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Guidelines for the definition of innovative industrial product-service systems (PSS) business models for remanufacturing

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Abstract

Remanufacturing represents a well-suited approach for sustainable development in environmental, economic and social dimensions. Product-service systems (PSS) are among the most important enabler for remanufacturing. Companies that remain owner of a product have an intrinsic motivation to design goods for longer lifecycles considering the possibility of remanufacturing the product or its parts after each use phase. In addition, as the end customer only uses the goods without having its ownership, the acceptance – and consequently the demand – for remanufactured goods is significantly improved. This paper presents guidelines for the definition of innovative business models for remanufacturing, utilizing both remanufacturing and PSS characteristics, and permitting the dissemination of knowledge needed for successful implementation within a company strategy and operations model. Focusing on industrial PSS, an illustrative application of the guidelines is demonstrated.

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1. Introduction

Fulfilling the needs of more than seven billion people with the traditional means of value creation and manufacturing exceeds the world's natural resources.

Companies face the worldwide challenge of shorter innovation and product development cycles whereas the complexity of the products is continuously increasing. Nasr et al. link this development of shrinking product use cycles to the rapid technology turn-over, as seen for example in the cell phone industry. However, companies have to take into consideration that the resources available to meet these demands are limited [1]. As of today, mankind is already consuming more than one and a half time of the earth's bio capacity [2]. Therefore, there is a need to augment utilization of fewer resources to be achieved by product and material reuse, whilst being implemented in large scale within closed-loop economy systems. Target state is a maximum use of products with a minimum consumption of resources exploiting the remaining value of products at their end-of-life (EOL) [1]. Closed-loop economy implementation has become one of the leading ideas around manufacturing in the 21st century [3]. Different product recovery or EOL strategies are possible. The alternatives of reuse, remanufacture or recycle are distinguished with the following: the larger the loop, the less desirable is the alternative. Reuse can thereby be defined as "the second hand trading of products for use as originally designed" [4]. Remanufacturing can be described as product rebuilding preserving the added value encapsulated in the product during the original manufacturing process (e.g. labor, material or energy), whereas recycling attempts to recover only the material value [5], [6], [7], [8], [9], [10]. Remanufacturing recovers used products and turns them into a product with the same quality, functionality and warranty as compared to a new one [11]. Therefore, remanufacturing represents a very promising opportunity to contribute to sustainable value

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creation in environmental, economic and social dimensions. Potential benefits range from decrease in costs and resources exploited in production processes, reinforcement and protection of the brand image for original equipment manufacturers (OEM) to the protection of market share [12]. Through its participation to more consciousness in material use, remanufacturing will equilibrate the workforce losses in the extractive industry by skilled labor needed for better maintenance and tracking of products, in addition to the development of labor intensive post EOL activities [13].
Despite the evident benefits in environmental, economic, and social dimensions remanufacturing has not gained momentum in all industries and thus its potentials have not yet been fully exploited. Many companies are still reluctant to implement remanufacturing in their company strategy and operations model due to the associated challenges and uncertainties, such as product development, core supply, remanufacturing operations, product marketing, information flow and legislative or normative regulations. According to Barquet et al. product-service systems (PSS) are able to increase the value of products on their use phase, for instance by means of maintenance and technical upgrade, and on EOL phase through remanufacturing [14]. PSS is among the most important enablers for remanufacturing providing unique synergies to cope with remanufacturing challenges and complexity.
This paper presents guidelines for the definition of innovative business models for remanufacturing, utilizing PSS characteristics, and permitting the dissemination of knowledge needed for successful implementation within a company strategy and operations model. The research has been performed in the context of the project "Networking of Small and Medium Enterprises (SME) for Competitive Remanufacturing", which is part of "BRAGECRIM – Brazilian German Collaborative Research Initiative in Manufacturing Technology" [15].
This paper is organized in seven sessions. The context of the research is described in session 1. Session 2 explains the methodology carried out to reach the goal of the research. After that, a background covering the topics remanufacturing and PSS is presented in session 3. The guidelines for remanufacturing are described in session 4 and its application is addressed in session 5. Session 6 and 7 respectively cover the conclusions and acknowledgments.

2. Methodology

The methodology carried out encompasses four steps. Firstly, an extensive literature review addressing both remanufacturing and PSS was performed in order to identify the elements which characterize the synergy between both approaches. Secondly, structured interviews and industrial case studies were utilized to validate these elements. Thirdly, based on these elements, guidelines supporting the implementation of business models including remanufacturing and PSS, as cornerstones of a company's strategy and operations model, were developed. The guidelines are composed by two elements: business model dimensions and templates. The content of these two elements was collected by literature review and verified though experts' evaluation. A detailed explanation about the development of the guidelines is available in section 4. Lastly, the guidelines were utilized and evaluated during a workshop with academia and industry experts from the fields of remanufacturing and PSS. One of the business models developed during the workshop is presented in section 5. Feedback from the workshop was collected to improve the content and usability of the guidelines.

3. Background

The subsequent literature review addresses firstly the overall synergies of implementing remanufacturing and PSS. In a second step, based on industrial case studies the common elements and prerequisites for a successful implementation are described.

3.1. Remanufacturing and PSS as synergetic approaches

The majority of companies that have adopted the concept of PSS offer the use of a product, but not the ownership of the respective product. They generally provide additional services, such as the maintenance of products' functionality and the monitoring of its performance. If a product can then no longer perform according to its requirements, it has higher chances to be remanufactured and to be used again by the same or a different customer. This system satisfies shared goals of remanufacturing and PSS regarding product longevity, durability and performance [16].
Several studies have addressed services supplied throughout the lifecycle of physical products by means of remanufacturing and PSS. Kerr & Ryan [17] as well as Sundin & Bras [18] claim that this combination generates several advantages, such as environmental and economic benefits for both PSS providers and customers. For instance, OEMs who offer PSS are encouraged to extend their products' lifetime as long as those products satisfy additional profitability thresholds. At the same time, products which are commercialized as PSS provide remanufacturing companies a better monitoring over the EOL products supply, enabling them to better plan their corresponding remanufacturing operations [18]. OEMs can remain owner of their products and thus have an intrinsic motivation to design goods for longer lifecycles considering the possibility of remanufacturing the product or its parts after each use phase.
In addition, as the end customer only uses the goods without having its ownership, the acceptance – and consequently the demand – for remanufactured goods is significantly improved. In such an environment the possibilities for a successful implementation of remanufacturing are increased. Moreover, further research proved the economic advantage of combining remanufacturing and PSS based on the example of baby prams [19]. This study revealed that the synergetic approach yielded higher revenues per pram than the traditional pram business.
However, with regards to environmental gains some authors claim that there is no evidence that simply replacing product selling through service offering is enough. For instance, the roles and boundaries of each entity in the value chain (OEM produces, retail sells, user pays for the costs in the use phase of the product) may limit the potential for environmental improvements [20]. In addition, Tukker argues that leasing cases may even increase the environmental impact considering a potentially less careful attitude of the customers, if they are

no longer the owner of a product. To conclude, PSS adoption will not automatically result in environmental benefits [21].
Even though the literature presents possibilities of environmental advantages, in most of the cases companies decide to implement remanufacturing and PSS because of the potential economic benefits and competitive advantages to be reached, whereas the environmental potential turns out not to be considered [22]. To conclude, several benefits of adopting a PSS business model for remanufacturing can be found:

- Motivation for companies to extend their products' lifetime;
- Cost reduction throughout the value chain;
- Dependent on the case, potential for reduced environmental impacts;
- Increased acceptance of remanufacturing by the customers through leaving-out transfer of ownership;
- Better monitoring over the products, enabling the prediction of when the EOL returns to be remanufactured;
- Competitive advantages.

3.2. Common elements of remanufacturing and PSS

Barquet et al. carried out two case studies on manufacturing companies that included remanufacturing and PSS in their business models [14]. One of them is a machine tool OEM's subsidiary and the other is a vending machine OEM. Although the products' characteristics of both companies differ, their business models share similar elements. Examples of common elements are: long term contracts and relational type of customer relationships throughout the product's use phase [23], [24], revenues based on renting or leasing by means of monthly payments [25], value proposition based on guaranteed product availability, functionality and services [26], and main costs related to product maintenance during its use [27]. Mont et al. state that most PSS examples come from business-to-business markets [19], so called industrial PSS, which is the case of the two companies studied.
In addition, in both cases, a service technician is allocated at the customer's facility to perform activities within the customer business processes, in order to guarantee products´ functionality. This enables OEMs to obtain information about their products' performance during lifetime and meet clients' needs and requirements in due time. In addition, OEMs not only know when their products will retire, but can actively manage the product recovery in terms of timing and residual value and quality remaining in the product. Another common element concerns the importance of the service technicians' experience and know-how, which can be utilized within the development of new products, hence providing the OEM a competitive advantage. Yet, the two companies have services providers as close partners to support attending customers located in distant places. Finally, in both cases remanufacturing and PSS are considered as cornerstones of their business models.
Based on these two case studies, Barquet et al. derive the following requirements for a successful implementation of remanufacturing and PSS as synergetic approach [14]:

- Take-over of responsibility for operating some activities within the customer business processes;
- Utilization of service technicians' experience and know-how who are in the majority of cases allocated at the customer's facility;
- Partnering with companies supporting in the remanufacturing operations as well as in the supply of services;
- Placement of remanufacturing and PSS as cornerstones of the business model.

The next session presents the objectives of the guidelines creation, as well as the target group it has been defined for. In addition, the organization of the guidelines content is described.

4. Guidelines for remanufacturing

As mentioned in the introduction, the guidelines for remanufacturing constitute one result of the BRAGECRIM project "Networking of Small and Medium Enterprises (SME) for Competitive Remanufacturing" [15]. In this context, guidelines has been developed to suggest steps to be taken for creating business models including remanufacturing and PSS. The guidelines are composed by two elements: business model dimensions and templates. The templates are utilized for the definition of characteristics for each business model dimension, including both qualitative and quantitative information. A demonstration platform includes complementary information to assist users in filling the templates properly.
The company using the guidelines should be willing to implement new policies in the processing of EOL products, while searching for tutoring for an appropriate definition of what are the characteristics of the company's current business model to be modified. As demonstrated in the literature review, relevant aspects for PSS are described and highlighted as solution elements to be integrated in the company strategy. The guidelines target as well entrepreneurs wishing to integrate remanufacturing in their new venture creation. The guidelines are thus formulated to offer a broad vision of remanufacturing concepts and a personalized advice in defining business models.

4.1. Definition of business model dimensions

In order to comply with the objective of offering the user a broad vision of the necessary characteristics in a business model, the guidelines are organized according to business model dimensions. In this sense, the canvas business model has been chosen as a reference to define the primary structure for the guidelines thanks to its very simple yet complete structure. Moreover, this model has reached important dissemination in both industrial and academic environments [28], and is therefore widely recognized and accepted. The canvas business model is defined as a visualization tool allowing the creation of a business activity snapshot in a short time and by the means of a collaborative brainstorming action. Also, the model allows the user to represent potential evolutions to an existing business model through adapting the elements within every dimension of their business model. However, the canvas business model gives very little

information on how to bridge the business activity snapshot to an effective description and application of identified improvement measures. Therefore, the information required to fill the business model dimensions has been refined according to their relevance for remanufacturing in a PSS context and to the level of detail expected in a professional business model. The guidelines dimensions represent an improvement in this specific application field in comparison with the canvas business model as it aims at a precise evaluation of the quantitative and qualitative modifications needed to bring a strategy to its application. The guidelines dimensions, their content, the main type of information as well as examples of required content are summarized in Table 1.

Table 1. Content included in the guidelines dimensions

Guideline dimension	Corresponding Canvas dimensions	Main type of information	Examples of required content
1. Strategies	None	Qualitative	Profitability, market, environmental and legal drivers
2. Customer segments	Customer segments	Qualitative	Customer type, profile and price sensitivity
3. Value proposition	Value proposition	Qualitative	Type of services associated, product ownership policies
4. Customer relationship	Customer relationship	Qualitative	Customer proximity and participation within products' life cycles
5. Network	Channels, Key partners, Key activities	Qualitative	Actors involved in distribution and remanufacturing processes
6. Resources	Key resources	Qualitative and quantitative	Valuation of needed resources to perform remanufacturing
7. Revenue	Revenue streams	Quantitative	Estimation of sales over a 5 years period
8. Costs	Cost structure	Quantitative	Estimation of workforce and infrastructure costs
9. Business case	Revenue streams, cost structure	Quantitative	Profit and loss statement, investment plan

According to the type of information expected to describe every dimension of the business model, templates have been designed using a standard structure that is described in the next section.

4.2. Structure of the business model templates

Two types of templates were developed in order to enable the creation of business models. The first one, which defines the qualitative dimensions of the business model, is an interactive word document, available to be downloaded on the website http://bragecrim2.wix.com/remanufacturing. It comprises instructions to transform input information into the necessary qualitative outputs that should be created by means of the guidelines utilization. Examples of required content are listed in table 1, and can be consulted on a detailed level on the above mentioned website. Its customization through the user is the objective of the guidelines, as it will represent a structured and tailor made business model. In the first section of the word template, the user has to describe the main trends of his business model by selecting answers to closed questions. These questions and their answer options are defined according to their relevance for remanufacturing and PSS, identified as research results from scientific articles. To help ensuring the coherence of the options chosen, a system of hyperlinks has been included throughout the template in order to facilitate the navigation between attributes that influence each other, given they may be located in different dimensions. The second section of the word template aims at generating free output to complement the answer options chosen in the first section. The process to fill the second section follows a standard structure. After presenting a checklist suggesting activities to collect necessary input information, a list of tools is provided to facilitate a deeper analyze of important elements of a business plan. The result of this analysis constitutes the final content to be included in the business model and it is named free output.

In order to define the quantitative dimensions of the business model, a customized financial planning excel spreadsheet has been designed, which is the second type of template. This template contains the tools for the dimensions 6 to 9 as well as formulas to compute the essential profitability indicators for an economic assessment.

The financial business planning spreadsheet comprises the following elements:

- Information input is separated in four categories: general input, revenues, human resources and investment plan. The purpose of this first category is to collect quantitative information expressing the financial needs and revenues expectations from the user;
- Profit and loss statement, as a universal investment analysis tool has the purpose to compute whether the information input generates profits or losses over a five year period;
- The output charts serve as a control panel for the user as it shows a graphical interpretation of the main economic indicators from financial analysis, both reflecting the operational financial flows such as turnover and margins as well as investment evaluation such as the net present value (NPV), the internal rate of return (IRR) and the return on investment (ROI).

The quantitative results of the financial business planning allow more details in the establishment of a concrete business model than the one suggested in the canvas business model. It additionally includes projections over a period of five years to represent the expected evolution.

4.3. Procedure to create customized business models

In order to provide tutoring to the entrepreneurs targeted for the use of the guidelines, a website has been realized to accompany the user in the creation of the guidelines. The templates and further information on how to use them are available on the website mentioned on session 4.2.

The website comprises a knowledge database created to inform the user about theoretical aspects from remanufacturing, scenarios for the development of remanufacturing, case studies on remanufacturing in a PSS context, legal framework, networking classification, development of remanufacturing oriented products as well as the main barriers for the implementation of remanufacturing. This general information about remanufacturing aims at making the user aware of the advantages and drawbacks from companies that implemented remanufacturing as a whole and to motivate the usage of the guidelines for their specific case.

To allow a better use of the guidelines, an interactive instruction was created to present in a didactically manner how the guidelines should be utilized. Implemented in the Prezi platform [29], every interaction step is commented by the means of a recorded voice track. The user then has the possibility to navigate back and forth inside the instructions in order to repeat a track that may not have been comprehensively understood. Use instructions are also summarized in the guidelines dimensions navigation page, to ensure that the most important elements are understood.

Figure 1 summarizes the procedure described to create customized business models. The last part of the figure shows the generation of customized outputs. The procedure for generating free output is summarized in a standard scheme, showing what information to input, what tools to process the input information and what output is to be expected. Further, a documented explanation of the tools is provided to facilitate their usage.

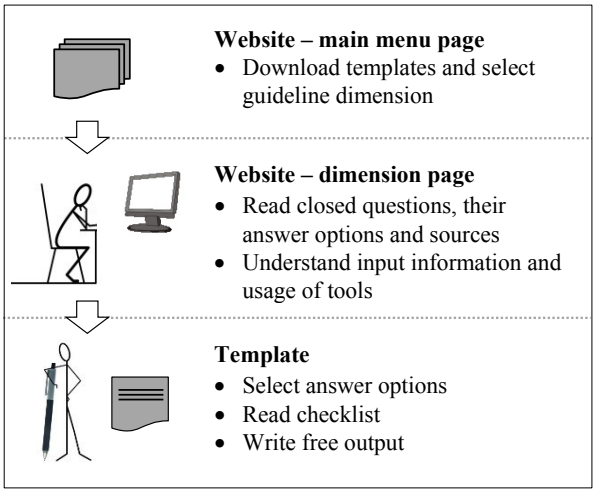

Figure 1: Interactions between the website and the templates

The objectives of the guidelines are then fulfilled. Along using the website, the user is accompanied by the guidelines to fill the templates.

5. Illustrative application

Within the 11th Global Conference on Sustainable Manufacturing (GCSM) [30], a workshop has been organized in order to test the guidelines with experts from the remanufacturing field with both industrial and academic experiences. The background information given to the workshop participants was a fictive case study for an industrial PSS case, representing a local vending machine manufacturer in Brazil required to design a strategy to face threat of new entrants in their home market. The participants were grouped in teams to define the business model of the fictitious company using the guidelines.

The results of one of the teams are presented in Table 2. As one purpose of the guidelines is to help framing the relevance of inputs, participants' discussions were based on the templates. These inputs were processed according to the methods suggested in the templates to obtain the expected outputs. Examples of specific inputs and outputs are respectively detailed on the second and third column of Table 2.

Table 2. Business model definition for the fictive case study

Guideline dimension	Inputs	Outputs
1. Strategies	Type of profitability driver; type of market drivers	Cost reduction and new market strategy through expanding the service offer
2. Customer segments	Type of customer segment; customer price sensitivity; profile of customer segment	National business-to-business niche market; high value added products; functionality oriented
3. Value proposition	Type of product and service package; types of services to be offered during the product life cycle	Total care package including installation, maintenance, repair and consumables management
4. Customer relationship	Type of customer relationship and contract; proximity level with customer	Vending machines provided under leasing contracts; strategic collaboration and information exchange
5. Network	Type of the core return system; types of product design strategies; actor responsible for remanufacturing	Centralized core returns; product design for multiple life cycles; remanufacturing controlled by OEM
6. Resources	Internal or outsourced execution of processes	Only distribution is to be outsourced
7. Revenue	Revenue estimations over 5 years period	Profit and loss statement
8. Costs	Yearly cost estimations, investment plan	Profit and loss statement
9. Business case	Profit and loss statement	4.2 years return on investment for the investments detailed

Directly after the workshop, participants were required to fill a survey to give feedback about their experience of using the guidelines. The evaluation provided by the users was generally very positive, with 80% or above of the participants evaluating the content organization, structure and visualization quality of the guidelines as satisfactory. Very encouraging comments were given from both academic and industrial members concerning the utility of such a tool in regard with the elements currently available for the implementation of remanufacturing

in a PSS context. Improvements proposed by the experts were mostly formulated concerning how to organize the information within each guidelines dimension in a more logical way, regarding input, tools and outputs. A second remark addressed the static character of the guidelines. Some of the experts believe it would be easier to navigate through it without necessarily following a specific order. This could provide the user more flexibility to fill in the template according to the information available, independently from which dimension comes first on the step-by-step. These remarks have been taken into account in the version of the guidelines presented in this paper, as well as in the actual version of the guidelines.

6. Conclusion

The guidelines were proposed as a web based tool to generate innovative business models for remanufacturing implementation in a PSS context in order to inform decision makers for these companies profile about the opportunities offered by an improved EOL management of their companies' products, while identifying what could be the best contribution of both remanufacturing and PSS. These considerations have been continuously driving the construction of the guidelines. Feedback from a workshop for applying and testing the tool with academy and industry experts was collected to improve the content and usability of the guidelines. Currently, the guidelines are being applied in a real case with industrial companies that intend to enter in the remanufacturing market. In this sense, more information about the benefits and challenges of using the guidelines will be generated and further improvements can be identified to upgrade the guidelines.

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