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Investment Decision Issues from Remanufacturing System Perspective: Literature Review and Further Research

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Abstract

Recently, remanufacturing has become very popular as one of the most efficient and effective strategies for economic, social and environmental "end-of-life" product management. However, the literature is not yet exhaustive in determining holistic remanufacturing investment inputs, processes and output requirements. This paper introduces a new definition of remanufacturing system to map investment decisions and provides a conceptual framework for remanufacturing investment decision making indicating alternative pre-inputs essentials based on the level of technology and types of companies; information and physical resources as input requirements; and direct and indirect outputs. Furthermore, the framework provides a foundation to conduct cost-benefit analysis for remanufacturing investment alternatives. Lastly, the study highlights the existing challenges and barriers in remanufacturing.

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1. Introduction

Remanufacturing is defined as the process of bringing used products to a like-new functional state with warranty to match [1]. Recently, like-new condition is additionally detailed to mean Original Equipment Manufacturer (OEM) performance specifications [2]. The remanufacturing sector is attractive because the price of a remanufactured product ranges from 30% - 40% of a new product with a profit margin amounting to nearly 20 - 30% with additional 55% profit arising from aftermarket activities [3, 4]. In the automotive industry, remanufacturing covers 70 % of all companies and has an annual turnover of 36 billion US$ [5]. Moreover, it was revealed that the energy consumption to remanufacture a product is less than 50%, while, labour force and raw materials are only 67% and 11.1% - 20 % compared to the production of virgin products [6]. In terms of quality, remanufactured products are not inferior compared with new products, but they are half as expensive as new ones [6]. Remanufacturing demonstrates some noted benefits in sustainability pillars. In the economic pillar the process requires a relatively small capital investment because no components are produced and most of the work has already been done by the OEM [7], cost saving is done by reducing the use of materials and energy [8]. In the environmental pillar the process is less harmful as it decreases pollution and solid wastes through safe disposal of substances [9]. In terms of the social pillar remanufacturing creates employment for nearly 500,000 people [5], stimulates constant training in different technologies, and it provides high quality products at a lower cost and with warranty. It also facilitates to achieve sustainable development in the countries [10]. Generally,

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remanufacturing is a process that has been revealed to be profitable and with high potential in the market for secondary use of remanufactured products [11]. Consequently, a large untapped market exists for product remanufacturers [12]. Therefore, a framework to help decision makers analyze and determine the level of investment needed for the untapped market is of paramount importance.

Remanufacturing is a complex business process due to the high degree of uncertainty, caused by two factors: the quantity and the quality of returned products [13]. With a high level of uncertainty on quantity and quality for the end-of-life returns, investors may find it difficult to plan, analyze, implement and consolidate the remanufacturing business. Such investment, which is a function of committed funds, inflation rate and future uncertainty [14], requires proper identification of factors for long term capital commitment; and making an investment decision must ascertain future benefits to be worthwhile [15]. There is therefore need to establish integrated decision tools to analyze and evaluate investment and decide on whether or not to venture into the business.

Presently, the most common tools in making decisions for any investment are Future Worth, Annual Worth, Rate of Return, Benefit-Cost Ratio, Net Present Value (NPV), Return on Investment (ROI) and Payback Period [16]. Investment assessment helps to identify risks and benefit among alternatives. However, decision makers can face difficulty doing investment analysis due to uncertainty and complexity which make analysis work tedious and time consuming. Uncertainty and intricacy are attributes of every investment decision, so the best way to mitigate such situation is to conduct analysis of cost and revenue implications for new investment [16]. In investment, the use of traditional appraisal systems such as payback, accounting rate of return, ROI, residual income, and discounted cash flow has been criticized as being too-narrow a perspective, excluding nonfinancial benefits, laying more emphasis on the short term and faulty assumptions about the status quo, inconsistent treatment of inflation, and promotion of non-value-adding behaviour [17]. Moreover, NPV also focuses on current predictable cash flows and ignores future managerial flexibilities, which may undervalue investment and mislead decision makers [18]. Discussing the criticisms, Kaplan [19] revealed that the weaknesses are functions of the users and not the techniques, and noted that the use of static discount rates is the mistake of the NPV user. Likewise, the inconsistent treatment of inflation, an overemphasis on the short term, faulty assumptions, and adopting a narrow view are users' errors. Investment decisions are sometimes viewed through a narrow decision-making lens, examined mostly from the single perspective of the investing organization. As such, decisions on benefits and costs that emerge outside that organization are often overlooked. The holistic view on investment analysis support recognition of qualitative and quantitative internal and external factors. Managers can do cost-benefit analysis on investment, but the bad thing is sometimes on fictional results on the benefits and costs [17] due to inaccurate or incomplete data, etc., but with the assistance of tools to imitate a human decision, it is easy to perform the analysis and build reference data for future decisions. Therefore, system investment analysis supports managers in more complex, more subtle and broader views of decision making [20, 21]. In investment, sometimes the chicken-and-egg situation exists with investors not knowing what, where, when, how much to invest and when is a return without knowing the investment requirements. Evaluation of viable investment alternatives as mentioned is still a barrier to remanufacturing. Determination of beneficial investment alternatives based on locations with different projected situations and the number of possible cost-benefit combinations in the future is practically infinite. Unfortunately, these challenges still exist and often encourage decision makers to avoid investment in some areas.

The process of evaluating investment alternatives is becoming more complicated due to a number of factors, including uncertainties and lack of skills or time, hence decision makers resort to less accurate and informal evaluation methods [21]. Uncertainty about timing and quantity of returns, materials recovered and highly variable processing time is a result of lack of appropriate information on material flows and its forecasting [22]. However, there is a lack of analytical tools for guiding firms in remanufacturing decisions and the positioning (pricing) of remanufactured products [1]. Different characteristics of end-of-life products add uncertainty and complexity of the vehicle system. For example, they make the decision to be difficult due to variability of product quality and quantity [11]. Hence, despite the potential of remanufacturing, there is the lack of a structured and holistic investment decision framework to guide investment analysis. However, a few attempts have been made. For example, Coates [24] designed a decision support costing system to understand the economics of vehicle recovery of future investment; Ho and Liao [18] evaluated mean value of the fuzzy NPV of investment projects; and Staikos and Rahimifard [25] also proposed a decision tool to calculate economic value of end-of-life shoes. Although many good examples of isolated investment decision tools can be found in remanufacturing (such as strategic, economic, and analytical), developing simple and more viable decision making tool which supports the use of multidisciplinary knowledge is necessary. Therefore, this study proposes a conceptual framework to support investment decision makers by considering the remanufacturing system perspective.

2. The Remanufacturing System Perspective

The growing recognition of remanufacturing researches and practices promotes collective struggle towards economic, social and environmental issues to the end-of-life product. Unfortunately, different definitions of remanufacturing in circulation distort the context and create confusion. It has been mentioned that before adopting the definition by British Standards Institute in 2010, definitions of remanufacturing were ambiguous and inadequate, creating confusion among researchers and practitioners [26], leading to a generation and dissemination of incorrect data and knowledge. On the other hand, having no high-level honored definition nurtures risks for importation of dubious quality, hence creating fears among developing nations that remanufacturing could be a style of

waste disposal from developed nations or an oppressive mechanism to suppress native industries in developing nations [26]. Many people still cannot see any difference between remanufacturing, repair and reconditioning, to the extent that some customers refuse to buy remanufactured products because they lack assurance of quality [27]. In an effort to elaborate the concept, Zwolinski and Brissaud [28] categorize remanufacturing in terms of costs, technology, environment and market. However, in the automotive industry, there is a discussion on differences in the terms "rebuilt" and "remanufactured". Some argue that there is no difference as "remanufactured" describes the sophistication of industry growth while "rebuilt" reflects the process of restoring used parts [29].

The extension of the definition for remanufacturing as a set of dynamic and interdependent systems with input, process and outputs still needs to include internal and external factors. The systems are open, containing smaller and larger systems with definite objectives and complex structures. Since a system is larger than the sum of its parts, the investigation of any part of a system should involve it as a whole. Remanufacturing starts with the collection of core processes and product delivery to the client [30]. Recently, numerous scholars have defined remanufacturing in the context of systems with inadequate coverage of outside company boundary. Some definitions are: *the industrial manufacturing of "good as new" products from used and returned products [5]; the process of bringing used products to a like-new functional state with warranty to match [1] and an assembly to like-new condition through replacing and rebuilding its components at least to current specification [4]*. Ortegon et al.,[2] elaborated further, like-new condition to meet performance of OEM specifications.

The cited definitions show that remanufacturing is part of the concept which reflects processes within a company's boundaries. A system-based definition shall consider the firm out-boundary activities [30]. According to Barquet et al. [31], remanufacturing system comprises of six elements, namely: Design; Reverse supply chain (RSC); Operation; Sales; Information flow; Labour knowledge and skills. Therefore, these elements are consolidated and organized in terms of input, process, output and services to enrich understanding of remanufacturing steps. Figure 1 depicts the interactions and interdependence among the elements to comprehend and consolidate holistic input (design, labour and RSC), process (operations) and output (sales) activities networked with forward and reverse information flow.

Remanufacturing inputs comprises information flow and resources. The proposed system signifies that information for technical, legislative, and business is critical. Moreover, remanufacturing is centered in its heart of initial performance by having fixed and variable resources.

Remanufacturing process refers to operation stages such as inspection, disassembly, cleaning, sorting, testing, upgrading, reassembly and testing [1]. Remanufacturing can be classified into internal processes with highly variable processing times

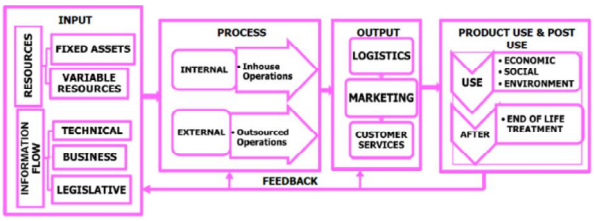


Figure 1: Holistic remanufacturing system perspective

and uncertainty in a number of factors [32] and external processes which coordinate input with output (products) from the remanufacturing process.

Remanufacturing output is characterized by tangible product and intangible service realized by customer as direct or indirect output. Environmental, legislation requirements, training, and after-sale service are indirect outputs. It is important for companies to consider direct and indirect output such as distribution and an end-of-life product treatment.

3. The Proposed Conceptual Framework for Remanufacturing Investment Decision Making

A holistic decision making framework for sustainable remanufacturing is timely, needed to ensure the completeness of the investment analysis, such as a financial decision [33]. However, lack of reliable and precise information about quality of core, location, market, labour and technology will increase remanufacturing cost [34]. Hence, there is need for a conceptual framework to stimulate thorough thinking to input requirements, internal and external process drivers, and direct and indirect outputs diversity to cover the system perspective from tail to head and compliment "one size fits all" (Figure 2). The proposed system (in Figure 2) illustrates information and physical resource requirements; level of technology and type of companies; and forward logistics, marketing issues, customer services and end-of-life treatment. The developed system is unique as it comprises of internal and external factors of companies' boundaries and support managers to continuously perform investment analysis before, during and after remanufacturing. This framework maps remanufacturing and captures the necessary requirements for investment analysis. Therefore, from a system perspective, remanufacturing can be defined as:
…. the determination of pre-inputs essential for collection of information and resource inputs, process to upgrade used products to meet original function specifications and deliver services to satisfy customers' requirements as it was originally.

The proposed conceptual framework will address holistic issues reflecting a continuous decision making process on input, process and output. Remanufacturing investment decision-making occurs early after the company has established its vision for sustainability together with the end-of-life priority decision to reuse, refurbish, recycle, incinerate, or dispose product while considering factors such as information and resources, types of company, technology, product logistics, marketing, customer and end-of-life treatment.

Besides these factors, investment cost-benefit analysis needs to be done early in the conceptual development stage by iterating phases to determine 1) optimal input parameters, 2) internal and external processes, 3) product outputs scenarios, and 4) product use and post use treatment. The optimal input parameters will direct the company on technology and processes for remanufacturing. At the output stage, different scenarios in the distribution, marketing network and varying demand will be analysed. Each scenario will be considered as unique; hence, analysis to estimate and compare the costs and benefits of an undertaking will be conducted. However, analysis of the phases might be changed or adjusted in order to provide flexibility for the type of product and guide decision on investment viability. The adjustments and changes could be attributed, among other factors, by resources, type and size of company, technology, nature of operations and, the presence of legislation in respective area.

4. Key Attributes of a Remanufacturing Investment Decision

The simplest way to analyze investment is to start by considering the pre-input requirements. The pre-inputs essential introduced in this study are level of technology and type of company which guide to identify promising resources for the remanufacturing systems. Most of the studies in remanufacturing investment assume the existence of big firms and availability of technology in their manufacturing process. The assumption might prohibit investment to some of the areas like developing countries where the nature of the company is relatively small and technology is lacking. The key pre-input and input attributes which influence decision making in remanufacturing process and output are discussed below.

4.1 Remanufacturing Companies and Level of Technology

In remanufacturing, processes can be structured in different ways. However, in this study processes are based on types of companies and level of technology.

4.1.1 The type of Remanufacturing Companies

Remanufacturing companies are classified into four groups, which are:

1. *Original Equipment Manufacturer-Remanufacturing (OEM-R)*

OEMs are companies which remanufacture products initially produced by the same companies. OEMs enlighten consumers to perceive similar products because of the same functionality, product style and conformity to specifications [35]. Other benefits include savings in labour, material and energy costs, shorter lead times, new market opportunities, and positive social image [36].

2. *Outsourced (Third Party) Remanufacturer (Outsourced-R)*

The outsourced remanufacturer is an independent company with a relationship to the OEM but operates in autonomous business model. The outsourced gets advantage of product information, easy access to core, technology secrecy, warranty to use the brand name, bypassing intellectual property rights (IPR), and staff are sometimes trained by the original equipment manufacturer [27, 37].

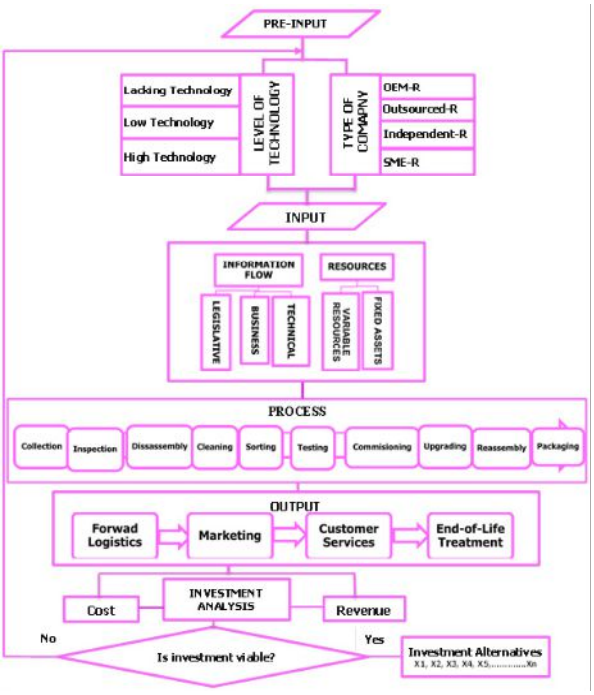


Figure 2: Conceptual framework for remanufacturing investment analysis

3. Independent Remanufacturer (Independent-R)

This is an independent company which receives core directly from customers and the community. These firms sometime obtain technical information on products by reverse engineering or by resorting to industrial espionage [27]. Independent remanufacturers are competitive companies, and their products can have a wide range of quality levels to fit the market in developing and developed countries.

4. Small and Medium Enterprise-Remanufacturer (SME-R)

Small and medium enterprises (SME) are differentiated from other companies based on their level of operations with little capital, few staff, low production volume, etc., unlike large multinational enterprises, with high production volumes and economies of scale. In some countries, SMEs have a significant minimized landfill size and energy usage [38], therefore, they have a great opportunity to salvage environmental pollution and improve economic and social value.

4.1.2 Level of Technology

The selection of level of technology is quite critical as the remanufacturing process may become technologically infeasible due to lack of expertise and technical know-how [39]. Technologies are multi-dimensional constructs and require identification of competences to make investment decisions. Hence, technology options to determine operational performance are categorized into three levels:

1. Lacking technology: remanufacturing process with hundred percent labour intensive [38].
2. Low technology: process with relatively low technology, thus, labour involvement is high [40].
3. High technology: process uses advanced technology thus shortening dismantling time [41].

The selection of technology assists the economic and effective implementation of remanufacturing considering

criteria such as cost, quality, time, service, resource use and the environment [42]. Thus, it is essential to make informed choices of level of technology prior to remanufacturing.

4.2 Physical Resources

The resources in remanufacturing are divided into two main groups based on fixed and variable cost: 1. Plant, land, buildings, etc., and 2. Core, labour, utilities, etc. These resources entail a long term commitment in which it is difficult to overcome mistakes. A poor choice of plant location, for example, might result in excessive transportation costs, shortage of labour and suppliers, loss of competitive advantage, and other uncertainty conditions. In the selection of optimal location, criteria such as size of land, labours, suppliers, utilities, and core need to be considered. Uwe Gotza [15] analyzed investment alternatives, thereby guiding managers to formulate a decision structure and breakdown using qualitative and quantitative criteria. It is essential to evaluate sufficient resources before deciding to invest.

4.3 Technical, Business and Legislative Information

Reduction of uncertainty on investment depends on accurate investment data which support analysis for decision making. In this study information is categorized into technical information, business information and legislative information.

4.3.1 Technical Information

Technical information mainly focuses on product characteristics embedded to the end-of-life product such as product structure, quality tests, valorization, and refurbishment [28] but also includes materials used, useful lifetime, design features, technologies, product design, function features, warranty, and legislations. In automotive, the existing technologies are internal combustion engine, electric and hybrid vehicles. Information on the specific technology used to produce a product has great influence in determining input resources and process requirements such as machinery. Therefore, it is vital to get information on technical, functional and design before remanufacturing.

4.3.2 Business Information

Competitive firms should be aware of vital business information such as price, taxes and competitors. Numerous studies mention the role of information in remanufacturing. Lee et al. [43] developed a framework for capturing, retrieving and analyzing information for the end-of-life product. Kumar [44] discovered that the return rate of vehicle which has reached its end-of-life varies between 5%-25%, due to poor information flow and other factors. Ward and Zhou [45] revealed that missing, incorrect and outdated data can lead to poor decision in investments. In Malaysia, for example, users of vehicles are increasing by 25% with an estimation of 40,000-50,000 vehicles reaching retiring age, thus creating a management problem as landfill cannot accommodate them [46]. Such potential information provides opportunity for investors to engage in remanufacturing business.

4.3.3 Legislative Information

Information on legislation such as an intellectual property right of a product, protection of importation of core, take back policies and patent rights are important before making an investment decision. In some countries there are penalties, fines, and legal costs for not complying with take back policies. Intellectual property (IP) protection in other countries is also a major concern whereby the use of patent license fees will result in an efficient allocation of excess profits from product remanufacturing [47].

5. Challenges and Barriers to Remanufacturing

Beside the mentioned benefits, there are challenges in remanufacturing which are yet to be resolved:

1) Protection of intellectual property (IP) is a major barrier to remanufacturing business [48].
2) Risk of OEM losing IP when remanufacturing is carried out by other firms [49].
3) Prevention of importation of the core leads to scarcity in the local market, hence companies choose a recycling approach to meet regulations and ignore remanufacturing as an opportunity [50].
4) Negative perceptions of customers that remanufactured products contain used parts, lead consumers who are not ready to pay less to regard the products as of lower quality [51].
5) Cannibalization of the market and sales for new products by remanufactured products due to low prices is a major impediment for OEM to engage in remanufacturing [52].
6) Managers are getting inaccurate perception of the financial performance of remanufacturing because accounting techniques are not well developed [8].

6. Conclusion

The review paper helps to understand the remanufacturing input, process, and output. It provides a conceptual view on input requirements for the remanufacturing system to assist information flow and resource analysis for investment decision. It has described the level of technology and actors in the remanufacturing process with their merits in business. The study has also introduced the concept of remanufacturing investment analysis, outlining its key issues to be considered. The review shows that holistic investment decisions are suitable for mapping remanufacturing system to assess investment routing in terms of process technology and companies and ultimate cost and benefit analysis. Remanufacturing has been characterized from its significance as more profitable and less harmful to the external environment than conventional manufacturing processes. With benefits listed, remanufacturing is still hampered by operational and management barriers such as uncertainty in the quality, quantity and availability of cores, complexity of decision processes in terms of timing and place for investment. Lack of well-developed accounting system techniques gives the decision makers inaccurate perception of the financial performance of remanufacturing, therefore misleading decision-making in investment. Hence, there is need for practical scrutiny of the specific remanufacturing system and the development of new decision tool to support analysis in remanufacturing investment.

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