worn out ball bearings will be replaced. Table, cross and tailstock screws will also be replaced. The hydraulic and lubrication system will be overhauled. The tailstock will be provided with a new barrel and screws. New spindle bearings will be mounted. Clutches and brakes will be replaced. The machine may be filled and primered prior to a two pack finishing paint being applied. The electrical equipment will be replaced or upgraded. Digital measuring systems (DRO) will be attached. On CNC machines, outdated control systems can be replaced if requested. Finally, the machine will be reassembled, gauged and a measuring protocol will be issued. The whole procedure will be carried out meticulously, so that no stage or component will be overlooked.
The customer's value is that they get price-worthy machine delivered with a complete measurement report and supporting documentation. Within the documentation often a risk assessment is conducted and manuals of how to maintain the remanufactured machine to make it last longer. As the aging process may improve the properties of the machine bed, by increasing its firmness and stability, there are a number of advantages in remanufacturing a machine. By comparing the purchase cost of a new machine against the cost of remanufacturing an old one, there is an estimated cost saving of 50% or more should you choose to remanufacture.
The key resources for Storebro are their long experience in machine remanufacturing and good collaboration partners that could help them to remanufacture machines for their customers.
The challenges are to be able to plan their remanufacturing process better. It is not easy to foresee how long time the reprocessing of parts will take. Getting access to cores is also a challenge that recently has become stronger.(Erik Sundin, Tomohiko Sakao, Mattias Lindahl, Chih-chuan Kao 2016)

Ståthöga MA Teknik AB

Firm information
Sweden, Norrköping
Since 1988
http://www.stathoga.se/
Product
Pumps and smoke channels
Value Proposition
We want to work with our clients to develop and find new solutions. For us the customer is always in focus. The right kind of maintenance activities have a direct positive impact on the profitability of the industry, environment and resource use. By providing skilled staff, high quality products and a lot of experience, we want to be a strong partner for maintenance and resource.
Core Sourcing
Cores are retrieved from customers who own them.
Business Description

The business concept is to find and upgrade existing pumps at their customers. The value for the customer is that they can prolong the use of their old equipment and also reduce the down time period since the remanufacturing time is quite short in comparison with replacing it with new pumps. The cost for remanufacturing is also significantly lower than the option of replacing with a new pump.
The normal procedure is that the used pump is transported to their workshop. In some cases, the work is done at the customer site. The first step is to assess the condition of the pump in order to plan the work. The next step is to clean the pump and this step is followed by repairing the pump. This could imply additive measures, e.g. removing roost and add new materials. Replace worn out components with newly produced ones. In order to prolong the life time, improve accessibility and to improve the efficiency of the pumps, they normally add a surface treatment with modern composite coating and sealing technology. Modern sealing composites have lower coefficient of friction as well as the composite coat inside of the pump this together can improve the pumps efficiency between 5-15%. While industrial pumps consume only about 25% of the installed electrical motor power, their potential for energy savings is one of the largest (Erik Sundin, Tomohiko Sakao, Mattias Lindahl, Chih-chuan Kao 2016).

Siemens Industrial Turbomachinery AB

Firm information
Sweden, Finspång
Since 1955
www.sit-ab.se
Product
Gas turbines
Value Proposition
We're positioned along the value chain of electrification. Our products are designed to generate, transmit, distribute and utilize electrical energy with particularly high efficiency. We've been leaders in this field until now, and it's here that our future lies. One engine of sustainable business is our ownership culture, in which every employee takes personal responsibility for our Company's success.
Core Sourcing
Cores are retrieved from customers (i.e. turbine users), and cores with the same quality (or the same entities) are returned to the customers after overhaul/repair. The overhaul/repair is often a planned activity (e.g. after a predefined length of operation)
Business Description
Siemens Industrial Turbomachinery AB carries out overhaul and repair of gas turbines for its customers (i.e. users) by using new, repaired or refurbished parts in sectors such as power generation and oil & gas, contributing to extending the lifetime of existing equipment. Overhaul options focus on operational demands through in-situ or factory-based overhauls, and/or by service exchange or leased engines (for the duration of the overhaul period). For its customers, the cost (lowest cost of ownership) is a major driver to pay for this service. Siemens overhaul and repairs, which can also incorporate modernizations and upgrades in certain cases, are designed to help customers realize optimal operational performance from their assets, by providing the turbines with a long lifetime, such as 20 years. The company's key resources are its product knowledge and facility. In particular, the company utilizes its OEM (Original Equipment Manufacturer) knowledge of operating parameters (ambient conditions, operating mode, operated fuel, etc.) and of component design, manufacturing parameters and tolerances. In addition, fact-finding in close cooperation with the Siemens design department is a strong asset. Regarding the facility, Siemens uses a global network of company-approved workshops to meet exacting quality and safety standards and guarantee the performance of its engines. Furthermore, guaranteed OEM parts for the turbines and access to the latest OEM-proven technology for extended economic viability of the asset are also important.
The process includes transport of the core (if needed), inspection, refurbishment, reassembly, test, transport (if needed), commission, and test (Erik Sundin, Tomohiko Sakao, Mattias Lindahl, Chih-chuan Kao 2016).

INREGO

Firm information
Sweden
Since 1995
www.inrego,se
Product
IT Equipments: computer, smartphones, Tablet
Value Proposition
For every computer that is reused and put to use again, we can reduce carbon emissions, save the earth's raw materials and build a circular economy, where resources and products are used more efficiently. But the philosophy of Reinventing and extending the service life of IT products is not just about the environment, but also about economics, quality and safety. It is about taking advantage of the product's value, long-term thinking and more intelligent consumption. Our mission is minimising the impact of used IT equipment on the environment and our ambition is to change how IT is handled in society
Core Sourcing
Inrego buys used professional IT-equipment from private and public organisations for reuse purposes.

Business

Business Description

Inrego buys used professional IT-equipment from private and public organisations, reconditions it, data wipes all information and resells or leases it to the next user. Inrego pays the seller for the product value and charges for the asset disposition services handling, data wiping and transportation. This way the seller, the buyer and society benefits as well as creating a profitable business for Inrego. The seller can be reassured all data on discarded equipment is permanently erased while at the same time easily getting unwanted IT-equipment fetched, payed for and inventoried in a controlled and transparent manner. The vast majority of IT-users do not need the latest and greatest hardware for operating their needs in business, home use, administration etc. A three year old reconditioned computer or smart phone by far fulfills these needs for the buyer, who can hereby buy or lease a fully functioning high end IT- product including one year warranty. Inrego's leasing or "Product as a service" is increasing and is an important area to promote, as products this way comes back for another life extension when no more needed and can fulfill IT hardware needs in other parts of the society. As every unit is tested thoroughly, Inrego experiences an even lower customer complaint percentage than suppliers of new manufactured equipment. All equipment is received and sorted for potential reuses at Inrego's ISO 14001, 9001, 27001 and OHSAS 18001 certified recondition facility. Around 90% of all received equipment is reused; the remaining is recycled downstream at an external recycling partner. At reception, all core units are bar code labeled with a unique ID tied to its serial number, which is scanned to track and register specifications and test results throughout the reconditioning process. The hardware functionality is tested and cosmetic damages inspected. Appropriate upgrades and repairs are performed based on standard cost/benefit analysis. Data is wiped using professional software that renders a data wiping certificate. The inventory list, data wiping certificate and environmental savings are reported back to the seller in a web portal, and payment is done for the product value. Products are resold online at www.inrego.se and can be customized to fit the customer's need of technical specifications and software(Erik Sundin, Tomohiko Sakao, Mattias Lindahl, Chih-chuan Kao 2016).

Philips Healthcare

Firm information

Netherlands

Since 1891

www.philips.com

Product

Health care machines

Value Proposition

Guided by our passion to improve people's lives. With the world facing the challenge of tackling climate change and energy constraints, as well as providing effective and affordable healthcare to a growing global population, we see compelling opportunities in the health technology and lighting markets.

Core Sourcing

They maintain the ownership of the system selling them to costumers as service (pay for use, lease contract and so on)

Business Description

The product's residual value is capitalized on through a trade-in mechanism offered to clients. Philips sells or leases a range of refurbished good to clients, with a follow-up customer care package and a full warranty. Through refurbishment different value propositions can be offered with different types of technology at different prices. The business proposition centres on making high quality equipment available at an affordable price, for the same warranty as for new equipment.

Refurbished Systems are sold for 60 to 85% of the equivalent new system price, depending on the generation of the product and the developments of its life cycle. Refurbishment can be strategic from a marketing and market segmentation perspective. In addition, in this case, the system upgrade approach saves costs by up to 50% on the upgrade bill of materials. The upgrades provide a means for new revenue through new sales and service contracts. Philip's Healthcare seeks to close material loops by adopting a platform design approach, product upgrading strategies and parts harvesting at the point of refurbishment. A key design approach for Philips Healthcare is designing for reliability in the first place and this is evident in the high residual value of the product. It has developed and approved an upgrade system which is based on material reuse (Sharon Prendeville & David 2016)

Martela

Firm information

Finland

Since 1945

http://martela.com

Product

Office furniture

Value Proposition

Martela designs and creates the best workplaces and learning environments for its customers. We offer ergonomic solutions for modern working environments – for mobile work and activity based offices.

Core Sourcing

Martela retrieves used furniture typically when selling new products. The remanufactured products are sold through a specific outlet-channel.

Business Description

Martela is one of the Nordic leaders in the office interior industry. It strives to offer the best workplaces environments, which has been guiding the company for seventy years. In addition to innovative and ergonomic furniture solutions Martela designs and implements various workplace related services. Martela helps improve the employee wellbeing while at the same time increasing the space use efficiency in workplaces, schools and welfare environments. Martela designs and supplies interior solutions, including chairs, desks, shelves and partition walls, for working environments and public spaces. Martela offer ergonomic solutions for modern working environments - for mobile work and activity based offices. The objective is to provide customers and partners with the best service in the business and high-quality and innovative products. Fast deliveries and an efficient delivery network help attain this objective. Martela develops its own designs. The main design objectives include usability, good ergonomics, visually pleasing products. There is no official Design for Rem process adopted, but the following features support it: easy disassembly and upgradeability, modularity, standardization of components, reusable packaging. Industry standards define the requirements for durability and other technical features, where manufacturability is also taken into account(Sharon Prendeville & David 2016).

AGCO Power

Firm information

Finland

Since 1990

www.AGCOPOWER.com

Product

Agricultural machines

Value Proposition

High-quality, highly efficient products through high-quality, highly efficient people, systems and practices.

Core Sourcing

AGCO Power uses a deposit system. When a customer buys a remanufactured engine he/she pays a deposit. When the used engine (core) is returned the deposit is refunded to the customer.

Business Description

AGCO is a leading manufacturer and distributor of agricultural equipment and related replacement parts throughout the world. AGCO sell a full range of agricultural equipment, including tractors, combines, self-propelled sprayers, hay tools, forage equipment and implements. AGCO products are recognized in the agricultural equipment industry and are marketed under a number of brands, including: Challenger, Fendt, Massey Ferguson and Valtra. Standardisation and modularisation are the most important factors in the design. The engine blocks are designed with extra working allowance, which allows for remanufacturing and machine-tooling of cylinders. AGCO reman engines and components are engineered and remanufactured to provide maximum value and increase uptime in the field for all AGCO customer equipment needs. They are upgraded to the latest OEM engineering specifications, fully tested and ready to install. AGCO Reman parts eliminate uncertainty and prevent complications during rebuilds.(Erik Sundin, Tomohiko Sakao, Mattias Lindahl, Chih-chuan Kao 2016).

Neopost

Firm information

France, Le lude

Since 1924

www.neopost.com

Product

Machineries for mailing management

Value Proposition

-

Core Sourcing

They maintain he ownership offering leasing contracts.

Business Description

Neopost offers mail management (mailing solutions, franking machines) services to corporate clients, predominantly SMEs (80%) within the public and private sectors. It designs and manufactures a variety of products to facilitate mail management. In 2011, it undertook a pilot remanufacturing activity, which led to an ambitious remanufacturing strategy which was deployed in 2012.

Historically Neopost has taken a proactive approach to ecodesign, driven partially by specific legislation (WEEE, RoHS, Ecodesign Directive). The company states that its experience in ecodesign and previous activities in refurbishment, paved the way for its uptake of remanufacturing. A new entry are some first attempts of upgrading, mostly electrical related to the motherboard to keep the products on the market. Prior to investing in remanufacturing, it actively refurbished some products, though this was a 'less

systematic' approach. According to Neopost remanufacturing offered the opportunity to improve its profitability, while also decreasing the environmental impacts of its activities(Sharon Prendeville & David 2016).

Caterpillar Inc

Firm information
USA, California
Since 1965
Product
Heavy machineries for construction
Value Proposition
We win by delivering valued, quality products, services and solutions to our customers that provide them the best economic proposition for their business. This value proposition, enabled by our unmatched customer support, creates the largest global field population, highest customer loyalty and attractive profitability through the business cycle.
Core Sourcing
Caterpillar use a deposit base system to receive the cores back in order to control better the flow and the quality.
Business Description
Caterpillar's remanufacturing activity began in 1973, and has since grown to encompass nine locations around the world, employing over 3600 people in a business model with an emphasis on component recovery.
Some product types lend themselves more naturally to the particular loops of a circular economy, with those relating to machinery and engines often enjoying a longer history of remanufacturing. Complex, durable components like gearboxes, drivetrains and brakes have traditionally been more readily able to be repaired and upgraded, hence a long-standing support and service industry around these products. However, challenges do still remain and the 2012 report Towards the Circular Economy highlighted significant economic benefit to be gained in this industry, especially through improvements in vehicle design and establishing professional refurbishing systems. Heavy machinery manufacturer Caterpillar is often seen as leading in developing practices and new technologies that enable greater value to be recovered during the remanufacturing process. Over the past 40 years, Caterpillar's remanufacturing activity has been improved and expanded; now employing over 3600 people worldwide. Through Cat Reman, the company has been able to increase profit margin whilst still producing components of the highest quality, by replacing products before they break and rebuilding them with a mixture of new and used parts. In order to intercept products before they break, it is crucial to have consistent knowledge of the condition of the key components. Typically, this is monitored through regular and simplified maintenance process between the dealer and the customer, but Caterpillar are now beginning to make use of digital technology to add a 'Product Link' service to units in the field. This enables the manufacturer to monitor a number of criteria related to the general status of the item, such as fuel levels and potential risks, allowing closer and more detailed tracking of the customer's assets adding value and lowering owning and operating costs while creating a more effective reverse cycle[15].

Xerox

Firm information
USA
Since 1906
www.xerox.com
Product
Copies machines and cartridges
Value Proposition
At Xerox, we engineer the flow of work. We apply our expertise in business process, imaging, analytics, automation and user-centric insights to help clients become more productive, efficient, secure and precise across a wide range of domains and industries.
Core Sourcing
Xerox apply a PSS business model offering to its customers leasing contracts for its products, in this way maintaining the ownership it can withdraw the main machines and the cartridges at the end of their life.
Business Description
Xerox is a leading company in the photocopier sector and cartridges in the Business to Business market. In 1987 it started a remanufacturing project in Netherlands with the purpose of recovering end of life copying machines in the market and be able to save money during the new production processes. This was called the Asset Recovery Operation (ARO). In 1989 5% of scrapped machines were remanufactured; by 1997 this had risen to 75% of the 80,000 printers returned. At the beginning of 1993 landfill

[15] https://www.ellenmacarthurfoundation.org/case-studies/design-and-business-model-considerations-for-heavy-machinery-remanufacturing

accounted for 41% of manufacturing waste but by 1995 this was only 21%. To encourage return, an incentive scheme was introduced in The Netherlands, and although the remanufactured printers compete with new Xerox machines, the company claimed to have saved $65million by 1996. By 2001, Xerox had remanufacturing facilities in the USA, the UK, The Netherlands, Australia, Mexico, Brazil and Japan. By retaining ownership through leasing, or other direct links with the users, they have been able to work towards their environmental goal of making waste-free products in waste-free plants. Arguably the single most important aspect of Xerox's remanufacturing strategy has been the decision to design products for remanufacture. This has enabled the disassembly, inspection and remanufacturing operations to be more efficient as decisions made at the start of the design process have allowed for eventual upgrading activities enabled by the replacement of key modules (King, Barker, and Cosgrove 2007).

Fairphone

Firm information
Netherlands
Since 2013
https://www.fairphone.com/en/
Product
Smartphone
Value Proposition
By making a phone, we're opening up the supply chain and creating new relationships between people and their products. We're making a positive impact across the value chain in mining, design, manufacturing and life cycle, while expanding the market for products that put ethical values first. Together with our community, we're changing the way products are made.
Core Sourcing
Fairphone lunch a recycling program aims to reduce e-waste by offering an infrastructure to collect and manage old phones. So customers and potential customers are given the possibility to send their phone back on voluntary base (and so when they think it is necessary)
Business Description
Fairphone produces modular designed smartphone to sell to the B2C, and recently, B2B markets. Its strength is in the creation of a strong network of partnership with its supplier and recycler centres in order to provide its customers ethic and easy recyclable products. Customers that buy a Fairphone can fix or upgrade it buying new modules on the Fairphone websites and they can resend the broken modules or the phone at the end of its use to the firm that get their ownership back and remanufacture them. Usually the phones pass through some recycle centres before in order to be disassembled. The network of recycling centre is organizing according to the end of life value of the phone that the customers can calculate on their own. If the phone has a low value they suggest you to send to smaller peripheral centres, on the other to some more specialized and centralized ones. Upgrading is reached through the selling of new modules or software updating. (Proske et al. 2016)

Re-tek

Firm information
United Kindgom
Since 1996
http://www.re-tek.co.uk
Product
IT products (waste)
Value Proposition
Re-Tek is a positive impact partner to our customers. This is demonstrated by our commitment to security, renewable energy, the circular economy, and giving our customer the opportunity to make a difference with their IT.
Core Sourcing
Re-tek collect technological equipments that firms don't use any more and than share the revenues of the new selling with the previous owners.
Business Description
For nearly 20 years, Re-Tek has concentrated on making the disposal of IT products and electronics easy, by successfully repairing and upgrading those which are functional, and selling them on. Set up initially to work with large original equipment manufacturers, the company now processes 7000 ICT items per month, in a custom built 22,000 ft facility, which, as a result of an extensive investment programme, is now powered by 70% renewable energy. Ensuring their clients' data security, and offering reuse as a viable method of asset retirement, Re-Tek is able to share the revenue gained with the equipment's previous owners. Of all the equipment received, approximately 80% progresses to be re-marketed. Only equipment which is completely non-functional, or has no market value goes to conventional recycling partners, and whenever possible, a non-functioning item is harvested for spare parts – thus the resulting landfill is just 1%. This approach also means that good quality, high spec assets are available to be sold on or re-deployed to

secondary emerging markets, charities and under privileged UK communities that are the target of the Government's digital inclusion strategy[16].

Toshiba Medical systems Europe

Firm information
Japan
Since 1950
www.toshiba-medical.eu
Product
Medical imaging equipment
Value Proposition
For over 140 years Toshiba's research and development has improved the health and welfare of people around the world. Today, Toshiba Medical Systems offers a full range of diagnostic imaging products and is a reliable service partner in more than 135 countries around the globe. Our Mission is to deliver the best quality products and services, as well as the industry's best after-sales support through long-term, customer focused partnerships.
Core Sourcing
The Toshiba Secondlife refurbishing program mostly remanufactures imaging equipment traded in with the purchase of a new Toshiba instrument. They will purchase TOSHIBA and NON-TOSHIBA UL, CT, MR, and Xray as a trade-in for new Toshiba or Secondlife refurbished equipment at a fair market value.
Business Description
Toshiba deals with the remanufacture of brands of instrument other than its own. After the careful selection of suitable units, they are collected, refurbished and provided with a one year warranty. Refurbishment involves disinfection of the system, testing and clean of all parts and components, replacement of worn or damaged parts with OEM spares and repainting of covers.
As a standard procedure, each system is upgraded to the latest applicable software. The process is rounded off by an electrical safety test and an extensive quality control procedure to ensure all Toshiba OEM specifications are met. A Secondlife sticker is placed on the product as a seal of quality and a full one year OEM warranty is provided(Parker et al. 2015).

Perkins engine

Firm information
UK
1932
www.perkins.com
Product
Motors and diesel engines
Value Proposition
With a history stretching back more than 80 years, Perkins is one of the world's leading providers of diesel and gas engines. We aim to set standards of engineering excellence, providing the most comprehensive range of innovative and reliable power solutions, tailored to meet the precise requirements of our customers. We're proud of our reputation as a socially responsible company, enhancing the lives not just of our employees but of the communities in which we work.
Core Sourcing
Buy/receive cores from OEM
Business Description
For over 70 years, Perkins Engines has been making a range of diesel engines in the UK for use in OEM products in the 5-800 kW power range. End uses are in agriculture, construction, mining and materials handling, military, auxiliary power (35%) and rail transport applications, embedded into others' products. Perkins has long experience of remanufacturing, and the skills and processes to support it. Its products are often embedded into other OEMs end products. This complicates control over the after-market for the goods. Engine remanufacturing has come in and out of fashion, heavily driven by the economic climate of the times. Perkins will rely on remanufacturing as part of a future extended service offering. It will also take advantage of specific EU legislation that is reversing the trend in longer service lives, by forcing overhaul or swap-out to upgrade performance. Key to the success of its remanufacturing facility will be management of core, which will require the field teams to filter out what is or is not viable for remanufacture. Auxiliary

[16] https://www.ellenmacarthurfoundation.org/case-studies/establishing-a-reverse-supply-chain-for-electronics

systems, such as electronic controls, are evolving but are relatively easy to upgrade as stand-alone packages. Based on diesel engines, technology improvement has seen progressive advances over the last ten years, and is expected to continue into the future. The use of sophisticated control electronics continues to add value to the product by both managing the power efficiency better, and by reducing its abuse[17].

Black Hill

Firm information
UK
1950
http://blackhillengineering.co.uk/
Product
Quarrying machines
Value Proposition
Proud of our heritage, we have been providing our customers with unique fabrication and machining services for over 60 years, from large complex assemblies to simple bespoke items.
Core Sourcing
Independent source of old equipment outside their traditional sector or withdraw of their own machines form customers**.**
Business Description
Blackhill has been operating for over 10 years, and employs around 23 people including 4 CAD staff, generating a turnover of about 1.2m in 2001 of which 30% is directly attributable to remanufacturing. Remanufacturing accounts for around 10% of sales in the quarry crusher market. Any company that relied solely on remanufacturing would suffer cash flow problems. Blackhill has diversified into a number of services encompassing new build, repair, remanufacture and bespoke engineering design, which use essentially the same skill set. They also re-engineer old equipment to include upgrades, and service customers outside of their traditional sector. Since the traded-in items retain a high value, representing a large sum of money tied up in Blackhills stock, a customers order is satisfied from a (near) complete remanufactured unit, while the actual cost of the job is related the cost of remanufacture of the traded-in machine. Typically, a remanufactured item can be presented at around 40% of the cost of an equivalent new item, or 30% of the price of a new marque machine[18].

Wealdstone Engineering

Firm information
UK
Product
Cars engines (and components)
Value Proposition
Core Sourcing
The core items for remanufacture come from the OEMs via their dealer networks as a result of the warranty and parts replacement programmes. This is subject to exclusive contracts, and prices based on negotiation with the BVPs. These are essentially 'cost plus', based on historic knowledge of the complexity of any particular job.
Business Description
Wealdstone is a privately owned company specialising in the remanufacture of engines and transmissions on behalf of branded vehicle producers (BVPs). This accounts for around 90% of business, the remaining 10% being attributable to own-brand remanufacture for the coach engine market and for the MOD. Wealdstone is one of the oldest UK remanufacturers in an industry that is well suited to the practice. A complex and comprehensive set of relationships covers the new market, OEM supplies, after-market, after-market support, contracted and independent remanufacture, and grey market activities. An important part of remanufacture is upgrading. Every engine that leaves is specified to modern standards of, for example, emissions. Wealdstone operates a classic remanufacturing process with an extreme emphasis on quality typical of top class auto manufacture. Distribution of remanufactured engines is strictly through the dealer networks. Quality is controlled rigidly to OEM standards, specifically enforced by the presence of BVP QA personnel on site. Remanufacturers such as Wealdstone are continually pushing for increased volumes of and ranges of models[19].

[17] http://www.remanufacturing.org.uk/resource-detail.php?report=43
[18] http://www.remanufacturing.org.uk/resource-detail.php?report=45
[19] http://www.remanufacturing.org.uk/resource-detail.php?report=47

Nextant Aerospace

Firm information
USA
2007
http://www.nextantaerospace.com
Product
Jet
Value Proposition
Nextant is the first aerospace company to offer com- pletely remanufactured aircraft, bringing to the business aviation sector all the associated advantages in lowered costs, competitive performance and improved customer experience. The company also promotes the benefits of remanufacturing for environmental sustainability.
Core Sourcing
The firm build their airplane using cores of old its own old plane versions, the firm draw the remanufacturing process and wrote "core collection" so we hypnotize that it simply recollect them from the market from its own customers without paying for them.
Business Description
Nextant Aerospace is recognized as the first company in the world to introduce aircraft remanufacturing to the business jet market. The Nextant 400XTi is a completely-rebuilt Beechjet 400A/XP with Williams FJ44-3AP engines and the Rockwell Collins Pro Line 21® integrated avionics suite. Nextant Founder and Chairman Kenn Ricci foresaw the potential benefits of remanufacturing when he established the company in 2007. His vision is now reality as Nextant produces aircraft that offer superior performance, a quieter and more spacious cabin and world-class reliability. Starting with some of the most popular and reliable airframes ever built, Nextant remanufacturing provides aerodynamic and engineering enhancements, state-of-the-art avionics and engines, advanced acoustic insulation, handcrafted interiors and custom exterior paint designs. The aircraft sell for roughly half the cost of new-build and produce significantly lower emissions to build and to operate. Its 200 employees remanufacture and upgrade Beechcraft aircraft, generating over $100 million dollars in sales annually[20].(Nextant and Aviation 2015)

Kyocera Documents Solutions

Firm information
Japan
1959
http://www.kyoceradocumentsolutions.com
Product
Copies machines
Value Proposition
To provide opportunities for the material and intellectual growth of all our employees, and through our joint efforts, contribute to the advancement of society and humankind.
Core Sourcing
Kyocera offer product as service, it leases its products and offer related services for them.
Business Description
KYOCERA is a diverse global corporation centred on core expertise in ceramics. One of the applications of ceramic technology is the manufacture of laser print drums that are far more durable than those made from other materials. This has enabled the development of an innovative print engine design where all functional parts are part of the printer, not part of the consumable. This avoids the need to repeatedly replace multiple working parts throughout the life of the product, thereby saving the raw materials, manufacturing, transport and waste emissions associated with those parts. KYOCERA has developed its own in-house ECOSYS3 process, which focuses on developing long-life products for the outset and uses an evaluation checklist to ensure each design meets specific standards. A durable, robust metal sub-frame provides structural integrity in a product that is designed for using long-life components. The design is upgradeable and modular upgrades are available to support changing customer requirements, avoiding the need to replace the whole machine when all that's needed is an extra paper cassette, for example. Care has been taken to design the product to enable easy serviceability through replacement of parts, to minimise the time it takes to repair and reduce down-time, and to increase the period between routine maintenance interventions(Sharon Prendeville & David 2016).

[20] http://www.nextantaerospace.com/corporate-media/press-releases/nextant-aerospace-becomes-first-aviation-company-to-join-the-remanufacturing-industries-council.html

Philips lighting service

Firm information
1981
Netherlands
http://www.lighting.philips.se/home
Product
Lighting System
Value Proposition
-
Core Sourcing
Philips has a Product Service System business model for the lightening system, thus it maintains always the ownership of the products and it is able to collect them at the end of their life.
Business Description
Philips offers lightening solution for municipalities and public or private companies. But instead of selling physically the products it sells only the use of it. The offer is differentiated in different packages. Each package has different prices and, thus, different services included. They also provide consultancy services to evaluate the impact of lightening on the overall cost of their customers and help them reducing the expenditures. Philips associate to this kind of selling products with a design that allows quick maintenance and remanufacturing. However recollection, remanufacturing and upgrading still represent a challenge for Philips designer as the kind of products (light and fragile) is not the best candidate for this kind of business (ResCoM 2016).

Roetz Bikes

Firm information
2014
Netherlands
https://www.roetz-bikes.com/
Product
Bikes
Value Proposition
At Roetz, we believe in second chances and pursue a circular and inclusive future. We don't judge a book by its cover: where others see waste and inability, we see useful materials and promising talent. At the Amsterdam-based Roetz Fair Factory, men and women with poor job prospects make new bikes from discarded ones. By hand and with pride. We train them to become skilled bicycle technicians and do everything in our power to help them find permanent employment.
Core Sourcing
Partnership with company that offers bike sharing or bike rental
Business Description
Roetz-bikes is a company that produces bicycles made from discarded bicycles. In 2014, the company started a pilot-project for NS (Dutch railways) to remanufacture the public-transport bicycle: bicycles that commuters can rent at railway-stations for follow-up transport. In the same year, NS had a total volume of 3000 rental bicycles across the Netherlands that were rented out 1.5 million times (that year), with 180,000 users. The bicycle has been specifically designed for NS. The bicycles are rented out for four years after which they are taken out of service. Goal of the remanufacturing project is to supply NS with remanufactured public-transport bicycles at a price that is similar to that of the new product. In addition, Roetz aims to achieve less malfunctions with the remanufactured design. In 2016, a new design will be introduced with integrated headlight and larger luggage. Also during remanufacturing, design improvements are implemented. For instance, the position of the lock was slightly altered to improve ergonomics, a saddle-lock (to prevent theft of the saddles) was added, as well as improved lighting without batteries. The selection of improvements is pragmatic, based on user experience reports. In the other bicycles that Roetz produces from discarded bicycles, they design the bicycles in a way that facilitates future reuse of parts, to which they specifically refer as an approach of design for remanufacturing(ResCoM 2016).

Gorenje

Firm information
1950
Slovenia
http://www.gorenje.com/
Product
Washing Machines
Value Proposition
-
Core Sourcing

Use of product service system business model

Business/Project Description

Gorenje Group is one of the leading European home appliance manufacturers with a history spanning more than 60 years. Its global presence is built on two brands: Gorenje, which includes the entire range of home products of the upper-mid price range, and ASKO, which is positioned as a global premium brand. An important division of Gorenje Group is 'Products and Services for Home' which produces and sells major household appliances, small domestic appliances, kitchen furniture and HVAC (heating, ventilation, and air conditioning). As part of the ResCoM case study, Gorenje's goRENT project is investigating the use of a 'pay-per-use' model. Featuring Gorenje's premium brand ASKO professional washing machine, goRENT is planned to launch next year. Gorenje is considering how modular the current product design is and what possibilities exist to improve the design to make it more viable to implement a multiple lifecycle concept. Gorenje has identified that it will be faced with a challenge to find the ideal business models for individual repairs in a large series production environment. A challenge in the product design phase is to account for additional requirements including serviceability and upgradeability[21].

Miele & Bundles

Firm information

2014

Netherlands

-

Product

Whasing machine

Value Proposition

-

Core Sourcing

Use of product service system business model

Business/Project Description

Miele is a company that work in the household appliances sectors that has among its product a washing machine that it sells to its customer at a medium high price. The main benefits that Miele offers as arguments for purchasing the W1-series are a long use life (2 years warranty extendable to 10 years with service certificate), innovative detergent dosage and high energy efficiency. The total costs of ownership of the Miele W1 is comparable to that of competing products in lower segments, the initial purchase price is higher. Since the purchase price influences a consumer decision more than long-term savings, a consumer might choose the less efficient machines that need replacement more often. To solve this problem Miele start a collaboration with Bundles. Bundles is a Dutch startup that bridges that gap by offering the use of Miele W1 machines in combination with extended user feedback, detergent, service and lifetime warranty in a package that is paid per bundle of washing cycles. The goal of Marcel Peters, founder of Bundles, is to prevent the sales of cheap washing machines that break and are scrapped within a few years by making a more durable device more accessible. In order to monitor the machine usage the firm design a tracking system to monitor the product performances linked to an App accessible also from the end users. The Miele W1 is apparently designed for efficiency and longevity but too little data has been published on the design process. The Bundles Buddy is a monitoring system that measures the power consumption of the Miele W1 to count the number of cycles and to deduce the load in the machine. An App that comes with the Bundles system alerts users when their behaviour could be improved to extend the product's use life. The Buddy data is also used to monitor malfunctions, predict maintenance and account any refunds if users stay below their bundle(ResCoM 2016).

[21] http://www.rescoms.eu/case-studies/gorenje