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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