OPEN ACCESS

Global Journal of Research in Engineering & Computer Sciences
ISSN: 2583-2727 (Online)
Volume 04| Issue 03 | May-June | 2024
Journal homepage: https://gjrpublication.com/gjrecs/

Review Article

A Comparative Study on the Purposes and Benefits of Remanufactured Products

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DOI: 10.5281/zenodo.11246668 **Submission Date: 18 March 2024 | Published Date: 23 May 2024**

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Abstract

Remanufacturing is the process of bringing used products and parts back to like-new, high-tech condition while using the least number of resources and money. Non-wearing parts are reused in a rebuilt product that integrates the technological advancements deemed necessary to guarantee that repairs can be completed promptly and the item is returned to functionality in an efficient manner. An overview of the remanufacturing process, its importance, and its contribution to sustainability are given in this review article. The scope and benefits of remanufacturing increase when industries adopt new technologies for component restoration, higher material recovery, and even the retention in-house of competencies that could have been outsourced previously.

Keywords: Opportunities, Sustainability, Remanufacturing, Reconditioning, Circular economy, Medical Equipment's.

I. INTRODUCTION

Remanufacturing was used in practice by the United States and the United Kingdom during World War II. Since all production facilities were dedicated to the production of military hardware, these countries produced neither automobiles nor replacement parts. Remanufacturing the outdated cars to keep them on the road was the only option left. This is how the concept is evolving. In the US, there are 70,000 remanufacturing companies that generate about $53 billion in revenue yearly [9, 10]. In today's competitive business environment, entrepreneurs are always looking for ways to reduce manufacturing costs, expedite manufacturing turnaround times, and improve manufacturing quality. Technology has been developed to meet these needs. Better technical solutions have made it possible to advance manufacturing procedures over the past ten years [11, 12]. Nevertheless, during the competition, environmental factors were ignored. One procedure that provides more sustainable and cost-effective options is remanufacturing. There are several reasons why remanufacturing is included, some of which are as follows: The process of taking products apart, cleaning, repairing, or replacing parts, and then reassembling them in a functional manner is known as remanufacturing. Stated differently, it entails repurposing waste materials to produce new products that are both aesthetically pleasing and functionally comparable to the originals. Although it is now commonly accepted as the industry term for this process, remanufacturing is interchangeable with a number of other terms, such as rebuilding and refurbishing [1–5]. Frequently, candidate products are moved to a production environment and disassembled there. Once cleaned, inspected, repaired, or reconditioned, the component parts are replaced as needed. Once the parts have been reassembled, the product is tested to ensure that it still meets its original performance requirements. Remanufacturing is the process of bringing a used item back to nearly new condition by recovering the value added to the material when the product was first produced. Remanufacturing reduces manufacturing costs and the amount of energy and materials used. In light of policies like the Landfill Directive (SD), waste remanufacturing has the potential to significantly contribute to sustainable development due to its financial benefits and positive environmental effects. The first industrial use of the technology was in tank remanufacturing during World War I. For a short period after the war, remanufacturing proved profitable for all UK automakers. Today, the remanufacturing industry is still largely specialized. Although Xerox, Flextronics, and Caterpillar

are three well-known international remanufacturers, much smaller companies handle the majority of remanufacturing. Most Xerox products are remanufactured in the USA by Flextronics, with a small amount occurring in Europe (Cosgrove, 2007b). In addition to providing a thorough analysis of the state of the UK remanufacturing industry and identifying possible future markets, the 2004 Oaken Hollins Ltd. (OHL) report Remanufacturing in the UK: A Significant Contributor to Sustainable Development highlights how remanufacturing can lower carbon emissions. This paper investigates the relationships between designs and remanufacture, building on the conclusions of the OHL report and supplementing some of OHL's analysis. The article from 2006 Nabil Nasr and Michael Thurston, "Remanufacturing: A Key Enabler for Sustainable Product Systems" Many products can be remanufactured, even though Erik Sundin's work in Product and Process Design for Successful Remanufacturing focuses on the details. This category includes a wide range of products, including cars, auto parts, electric motors, computers, office furniture, industrial equipment, photocopiers, and toner cartridges. Remanufacturing, however, has the longest history and the highest representation in the automotive industry today. The automotive sector accounts for two thirds of all remanufacturing activity. Different industry sectors may use different terminology when discussing remanufacturing. For example, reconditioned parts and systems are utilized in autos, whereas refilled parts are utilized in imaging devices like laser and toner cartridges. Other related terms that refer to essentially different processes are recycled, repaired, restored, and reconditioned. A recovered product that is made to look "like-new" is called a remanufactured product [18]. In reality, there are a lot of variables to take into account when thinking about product remanufacturing, including the carbon tax, production plan, recycling methodology, etc. Governments can encourage the production of remanufactured products primarily through two measures: production subsidies and carbon taxes [19]. examined how carbon taxes and carbon caps affected remanufacturing choices and suggested the best carbon policy for the scenario under consideration [20]. examined carbon tax and remanufacturing subsidy policies in a dual-channel supply chain that sells both new and remanufactured goods [21]. discussed a tax policy, a subsidy policy, and a tax-subsidy policy for a remanufactured problem, and designed a proper regulatory policy [22]. Considered both fixed carbon emissions and variable carbon emissions for remanufacturing products, and presented three production decision models.

II. RELATED WORKS

An increasing number of original equipment manufacturers (OEM) are engaging in remanufacturing as a means of competing with independent remanufacturers (IR) as the practice gains popularity and maturity. Customers' opinions of various products, OEMs' modular product designs, and the government's carbon tax policy all have an impact on the competition between new and remanufactured products in this complex environment of product line competition. However, it is unclear how these factors' interactions impact the environment, OEMs, and IRs' operational decisions. Therefore, a two-stage Stackelberg model with an OEM and an IR is established, taking into account consumers' perceptions of various products, and their optimal production and remanufacturing decisions along with profits are determined. Then, it is investigated how important elements (such as the carbon tax, the remanufacturer's identity, the modular design of the product, and the consumer's perception of the discount on the remanufactured product) affect their best choices and earnings. Additionally, the effects of product modular design and the carbon tax on the environment are investigated. The findings indicate that while other important factors, like consumers' opinions of the remanufacturer's identity and the discount on the remanufactured product, and product modular design, always help IR, carbon tax always hurts IR. The new product's profit, the remanufactured product's tax intensity, and the modular nature of the product determine how those factors will affect OEM, though. The environmental implications of improving the carbon tax and product modular design are related to the profit of the new product, the unit tax intensity of the remanufactured product, and the relative environmental impact of the new product, so they are not always beneficial to the environment. This study helps businesses make better decisions about production and remanufacturing in a complex environment. It also provides policymakers with guidance on how to best implement carbon tax policies to safeguard the environment and foster the expansion of the remanufacturing sector. This study adds to the still-small body of research on consumers' attitudes and intents to buy remanufactured goods in emerging economies. Additionally, since knowing what influences consumers' purchase intentions may help refocus marketing strategies to boost demand and competitiveness, the industry may gain from this work [7]. The willingness of customers to buy such products is a major factor in determining the efficacy of a closed-loop supply chain strategy for a viable circular economy. It's interesting to learn about consumers' attitudes and purchase intentions, though, as research has shown that consumers are dubious about these products. There is little evidence in the literature to support the claim that certain contextual marketing stimuli influence consumers' propensity to buy goods made using a closed-loop supply chain methodology. By investigating the impact of customer perceptions of seller reputation and distribution on the intention of consumers to buy a specific kind of these products—refurbished smartphones—this study seeks to close this significant gap in the market. This study integrates knowledge from prospect theory and the stimulus response model to achieve this goal. Results from structural equation modeling show that perceived value and risk are strongly correlated with customer importance of seller reputation and distribution, which in turn influences attitude and intention to buy refurbished goods. Furthermore, the results emphasize how important the attitude construct is to the model. The implications of these findings may help sellers, remanufacturers, and managers of closed-loop supply chains enhance their marketing campaigns and guidelines. In the long run, our theoretical model can assist researchers in better comprehending the thought processes that consumers use to assess

refurbished goods [8]. In order to optimize the use of remanufactured components in remanufacturing processes, this paper suggests a problem formulation and a concept that involves changing the bills of material for remanufactured products. The idea applies a dynamic mixture of new and remanufactured components to increase the number of remanufactured products while adhering to process and technical constraints (e.g., quality requirements, production and material planning). This is accomplished by implementing a dynamic infill of new parts. The utilization problem is decomposed into a general multidimensional knapsack problem and found to be a combinatorial optimization problem. A meta-heuristic is applied to optimize the resulting knapsack problem in order to find a workable solution for the use of remanufactured components. The idea is developed, tested, and validated with an automotive OEM in accordance with the case study methodology [14]. Remanufacturing is an important step in becoming carbon neutral. The literature that is currently available, however, demonstrates that consumer concerns about the quality of remanufactured products limit the remanufacturing industry's ability to grow on a large scale. There are few studies on the quantitative assessment of remanufactured product quality. Consequently, we suggest a quantitative model for assessing the quality of remanufactured goods. Based on Taguchi's quality concept, the quality loss function of remanufactured parts and assemblies was constructed, extending the formation process of the quality of remanufactured products. The relationship between the functional limit, social loss, and quality loss of remanufactured products was then evaluated. Consequently, a model for measuring quality was developed for remanufactured products. In addition, the neural network-based parameter estimation algorithm was assessed for handling the uncertain and dynamic nature of the remanufacturing market and remanufacturing technology. Ultimately, a case study involving a quantitative assessment of the quality of remanufactured engines illustrated how the suggested model could be applied. Feedback from the market confirmed the model's applicability. This article can offer decision-makers and practitioners fresh, practical tools and insights to raise the caliber of remanufactured goods and close consumer cognitive gaps. It is anticipated to quicken the remanufacturing sector's development toward excellence [15]. In order to support the sustainable growth of the remanufacturing industry, this study will examine how government subsidy policies affect the growth of remanufacturing businesses and product quality in relation to carbon peaking and carbon neutrality. It creates a game model that compares two scenarios of remanufacturing businesses that produce high- and low-quality remanufactured goods. We study how government subsidies affect the forms, prices, profits, and consumer preferences of remanufactured products when they are limited to high-quality remanufactured goods. The findings demonstrate that government support for high-quality remanufactured goods not only lowers wholesale and retail prices and lowers the quality cost of remanufactured goods, but also increases consumer preference for high-quality remanufactured goods, boosts remanufactured product demand, and encourages the remanufacturing industry's growth on a large scale. This study has significant practical value for achieving carbon peak and carbon neutralization goals. It offers theoretical and methodological support for the decarbonization and scale-up of remanufacturing and reduction of environmental pollution. It also helps governments formulate subsidy coefficients for remanufacturing enterprises [16]. While previous studies have applied the circular supply chain to a variety of industries, the rubber recycling industry has not yet been thoroughly examined. Consequently, in order to improve the framework of the circular supply chain utilized in remanufactured products, this study determined its essential components. In order to help businesses in the rubber recycling sector understand which way to go with the implementation of creating a circular supply chain for remanufactured products, this study proposed five aspects and nineteen criteria. This study proposed important factors, carried out the importance ranking, and combined expert opinions with the fuzzy Delphi method and the fuzzy decision-making trial and evaluation laboratory. The findings show that the circular supply chain's risk management (A2), enhancing the value of its resources (A4), and circular business model (A3) are important components. Optimizing the production process (C2), exchanging data throughout the product lifecycle (C4), efficiently tracking and recycling products (C5), redesigning remanufactured products (C13), improving resource efficiency (C16), and determining waste composition and material separation (C14) are the factors that the rubber recycling industry needs to focus on. In this study, we had a discussion based on the previously mentioned [17]. Remanufactured products are gaining a lot of attention due to the growing concern over resource shortages and environmental pollution. We build decision models for both the single-product and mixed-product markets to ascertain the best production and pricing strategy. The varying preferences of consumers for both new and remanufactured products are taken into account. Firstly, in order to find the best course of action, we build pricing models for a market with just one product and meet a judging condition. Second, we create a pricing model for a market with multiple products and present an argument against the multiple-product strategy. Lastly, numerical examples are created to investigate the effects of the two important variables and determine the prevailing areas for every tactic. We demonstrate the superiority of the remanufactured product when the additional demand drawn by the emission-saving is significant by introducing an emission-sensitive demand [23]. Since more stringent environmental regulations came into effect, remanufacturing has become more and more important. Remanufacturing is thought to be the primary way to promote a circular economy by maintaining value in used goods and componentry. It is more complicated than traditional manufacturing, though, because there are unknowns about the quantity, quality, and return schedule of used goods and components. In recent years, a number of techniques for improving remanufacturing results have been developed. These techniques include choosing the best end-of-life (EOL) options, obtaining the appropriate number of cores, selecting the appropriate level of disassembly, using appropriate cleaning methods, and taking into account product commonality across different product families. One remanufacturing activity's decision will have a significant impact on the decisions made at subsequent activities, which will impact the

remanufacturing outcomes (productivity, economic performance, effectiveness, and the amount of salvageable core). Thus, to close a significant knowledge gap and improve remanufacturing outcomes, a comprehensive approach to integrating various decisions across multiple remanufacturing activities is required. In addition to highlighting opportunities and challenges, this paper reviews current remanufacturing practices and, more importantly, provides helpful insights on how to close this knowledge gap [24]. Among the emerging technologies, artificial intelligence (AI) is an essential technology. It is essential for optimizing resource efficiency, particularly in the manufacturing and remanufacturing industries. These materials can be applied in various ways to improve material utilization, which not only benefits the environment but also has the potential to transform important remanufacturing procedures. Most notably, deep learning—a hierarchical method for deriving abstract concepts from data—is used in the inspection and process control applications to model these processes using AI-based techniques. In order to train a deep convolutional neural network, case-specific samples of product and component images are collected and utilized, for instance, in the application of deep learning models in post-cleaning process control. For additional processing, the model is used to categorize parts that are dry and parts that have water clogs. Furthermore, upon detection of wet samples in the real-time image feed, the process control initiates a different subsystem. During the post-cleaning inspection procedure, the torque converter (TC) system casings were used to test the deep learning-based system for inspection and process control. The developed model was tested using data that was obtained from Mackie Transmission Limited, a torque converter remanufacturing facility located in Glasgow, United Kingdom. A live video feed sample and an 80–20% train test split for the training and test samples, respectively, verify the model's generalizability. When tested on test samples, the model demonstrated 99% accuracy in identifying the components of the torque converter system, having been trained on an NVIDIA RTX2080 SUPER GPU. In addition, the process control application yielded a 99.9% prediction accuracy on the test set that was utilized to assess the model. These findings demonstrate that it is feasible to improve production during remanufacturing by utilizing digital technologies. By automating the post-cleaning inspection procedure, enhancing process effectiveness, and optimizing resources utilized to accomplish remanufacturing, this model can enhance remanufacturing inspection while reducing environmental impact [25].

III. REMANUFACTURED PRODUCTS

A key element of a manufacturing sector that uses resources efficiently is remanufacturing. Significant energy consumption and emissions to the air and water (such as CO2 and SO2) can be avoided by keeping components and the material that makes them up in use for longer. Remanufacturing offers advantages for the environment as well as chances for economic expansion and the creation of highly skilled jobs.

The salient features of a remanufactured product are outlined below.

1. To restore a used product to at least its initial functionality while providing a warranty that matches or exceeds that of a newly manufactured product.
2. It entails taking the product apart, repairing and replacing its parts, and testing each component separately as well as the entire assembly to make sure it still adheres to the original design specifications.
3. Remanufactured products are comparable to new products from the perspective of the customer.
4. Usually, a subsequent warranty is at least as good as the one on a new product.
5. It is anticipated that the performance following remanufacturing will meet or surpass the initial performance requirements.

IV. BENEFITS OF REMANUFACTURING PRODUCTS

1. **Local jobs**
   Even if a product was initially made abroad, remanufacturing offers the chance to create jobs locally because these operations typically take place close to the market.
2. **Higher profit margins**
   The profit margins on remanufactured goods are frequently higher than those on originally manufactured goods.
3. **Skilled jobs**
   Remanufacturing is a more satisfying job than production line work, a great place to hone problem-solving skills, and it keeps a lot of traditional industrial skill sets.
4. **New manufacturing techniques**
   Modern manufacturing processes, such as material traceability, lean techniques, and employee investment, are welcomed by cutting edge remanufacturers since they are essential to their company's success.
5. **Better customer relationships**
   Manufacturers who remanufacture products instead of relying on one-time, throwaway purchases can establish stronger customer relationships through trade-in programs [26].

Conclusion

Because of its inherent benefits of using less material and energy and creating second and third lives after the end of the original life, remanufacturing is becoming more important and the industry is growing at a faster rate. Remanufacturing encourages sustainable development by repurposing materials to create goods that function and look as well as original products [13]. This study included a systematic review of the literature, an explanation of the remanufactured product's goals, and a discussion of its primary advantages.

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CITATION
Abdullahi M.G, & Muhammad A. B. (2024). A Comparative Study on the Purposes and Benefits of Remanufactured Products. In Global Journal of Research in Engineering & Computer Sciences (Vol. 4, Number 3, pp. 21–26). https://doi.org/10.5281/zenodo.11246668