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Analytical Research on Operational Issues of the Remanufacturing Process in India

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Abstract
Environmental awareness among the masses compelled many companies to adopt sustainable practices in their business operations. Remanufacturing is a well-tested and successful business model practiced in many European countries. But in many African and Asian countries, it is still nascent, including India. This research study tries to identify the critical factors in the "Operational Management" area for the viability of remanufacturing business in India. For this purpose, a questionnaire was developed based on the important factors identified from the extensive literature review. An online questionnaire survey was conducted among Indian white goods appliance manufacturing companies and their suppliers. The responses were analyzed statistically and ranked based on their criticality in initiating remanufacturing business in India. The findings may help the Indian government and manufacturing firms to frame proper strategies related to the operational management issues of remanufacturing business in India.

Keywords
Remanufacturing; Barriers; Operational management; Production planning; Assembly and disassembly.

Introduction

As the population grows, non-renewable resources are depleted at an increasing rate. This leads to the exhaustion of non-renewable resources. Additionally, the depletion of non-renewable resources destroys the ecosystem and pollutes the environment. Because of environmental issues, the government and manufacturing companies are compelled to include product recovery operations in their business plans. Remanufacturing is one of the most effective methods and is concerned with the process of product recovery. Additionally, it is a value recovery process where old and discarded products, components, and parts are put through a series of value-adding processes to make them into reusable ones (Lund et al., 1996). It is different from recycling, reconditioning, refurbishing, reusing, or repairing, but it may involve some or all of these processes. More of the energy used to create finished items from raw materials was retained during this process (Nasr et al., 2006). Preventing waste material incineration and landfilling indirectly protects the ecosystem (Russell & Nasr, 2020). Alternately, it promotes a circular economy through resource conservation, waste reduction, energy efficiency, and economic growth (Reike et al., 2018). Thus,it can be said that remanufacturing plays a key role in realizing the goals of a circular economy.

Although the top three global remanufacturers are Caterpillar, Xerox, and Flextronics, most of the remanufacturing is done by much smaller companies (Gray et al., 2006). Several companies, including IBM, Fuji Film, Kodak, BMW, Volkswagen, Honda, and Ford Motors, have been actively involved in remanufacturing for more than twenty years (APEC, 2013). Remanufacturing has been successfully adopted as a lucrative business alternative in several nations, including the United States, United Kingdom, Japan, Denmark, etc. (Thierry et al., 1995). However, this technique is still in its adolescent stage in many African and Asian nations, including India (Sinha et al., 2017). Western nations have published numerous research papers in remanufacturing-related journals (Govindan et al., 2019; Vogt Duberg et al., 2023). However, very little research has been conducted in the Indian context, particularly with regard to "Operational Management" issues in remanufacturing.

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Taking into account of India's enormous population base, the remanufacturing industry has enormous potential to flourish. The major considerations for evaluating the demand for remanufactured goods include a rapidly expanding middle class, a stable economy that is focused on the market, the availability of trained labour at a reasonable cost, reasonably well-developed credit and financing facilities, and an affordable local supply of almost all raw materials. Low maintenance and ownership costs are important to Indian consumers (Sinha, 2013). For the vast majority of Indian buyers, these are the purchasing factors that matter most.

According to the aforementioned facts, India possesses all the favourable conditions, including a market with tremendous growth potential, a demand for remanufactured goods, and a market that is price sensitive (Sinha, 2013), to start a remanufacturing business. With this backdrop, this study attempts to find the answers to the questions below.

I. What are the operational management factors considered critical for the viability of remanufacturing business in India?
II. Prioritizing these factors as per their importance in taking up remanufacturing business in India.

This research paper comprises six sections. The first section discusses the remanufacturing process, its current status in India, and the objective of the study. The second portion reviews the literature on remanufacturing operational challenges and identifies factors for conducting research. The third section discusses the research methodology that was used in the research study. The fourth section focuses on data analysis, where critical factors are identified and ranked based on their importance in remanufacturing activities. The fifth section is the result and discussion based on data analysis, and the sixth is the conclusion.

Literature review

The process of remanufacturing includes a number of steps, including disassembly, cleaning, inspection, reconditioning, reassembly, and testing. Figure 1 shows a flowchart of the steps in the remanufacturing process.

The remanufacturing process begins with the acquisition of client returns or cores. These collected cores are transported to the remanufacturing facility for further processing. To maximize the flow of returns, the facility should be situated optimally (Jayaraman et al., 2003). These used products are completely dismantled down to the component level, followed by a thorough inspection. The disassembly operation for remanufacturing needs to be non-destructive. To prevent the pieces from breaking, proper sequential disassembly should be used. Permanent fasteners, oil/dirt, and corrosion/rust are the most frequent problems that slow down and increase the cost of disassembly (Hammond et al., 1998). The disassembled parts are cleaned properly to remove the oil/dirt and rust content on it.Several techniques are used to clean the parts, including sandblasting, water jet cleaning, ultrasonic cleaning, and gasoline cleaning (Guide et al., 1999). The next step in the process is inspection, where clean parts are thoroughly examined to ascertain the component's condition.Along with non-destructive testing methods like dye penetrant, magnetic particle, Eddy current, and ultrasonic procedures, visual inspection is frequently utilised. The recovered part must fit, function, and meet the reliability criteria and safety requirements as specified, and it must have a residual life that is at least equal to its design life (Gray et al., 2006). In the reconditioning process, various manufacturing operations like milling, turning, grinding, heat treatment, welding etc, are performed to bring the used components into working condition. The parts which cannot be repaired are replaced by new ones to make the component as sound as or even better than earlier. The Reassembly operation is almost the same as that of the assembly process except the components/parts used are carried out with a combination of recovered parts, new parts and some mandatory parts. The tools used are the same as were used for assembly operations of new products (Guide, 2000). The production line is likely to be lowered in the remanufacturing, as reassembly takes place on small batch assembly lines (Golany et al., 2001). Finally, testing of remanufactured products is performed which is similar to that used on newly manufactured products. Remanufacturer uses 100 per cent inspection testing of the remanufactured finished goods, which may be higher than a new manufacturer who may sample a percentage of the products for test-

Fig. 1. Remanufacturing Process (Priyono., 2015; Sinha & Rao, 2023)

ing (Hammond et al., 1998). Table 1 consists of the list of important factors discovered through a literature review in the field of operational management.

These identified factors will be taken into account while creating a survey questionnaire in the subsequent section. The description of these factors is given as follows. Storage facility location (F1) is deciding about the location of storage facility for storing used products. Space required for storage (F2) is deciding about the space required for storing used products. Balance of demand with returns (F3) is establishing the balance between the demands of remanufactured products with the supply of cores. The lot sizing problem (F4) is deciding about the inventory lot size used for replenishment during assembly operations. Uncertainty in demand (F5) is the uncertain demand for the remanufactured product that arises at the customer end. The problem in buffer stock maintenance (F6) is the difficulty in managing buffer stock of used products during remanufacturing. MRP-based system

Table 1
List of important factors under operational management

S. No.	Factors	Notation	Reference
1	Storage facility location	F1	Jayaraman et al., 2003
2	Space required for storage	F2	Jayaraman et al., 2003
3	Balance of demand with returns	F3	Guide et al., 1999; Jing et al., 2014
4	Lot sizing problem	F4	Golany et al., 2001; Baki et al., 2014
5	Uncertainty in demand	F5	Fleischmann et al., 2003; Jing et al., 2014
6	Problem in buffer stock maintenance	F6	Minner., 2001; Naeem et al., 2013
7	MRP based system	F7	Ferrer et al., 2001; Kenne et al., 2012
8	Location of remanufacturing facility	F8	Jayaraman et al., 2003
9	Technology for remanufacturing	F9	Guide, 2000
10	Uncertainty in quality and timing of parts return	F10	Guide et al., 1999; Cai et al., 2014
11	Disassembly sequence	F11	Hammond et al., 1998
12	Lead time variability	F12	Kiesmuller et al., 2003
13	Parts matching problem	F13	Guide et al., 1999
14	Complex scheduling & capacity planning	F14	Guide et al., 1997; Benedito et al., 2013
15	Skill of employee	F15	Hammond et al., 1998
16	Homogeneity in product	F16	Hammond et al., 1998
17	Complexity in product design	F17	Hammond et al., 1998
18	Design for remanufacturing	F18	Gray et al., 2006
19	Corrosion/rust on used products	F19	Hammond et al., 1998
20	Dirt/oil on used products	F20	Hammond et al., 1998
21	Testing and inspection	F21	Hammond et al., 1998
22	Tolerances for wear	F22	Hammond et al., 1998
23	Type of material used	F23	Hammond et al., 1998
24	Defining specification	F24	Hammond et al., 1998
25	Fragility of parts	F25	Hammond et al., 1998
26	Destructive disassembly required	F26	Hammond et al., 1998
27	Assembly/disassembly problem	F27	Guide et al., 1999
28	Reliability of product	F28	Gray et al., 2006

(F7) is a materials requirement planning system used during remanufacturing. The location of the remanufacturing facility (F8) is deciding about the geographical location of the remanufacturing facility. Technology for remanufacturing (F9) is the machinery and equipment used for remanufacturing process. Uncertainty in the quality and timing of parts return (F10) is related to the vagueness in the quality and timing of return products. Disassembly sequence (F11) is about the sequential steps to be followed during disassembly of the cores. Lead time variability (F12) is the variation in the lead during remanufacturing operations in subsequent cycles. The parts matching problem (F13) is the difficulty in parts matching during the assembly process. Complex scheduling & capacity planning (F14) is related to the difficulty in properly scheduling the remanufacturing activity and deciding about the production capacity. The skill of employee (F15) is the technical skill set required by the employee for performing the remanufacturing activity. Homogeneity in product (F16) is uniformity in the shape and size of the used products. Complexity in product design (F17) is the complicated design used in designing the product. Design for remanufacturing (F18) is the design of the product for multiple-time usage. Corrosion/rust on used products (F19) is the availability of corrosion and rust on used products. Dirt/oil on used products (V20) is the availability of dirt and oil on used products. Testing and inspection (F21) is the process of testing and inspection performed on cores. Tolerances for wear (F22) are the allowable tolerances provided for wear and tear of the products. The type of material used (F23) is related to the physical characteristics of the materials used for manufacturing the components. Defining specification (F24) is related to the designing specifications of the components. The fragility of parts (F25) is related to the damage that occurs during handling and movement of cores. Destructive disassembly required (F26) is the process of disassembly in which a product loses its identity. The assembly/disassembly problem (F27) is the difficulty associated with assembly and disassembly operations during remanufacturing. The reliability of the product (F28) is related to the proper functioning of the remanufactured product when operated.

Methodology

In order to determine the likely factors under the "Operational Management" category that can be viewed as barriers to starting remanufacturing operations, a questionnaire survey approach was adopted. A series of questions pertaining to the factors thought to be critical for starting remanufacturing activities make up the survey instrument. A questionnaire is created based on the literature review in order to survey Indian manufacturing companies. These companies include both original equipment manufacturers (OEMs) as well as component suppliers. The questionnaire set included a total of 28 closed-ended questions (see Table 1). On a 5-point Likert scale, 1 represents the factors of initiating remanufacturing activities that are least significant, and 5 represents the factors that are most important. The respondents were asked to rate each item based on how important they thought it would be to start a remanufacturing business in India. Google Forms were used to conduct the questionnaire survey among the company's employees online.In all, 459 questionnaires were sent to employees of manufacturing companies that comprise the population. The responders' job titles ranged from manager to supervisor. Only 72 responses, representing the sample size out of 459 were received.Of these, 25 are original equipment manufacturers and 47 are component suppliers located in eastern and northern India. They are primarily engaged in the production of white goods appliances and the supply of their parts. Microsoft Office Excel 2010 and SPSS software (version 23) were both used for data analysis. First, a one-sample t-test was performed using the SPSS statistical package to determine the importance of the factors. The selected factors were then taken for additional analysis to provide the rank based on the relative importance index approach using MS Excel.

Data analysis

Table 2 displays the descriptive statistics for each of the 28 factors that were obtained from the questionnaire survey. Then, one sample t-test was carried out to determine the t-statistics values from the data to test whether a factor is considered to be significantly important or not, i.e., the mean value being greater than or equal to 3.

Factor F17 had the highest mean value and factor F25 had the lowest, whereas F5 had the highest standard deviation and F17 had the lowest. Taking into account only significantly important factors with mean values of at least three using t-statistics. As a result, fourteen critically important factors were identified and are shown in the last column of Table 2 with an asterisk. These fourteen factors are taken for further analysis and ranking based on their frequencies.

Table 2
Descriptive statistics of factors under the operational management category

S. No.	Issues	Notation	Mean	Std. Dev.	t-values
1	Storage facility location	F1	3.111	0.640	1.472*
2	Space required for storage	F2	2.306	0.850	−6.934
3	Balance of demand with returns	F3	3.917	0.666	11.678*
4	Lot sizing problem	F4	3.375	0.701	4.540*
5	Uncertainty in demand	F5	3.458	0.918	4.235*
6	Problem in buffer stock maintenance	F6	2.944	0.870	−0.542*
7	MRP based system	F7	3.083	0.868	0.815*
8	Location of remanufacturing facility	F8	3.028	0.691	0.341*
9	Technology for remanufacturing	F9	3.431	0.601	6.078*
10	Uncertainty in quality and timing of parts return	F10	2.417	0.801	−6.183
11	Disassembly sequence	F11	2.667	0.787	−3.593
12	Lead time variability	F12	3.153	0.781	1.660*
13	Parts matching problem	F13	2.500	0.872	−4.865
14	Complex scheduling & capacity planning	F14	3.931	0.877	9.000*
15	Skill of employees	F15	2.194	0.799	−8.559
16	Homogeneity in product	F16	3.556	0.820	5.747*
17	Complexity in product design	F17	4.361	0.512	22.558*
18	Design for remanufacturing	F18	4.236	0.760	13.805*
19	Corrosion/rust on used products	F19	2.625	0.795	−4.002
20	Dirt/oil on used products	F20	2.278	0.755	−8.120
21	Testing and inspection	F21	2.431	0.728	−6.635
22	Tolerances for wear	F22	2.292	0.879	−6.837
23	Type of material used	F23	2.806	0.781	−2.113
24	Defining specification	F24	2.722	0.843	−2.796
25	Fragility of parts	F25	1.889	0.683	−13.806
26	Destructive disassembly required	F26	2.139	0.877	−8.331
27	Assembly/disassembly problem	F27	3.028	0.888	0.266*
28	Reliability of product	F28	2.583	0.645	−5.485

* Decision criteria, If $t \geq -1.667$ (at 5% significance level) then the factors have a mean significantly greater than or equal to 3 (at 5% level of significance).

The frequency of various ratings (from 1 to 5) against the critical factors is displayed in Table 3 below.

In order to prioritize the factors, a weighted score was then computed using the values from the above table. The factors' weighted values and corresponding ranks are displayed in Table 4.

A rank chart was created based on the weighted score to show and rank the variables in order of relevance for starting a remanufacturing business. Figure 2 below shows the rank.

According to the analysis, F17 (Complexity in Product Design) is ranked first, while F6 (Problem in Buffer Stock Maintenance) is placed fourteenth in terms of its importance to the remanufacturing activity. The remaining variables are situated between these two extreme values.

Table 3
Frequency distribution of critical factors

Rating	1	2	3	4	5
F1	0	11	42	19	0
F3	0	1	16	43	12
F4	0	8	30	33	1
F5	0	10	30	21	11
F6	0	25	30	13	4
F7	1	18	30	20	3
F8	0	12	42	15	3
F9	0	4	33	35	0
F12	2	11	33	26	0
F14	0	5	15	32	20
F16	0	10	11	46	5
F17	0	0	1	44	27
F18	0	13	8	49	2
F26	1	22	25	22	2

Table 4
Composite score of factors and their rank

Factor	Total	Rank	Level
F17	314	1	I
F14	283	2	II
F3	282	3	
F16	262	4	III
F18	256	5	
F5	249	6	IV
F9	247	7	
F4	243	8	
F12	227	9	V
F8	225	10	
F1	224	11	
F7	222	12	
F26	218	13	VI
F6	212	14	

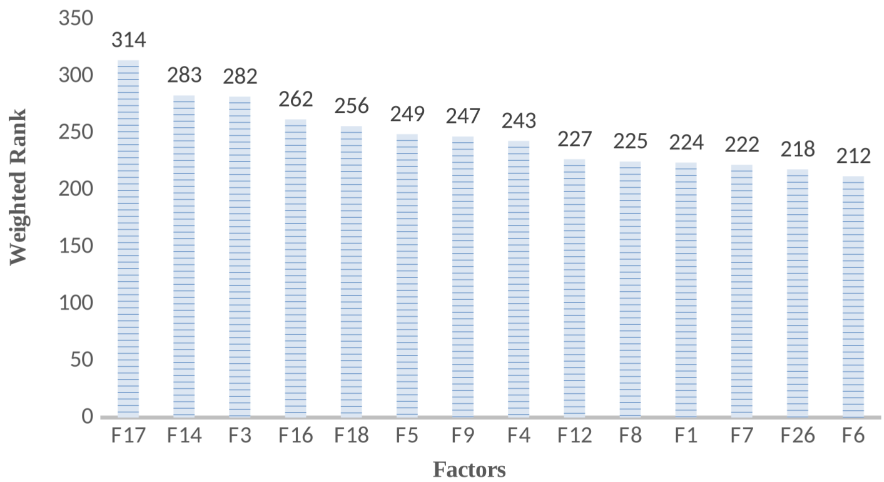

Fig. 2. Rank chart

Result and discussion

The data analysis identifies a total of fourteen factors as critical. The importance of each of these factors for initiating remanufacturing activities is then ranked.

The first level of consideration is given to the highly important element of product design complexity (F17). The product should be adaptably designed for multiple uses for remanufacturing. However, due to the intricate design of the original components, it is highly challenging to disassemble them into their component levels without causing damage to their size and shape (Hammond et al., 1998).

Second-level identifications include Complex Scheduling and capacity planning (F14) and Balance of Demand with Returns (F3). These two elements are also thought to be critical for starting a remanufacturing business. Due to consumers' lack of understanding, the market demand for remanufactured items is unstable, making it challenging to plan remanufacturing activities and determine the appropriate level of production. As a result, it is exceedingly difficult to strike a balance between the supply of cores and the need for remanufactured goods (Dekker et al., 2000; Inderfurth et al., 2004).

Homogeneity in Product (F16) and Design for Remanufacturing (F18) are critical elements at the third level. The regularity in shape and size of the returns is fraught with ambiguity. This might be because of the intricate designs of the parts and products, the usage of permanent fasteners, and the materials selected for initial manufacturing. This could cause issues during disassembly processes, which would ultimately make remanufacturing activities more difficult. Design for remanufacturing is therefore a crucial factor to take into account in order to make the remanufacturing procedures technically possible (Ishii et al., 1995; Gungor et al., 1999).

Demand uncertainty (F5), remanufacturing technology (F9), and the lot sizing issue (F4) are seen as crucial factors at the fourth level. Due to ignorance and lack of understanding, consumers are not well informed about the advantages of remanufactured items (Steinhilper, 2006). As a result, the market's demand for remanufactured goods is extremely erratic. This fluctuation in demand makes it more difficult to produce remanufactured goods because it causes an issue with the size of inventory lots utilized for replenishment during assembly operations (Golany et al., 2001; Yi et al., 2012). Additionally, remanufacturing uses different technology and equipment than manufacturing (Guide, 2000). The purchase of this equipment could result in additional expenses. Additionally, to run this equipment safely and with great care, highly qualified personnel are needed.

Fifth-level factors include Lead time variability (F12), Location of remanufacturing Facility (F8), Location of Storage Facility (F1), and MRP-based System (F7). There are a variety of brand-new difficulties that arise in remanufacturing operations due to the lead time uncertainty and material requirement planning (MRP) problem. These issues are primarily brought on by the unknowns associated with core acquisition. Due to these uncertainties, there is a challenge with returns flow integration, which eventually makes the producer's MRP system more difficult (Inderfurth et al., 2004; Kiesmuller et al., 2003). Additionally, it causes differences in lead times during subsequent cycle procedures including part assembly. A very important choice is where to locate the remanufacturing plant. It greatly affects the reverse logistics and core acquisition costs. Additionally, the cost and rate of core collection are affected by the location of the storage facility. In order to reduce the uncertainty in the number and timing of returns, it should ideally be situated close to the customer base (Jayaraman et al., 2003).

Finally, the factors discovered at the sixth level are problems in buffer stock maintenance (F6) and Destructive disassembly necessary (F26). It is possible to separate parts using either a destructive or non-destructive disassembly procedure. In destructive disassembly, the components are broken down to component level by applying force, which causes some functional units to break along with obsolete ones. This causes uncertainty in product recovery, which results in the release of parts without control, which could result in long lines at machine centers (Han et al., 2013). Due to this circumstance, lead times and processing times may vary (Guide et al., 1996). The issue of buffer stock maintenance throughout the reassembly process is mostly caused by the uneven rate of product recovery and unpredictability in product demand (Minner, 2001).

Conclusions

Activities that involve remanufacturing have enormous advantages. Its adoption of traditional manufacturing practices benefits many European nations greatly. However, it is still in a promising stage in India. This study addresses "Operational Management" issues that were critical to the success of the remanufacturing business in India. Fourteen crucial elements have been found through data analysis and evaluated according to how important they are for starting remanufacturing activities. The research's main findings indicate that used product design is a highly important factor in remanufacturing decisions. For executing a complete disassembly of the product, factors including complex product design, lack of homogeneity in return product, and design for remanufacturing are thought to be extremely crucial. The product's design for remanufacturing enables simple disassembly and repeated assembly iterations for multiple lives (Gray et al., 2006). In addition, concerns with inventory management and production capacity are thought to be crucial for remanufacturing. The amount, quality, and timing uncertainty related to the used items makes the process of production planning and inventory control difficult. Problems with capacity planning and scheduling are caused by the late arrival of cores at the remanufacturing facility, an inconsistent product recovery rate, and an uncertain demand for the remanufactured items (Jing et al., 2014). Additionally, it makes it more difficult to make decisions on the amount of inventory lots, the maintenance of buffer stocks, the variation in lead times, and the use of conventional MRP-based systems.Adopting the Reverse MRP system in the process could help solve this uncertainty issue (Ferrer & Whybark, 2001).

In summary, the general perception of the manufacturing firms that were outlined in the study can serve as a foundation for formulating strategies for the viability of the remanufacturing business in India. Together, the government and manufacturing companies should work collaboratively on strategy formulation related to the feasibility of remanufacturing in India. The outcome of this research work would provide a roadmap for the Indian manufacturing sector to contribute significantly towards Sustainable Development Goals (SDGs) for the progress of the country towards a circular economy.

Limitations and future research

The research presented in this study only considers the viewpoints of white goods manufacturing companies and their component suppliers. In order to obtain a more comprehensive understanding of the operational issues ofthe remanufacturing process, it is necessary to collect and share the perspectives of different manufacturing sectors too.

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