Project Completion Report

DEVELOPING A FRAMEWORK OF CRITICAL INDICATORS FOR SUCCESS OF REMANUFACTURING IN INDIA

Implemented by

DR. SANDEEP MONDAL
PROFESSOR, DEPARTMENT OF MANAGEMENT STUDIES,
INDIAN INSTITUTE OF TECHNOLOGY (INDIAN SCHOOL OF MINES), DHANBAD-826004

DST PROJECT NO. DST/NSTMIS/05/10/2017-18 Dated 01.05.2019

Study Sponsored by

National Science and Technology Management Information System (NSTMIS)
Department of Science & Technology
Government of India

(September, 2021)

Preface

Remanufacturing is an approach by which we can achieve the resource efficiency and operationalize the concept like sustainability and circular economy. It is a form of product recovery option, where used and discarded products/components/parts are subjected to a sequence of value-additive operations, so as to convert them into reusable ones. India is going to focus on achieving the resource efficiency, as highlighted by the NITI Aayog in its strategy. Also, Government of India after Paris summit took the pledge for achieving higher level of sustainability. As per her INDC (Intended Nationally Determined Contribution) announcement, by 2030 India is planning to reduce carbon emission by 35 percent of the level of 2005. It is likely to achieve the goal of significant shifting of power generation from renewable resources and creation of huge carbon sink. Government has introduced several schemes in this pursuit. Recycling and remanufacturing as product recovery options are also included in its future agenda.

This research project, funded by National Science and Technology Management Information System (NSTMIS), Department of Science & Technology, Government of India is a maiden attempt to initiate a research study in finding out the critical success factors to initiate such a business sector in India.

Acknowledgement

I take this opportunity to first thank National Science and Technology Management Information System (NSTMIS), DST, Govt of India for sponsoring this research project. I express my profound gratitude and indebtedness to Dr. Praveen Arora, Dr. A.N Rai, Dr. Akhilesh Gupta, Dr. R.K. Panigrahy and Shri P.K. Arya from CHORD Division, DST for their valuable inputs and suggestions throughout the work.

I wish to accord my sincere thanks to all the LPAC members of this project, Prof. Chandan Bhar, IIT(ISM), Dhanbad; Dr. Praveen Arora, CHORD Division, DST; Dr. A.N. Rai, CHORD Division, DST; Dr. Biswajit Ruj, CMERI, Durgapur; Dr. Satyendra K Singh, CMFIR, Dhanbad; Dr. Gautam Bandhopadhyay, NIT Durgapur; Dr. Manoj Kumar, NIFFT, Ranchi; Dr. Prakash Kumar, BIT, Sindri; Dr. Niladri Das, IIT(ISM), Dhanbad; Dr. Somnath Chattopadhaya, IIT(ISM), Dhanbad; for their necessary help and suggestions in carrying out this work.

My sincere thanks to all the seven remanufacturing companies, Volvo Reman India Pvt. Ltd., Peenya, Bengaluru; Printech Solutions India Pvt. Ltd., Jayanagar, Bengaluru; 4R recycling Pvt. Ltd., Bengaluru; Reman Infrastructure Pvt. Ltd., Namakkal, Tamil Nadu; Eco Recycling Limited, Andheri (E), Mumbai; Texcool Limited, Cuffe Parade Mumbai; Bijoy Engineering Works, Dhanbad for allowing us to carrying out the case studies and extending their helping hands towards completing this research work.

I would also thank all my research colleagues and staff members of the Department and Institute for their help and immense support and encouragement in preparing this research report.

Sandeep Mondal

Table of Contents

Executive Summary

- **Importance of this study (why this study)**

As per the facts and figures mentioned earlier, India has all the favorable conditions like enormous market growth, demand for remanufactured products, price sensitive market etc. for initiating remanufacturing business, but still it is yet to get its acceptance as an organized business sector. With this backdrop, this research project is carried out on remanufacturing of products to seek answers to the following questions.

a) Why many Indian manufacturers are still not interested in remanufacturing their products?

b) What are the critical indicators for a successful remanufacturing business?

c) What are the possible enablers that can possibly motivate the industry for adopting remanufacturing?

Previous studies are based on either opinion from experts or research framework meant for other countries. In fact, we require an exclusive study that addresses the Indian business environment and identify the success factors for Indian remanufacturing business. This research project is a maiden attempt to initiate such a study for developing a framework of critical success factors of Indian remanufacturing business through a case study based approach of successful remanufacturers in India.

- **Objectives of the study**

The research study is based on case studies of 10 to 15 remanufacturing companies from different sectors in India. While carrying out each of the case study, the following objectives are to be addressed.

- Study the various business operations of the selected remanufacturing company and develop a process flow diagram of the existing operations.
- Study the technological infrastructure required for its implementation.
- Identification of the key issues which are relevant to the remanufacturing business.
- Identification of the critical indicators for a successful remanufacturing business.

- **Methodology details (how this study was carried out)**

The study was carried out in the following way:

(i) The list of Indian remanufacturing companies were contacted and request letters were send to conduct case studies in their plants. 12 of them initially agreed to the proposal.

(ii) Seven case studies in the following companies are completed

a. Volvo Reman India Pvt. Ltd., Peenya, Bengaluru

b. Printech Solutions India Pvt. Ltd., Jayanagar, Bengaluru

c. 4R recycling Pvt. Ltd., Bengaluru.

d. Reman Infrastructure Pvt. Ltd., Namakkal, Tamil Nadu.

e. Eco Recycling Limited, Andheri (E), Mumbai

f. Texcool Limited, Cuffe Parade Mumbai

g. Bijoy Engineering Works, Dhanbad

Due to COVID-19 and travel restrictions many companies did not agree to further continue with the study, so we finally ended with the 7 case studies.

(iii) Each case study is being carried out with one-week visit to the company and understand their process of remanufacturing, labour employment, their financial and other business performance, critical success factors, etc. The primary data is

collected through interviews and filling open-ended and unstructured questionnaires.

(iv) Some of the unique operations and technology needed to be given due emphasis, are the *acquisition process of cores*, *reverse logistics*, *disassembly*, *cleaning*, *inspection and testing*, *special tools and machines*, *technology*, *design for remanufacturing*, *reassembly* and *marketing*.

(v) Process flow diagram to be constructed, which will help to summarize various technical and operation issues.

(vi) From the study, we could identify the issues which are relevant to their remanufacturing process. These issues are listed down and their importance are rated using 5-point Likert scale.

(vii) The critical ones needs to be identified, based on which the success of the remanufacturing business will depend.

- **Results & Discussions (what the study reveals)**

The data from all of the 7 case studies indicate few major findings which are discussed in the below section.

- It has been seen that most of the companies operate in small scale businesses with an annual turnover from Rs. 1 to 10 crores. These companies generate employment of 10 to 50 employees. These workers range from skilled to semi-skilled persons.
- The products which are popularly remanufactured are automotive parts and components, machine tools, industrial machines, transformers, pumps, printer cartridges and recycling of e-wastes.

- All the seven companies have responded that remanufacturing is a profitable business option in India. The profit percentage range from 3% to 37%. However, they also responded that building green image among customers is also a secondary reason.
- All the companies mention that the remanufacturing business decisions are mainly centred around 10 prime factors as, Acquisition process of used products, disassembly issues, cleaning issues, sorting issues, inspection issues, reassembly issues, design issues, inventory issues, marketing issues, and government policies. Further these ten factors are sub-divided into several items, so that a detailed decision-framework can be established. The success of the remanufacturing business lies in how the company efficiently manages these set of decision issues.
- Intervention of Government and other managerial policies are also impacting the remanufacturing industries. Prevention and control of pollution are one of the crucial issues that have to be considered not only among the remanufacturing industries but also in every sector. Similarly, laws related to environmental protection and the restriction of the usage of hazardous products are also important issues marked by 90 % of the industries.
- One of the biggest portions of the total expenditure that every remanufacturing industry invests in New Technology/Machine/Capital. It is on an average of 25-30%.

- **Policy implication, suggestions & recommendations**
    - Most of the remanufacturing companies are operating as a small scale business, with an annual turnover of Rs. 1 to 10 crores. The number of employees range from 10 to 50. Moreover, we found that the technology/capital cost of these companies contributes on an average of 30%. Thus, under such a situation governmental support of soft loans can boost such industry. This would further generate employment in the country.
    - Since, sorting and inspection activities are found to be the most critical activities in remanufacturing business, skilled manpower requirement is more. Training and skill development programs may be initiated in these areas. Moreover, in remanufacturing determination of remaining life of used products is one of the difficult task. Special technology is required for determination of residual life and inspection due to safety and reliability issues of the product design. Research initiatives in this area is highly recommended.
    - Most of these companies abide by all the governmental laws related to Environmental Protection Act, but they put forward a point that they are not allowed participate in governmental contracts due to the fact that they are selling remanufactured product.
    - A social awareness program is required from the end of the government, as most of the company feels that though they are contribution to the society in reducing environmental pollution by reuse of waste material, they are still not considered as the mainstream business or not a part of organised business sector. Government should think of initiating a separate policy for promoting a healthy remanufacturing business.

Chapter 1: Introduction

1.1. Introduction

Remanufacturing is considered as one of the product recovery options (Ijomah et al., 2007) where used and old products are collected from the customers, followed by sorting, disassembly, reconditioning, salvaging and reassembling to convert them to 'as-good-as-new' refurbished products and subsequently, remarket in another market segment (Bras, 2015). The American National Standards Institute (ANSI) has approved an industry standard that defined remanufacturing as "a comprehensive and rigorous industrial process by which a previously sold, leased, used, worn or non-functional product or part is returned to 'like new' or 'better than new' condition, from both a quality and performance perspective, through a controlled, reproducible and sustainable process". The quality of the remanufactured products is considered as same as the new products. Many businesses across developed countries have become successful in practicing this remanufacturing process. Companies like Xerox, IBM Europe, Fuji film, Kodak, Caterpillar, Flextronics, BMW, Volkswagon, Ford motors, Pedco Remanufacturers (US) are actively engaged in remanufacturing activities for more than a decade. If we consider the remanufacturing business of automotive sector alone, it represents an estimated $85-100 billion industry worldwide. Based on estimates by US Automotive Parts Rebuilders Association (APRA) in the year 2015, $35 - $40 billion worth of remanufactured auto parts was marketed in United States. There are roughly 150 production engine remanufacturers and around 1000 automotive parts remanufacturers in US. The European Remanufacturing Network (ERN) estimated value of remanufacturing in 2015 at just under €30bn in the European Union, followed by Japan (€3.8bn), Malaysia (€825m) and South Korea (€670m).

The increasing concern over environmental issues, take-back obligations and disposal bans along with growing environmental awareness among customers, the economic benefits from remanufacturing, creation of stock of components/parts from disassembly operation, and demand of spare parts during post Product Life Cycle period are found to be the prime reasons, which motivated the industry towards reuse and remanufacturing of used products. Various European countries, Japan and several states of USA have stringent laws on reuse and product recovery like, take-back programs and Extended Producer Responsibility (EPR) law of Europe (and Japan), European Union's directives, WEEE and End-of-Life Vehicles (ELV) take-back policies, The Universal Waste Rule (1995) of US etc. These laws are primarily responsible for evolving organized remanufacturing sector, particular in western world. Moreover, in terms of economic benefits, a remanufactured item is often cheaper than a new one as a large part of processing and manufacturing expenditures (time, energy, cost etc.) are avoided. It is estimated that one can save 40 to 60% of the cost of manufacturing a new product, while requiring only 20% of the energy. Profit margin is around 20% or even up to 40% for automotive sector. The annual energy savings from remanufacturing in U.S. alone may be estimated to be equivalent to electricity generated by 5 nuclear power plants or 85 million barrels of oil. Presently, a wide range of products are being remanufactured world-wide like automotive parts, locomotives, aircrafts, engines, machine tools, electronic equipment, photocopiers, cellular phones, computers, etc. However, Lund (1998) has presented seven criteria for a product to be remanufacturable. They are listed as, that the product is a durable good, it fails functionally, the product is standardized and the parts are interchangeable, the remaining value-added is high, the cost to obtain the failed products is low compared to the remaining value-added, the product technology is stable, and the consumer is aware that remanufactured products are available.

Although remanufacturing has been accepted as an alternative business practice for value recovery of used products, this practice still remains in adolescence stage in many African, South American and some of the Asian countries including India. In India remanufacturing is yet to get its acceptance as an organized business sector. According to ERN report, the remanufacturing sector in India is not well organized. Most remanufactured products are IT products, mainly printer cartridge, where the definition of remanufacturing is modified from the actual definition of remanufacturing (given by ANSI, 2017). More than 30,000 business are engaged in cartridge refilling process, but most of them are unorganized and unregulated. On the other hand, Heavy-duty and off-road (HDOR) sector including Indian Railway which remanufactures the diesel locomotive engines at Patiala, Volvo, operates a remanufacturing facility for construction equipment at Bangalore, and Cummins remanufactures the automobile parts and engines at their remanufacturing facilities at Pune. Being one of the Asian giants, India has been taking enough care in implementing its plan for massive technology and societal development through globalized economy since early 90s. Market is enlarging and thus most of the remanufacturable products are being produced at a rate much faster than what it used to be a decade earlier. The growth of business activities will be more realistically perceived, if we consider the huge population base of India. The global trend, the resultant benefits from remanufacturing and the above-mentioned Indian industrial scene strongly justify the logical conclusion that India should be one of the prospective countries for initiating and maintaining remanufacturing sector. The expected benefits may also be quite understandable from the following facts (not an exhaustible list).

- Material cost savings from remanufacturing, in general, lies between 40 and 65%.
- Energy consumption of a remanufactured product is only 15% of the new product.

- Remanufacturing being labor intensive operation (50% casual labor), India may be an appropriate destination with the availability of cheap labor and also leads to generation of employment.
- Profit from remanufacturing activities is almost around 20%.
- Price of remanufactured product remains 30 to 40% of the new one (suitable particularly in developing countries).
- Electronic equipment, even in India are becoming obsolete in 2-3 years causing disposal problems and environmental degradation.
- Moreover, we are also to admit that India is a developing country with its price sensitive market. This means that if there were availability of remanufactured products, one would definitely plan to buy a remanufactured product from the market, as the price is comparable to a secondhand product and the quality is comparable to a new product.

As per the facts and figures mentioned earlier, India has all the favorable conditions like enormous market growth, demand for remanufactured products, price sensitive market etc. for initiating remanufacturing business, but still it is yet to get its acceptance as an organized business sector. With this backdrop, this research project is carried out on remanufacturing of products to seek answers to the following questions.

a) Why many Indian manufacturers are still not interested in remanufacturing their products?
b) What are the critical indicators for a successful remanufacturing business?
c) What are the possible enablers that can possibly motivate the industry for adopting remanufacturing?

The investigator of this project have already initiated a research study in this direction of remanufacturing business in India. An empirical investigation was carried out in a small scale among Indian business houses with the objectives of finding out the critical factors that need to be addressed for initiating remanufacturing as an organised business sector in India (Mondal *et al.* 2006). The outcome of the study showed that the remanufacturing business in India is probably governed by the six underlying factors. These six factors according to their importance are given as *acquisition of returns*, *technology for remanufacturing*, *market conditions*, *customers' attitude*, *profitability* and *legislation*. Literature shows that in the US automotive remanufacturing sector (Hammond *et al.* 1998) market demand, availability of parts and profit potential are the three key criteria that are considered while deciding whether or not to remanufacture a product. It seems that while environmental legislation is considered to be the genesis of remanufacturing business in the European countries, market economy and financial incentives represent the prime driving forces in India. Guide (2000) has mentioned that the main motivation behind remanufacturing in Europe is the legislation and that in US is the economics or profitability.

The above-mentioned issues are based on either opinion from experts or research framework meant for other countries. In fact, we require an exclusive study that addresses the Indian business environment and identify the success factors for Indian remanufacturing business. This research project is a maiden attempt to initiate such a study for developing a framework of critical success factors of Indian remanufacturing business through a case study based approach of successful remanufacturers in India.

1.2. Objectives of the research

The research study is based on case studies of 10 to 15 remanufacturing companies from different sectors in India. While carrying out each of the case study, the following objectives are to be addressed.

- Study the various business operations of the selected remanufacturing company and develop a process flow diagram of the existing operations.
- Study the technological infrastructure required for its implementation.
- Identification of the key issues which are relevant to the remanufacturing business.
- Identification of the critical indicators for a successful remanufacturing business.

1.3. Limitations:

a. The study is limited to a small sample (10 to 15 case studies) due to time and cost constraints.

b. The duration of case studies for some of the companies lasted for 3 days and some for 6 days, depending on the scale of operation and size of the company. As most of the companies are operating in a Small-Scale business, the companies allowed a maximum of two to three days.

c. Due to COVID-19 and lockdown, only seven case studies can be completed. This report is based on only seven case studies.

Chapter 2: Review of Literature

2.1. Introduction

Researchers and management scientists, particularly from Europe and US have taken up remanufacturing as one of the emerging areas and numerous studies have been completed and published in leading journals. In this context, the noteworthy contribution of team members in REVLOG project, sponsored by European Union is to be acknowledged and mentioned. Rochester Institute of Technology's National Center for Remanufacturing and Resource Recovery is another leading center for applied research in remanufacturing. Theoretical studies have been carried out on possible structures in the automotive industry incorporating remanufacturing strategy and interaction among the major barriers for automobile remanufacturing. A few empirical studies have also been carried out by Autry (2005) and Daughterty *et al.* (2005). Autry studied the relationships between formalization, liberal policies, and related capabilities and overall effectiveness of remanufacturing for a sample of firms in the automobile aftermarket parts industry in US, whereas Daughterty *et al.* (2005) carried out a survey of automobile aftermarket industry in US and identified a few key strategic decisions for remanufacturing like developing information technology capabilities. Schultmann *et al.* (2006) have presented the peculiarities of establishing a closed-loop supply chain (CLSC), based on an example considering the end-of-life vehicle (ELV) treatment in Germany. Different design options for CLSC scenarios are discussed based on real case data. In their paper, Gerrard & Kandlikar (2007) presented an evaluation framework based on five anticipated changes that could result from the ELV Directive. These changes relate to three areas: vehicle design, level of ELV recovery, and information provision.

2.2. Literature Analysis

2.2.1. Material Selection

A systematic search has been conducted where we consider research papers ranging from 2006 to the beginning of June 2021. The structured keyword search was conducted on the following major databases of peer-reviewed literature and websites of publishers - Scopus, ScienceDirect, Emerald, Springer, JSTOR. The following keywords are used in this study for the purpose of data collection - “Remanufacturing”, “Product Recovery”, “Hybrid Manufacturing/ Remanufacturing”, “India”, and “developing countries”. In the developing countries, especially the BRIC countries, face a lot of challenges while executing the remanufacturing operation. Some research papers highlighted the status of remanufacturing in the developing nations and also addressed the existence of multiple barriers. A total 137 research article have been identified during 2006 to 2021 related to research on remanufacturing activities in India or feasibility of remanufacturing activities in Indian Economy. After removing duplicates and filtering, 113 articles are remaining for further analysis. In the next phase, we then analysed and reviewed the abstracts of 113 articles. For this purpose, we followed the evaluation method proposed by Liao et al. (2017) which consists of three phases. In the first phase, the criteria for inclusion and exclusion are outlined. Table 2.1 represents the criteria for inclusion and exclusion. In the eligibility phase, all research articles passed the initial phase (113 articles) are reviewed by reading the abstract and full text. The second phase is related to objective review strategy where each collected research article should be reviewed by two examiners or collaborators of this research for the final decision. Based on the second steps, finally 93 articles are selected. All the eligible research articles are considered for the detail analysis in the third phase i.e. data collection with evidences. The material collection stage thus yielded a dataset comprise of 93 articles.

Table 2.1: Inclusion and exclusion criteria for the material selection

Inclusion/Exclusion	Criteria	Illustration	Number of Research articles
Inclusion	Scopus database (only Journal article)	Keywords: Remanufacturing", "Reverse logistics", "Hybrid Manufacturing/Remanufacturing", "India", "Indian Economy"	113
Exclusion	Loosely Related (LR)	LR1: "Remanufacturing" and "Indian Economy" or as a "Developing Country" are seen only in a cited expression	5
		LR2: "Remanufacturing" or "Indian Economy" or as a "Developing Country" is seen only in keywords and/or references	3
		LR3: "Remanufacturing" or Indian Economy" or as a "Developing Country is seen only in problem definition	3
	Not Related (NR)	The article is related to other discipline	9
Articles			93

2.2.2. Descriptive Analysis

In this stage, the formal characteristics of the collected papers are analyzed and assessed. Information related to the research articles across the various journals, publication date, institutions, author collaboration, methodology, data analysis technique, and theoretical perspective are evaluated from each paper. The bibliometric analysis could help us to find out much more detailed descriptive analysis from the bibliographic elements such as authors, keywords, countries, and affiliations. To extract the intellectual contribution, total of 5047 references of all 93 research articles are considered for analysis. Before we start the bibliometric and network analysis, we need to standardize the records. Different network structures can be constructed by using the bibliographic elements. To develop and visualize the network analysis, R and VOSViewer (Van Eck and Waltman, 2010) software packages are used. Both R and VOSViewer are non-commercial software packages.

2.2.3. Material Evaluation

In the material evaluation stage, all the research articles had been categorized, then key elements or factors related to pricing decisions are identified in remanufacturing. We also integrated the summaries which figured out the main topics, gap and areas of the future research.

2.3. Review Results

Thus, it is important to find out the core authors who have greater contribution in this domain. We used h-index of to find the first 10 authors in this field. Table 2.2 represents the author impact of the first ten authors as per the h-index in India.

Table 2.2: Author Impact in India

Author	h_index	g_index	m_index	TC	NP	PY_start
SINGH RK	3	6	0.5	110	6	2016
AGRAWAL S	3	5	0.5	110	5	2016
MONDAL S	4	5	0.308	111	5	2009
CHAKRABORTY K	3	4	0.6	48	4	2017
GARG SK	4	4	0.5	89	4	2014
GOVINDAN K	4	4	0.571	451	4	2015
KANNAN G	4	4	0.286	689	4	2008
MUKHERJEE K	3	4	0.231	106	4	2009
SHANKAR R	4	4	0.25	74	4	2006
JENA SK	3	3	1	45	3	2019

Similarly, Table 2.3 represents the author impact of the first ten authors as per the h-index, globally.

Table 2.3: Author Impact worldwide

Author	h_index	g_index	m_index	TC	NP	PY_start
IJOMAH WL	8	8	0.533	606	8	2007
ZHU Q	8	8	1	445	8	2014
WANG Y	6	7	0.667	456	7	2013
CHEN X	4	6	1	51	6	2018
WAHAB DA	3	5	0.25	34	6	2010

ZHANG X	3	4	0.75	33	4	2018
CAO J	2	4	0.5	27	4	2018
CHEN M	3	4	0.333	64	4	2013
CHEN Y	3	4	0.273	44	4	2011
LI J	4	4	0.308	136	4	2009

The corresponding country and institution affiliation of an author are extracted from the data source. From the affiliations data, it has been observed that contributing organizations/institutions are distributed across the globe, with a higher density in China, the United States, Taiwan, and Germany. Figure 2.1 represents the geographical locations of different organizations/countries which are involved in analyzing pricing related decisions in remanufacturing. The density variation of blue colour in Figure 2.1 is proportional to the degree of contribution of each organization/country.

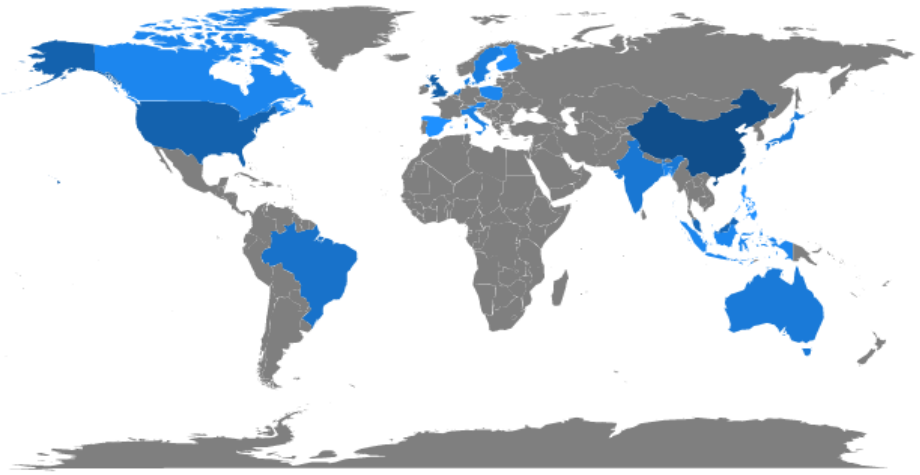


Fig. 2.1: Geographical locations of all contributing countries/organizations

2.3.1. Citation Analysis

We have conducted another analysis based on citation (locally). The result of the analysis has been shown in Table 2.4. Based on the analysis, we can identify the base papers in the area of remanufacturing specifically in India. Similarly, citation analysis is carried out research articles globally where remanufacturing is quite popular and is shown in Table 2.5.

Table 2.4: Most Local Cited Documents from India

Document	DOI	Year	Local Citations	Global Citations
SRIVASTAVA SK, 2008,	10.1016/j.omega.2006.11.012	2008	16	397
SRIVASTAVA SK, 2006,	10.1108/09600030610684962	2006	10	175
RATHORE P, 2011,	10.1016/j.jclepro.2011.06.016	2011	10	124
SHARMA V, 2016,	10.1016/j.jclepro.2014.11.082	2016	8	61
XIA X, 2015,	10.1016/j.jclepro.2014.09.044	2015	7	221
KANNAN G, 2009,	10.1016/j.resconrec.2009.06.004	2009	6	411
MUKHERJEE K, 2009,	10.1080/09537320902969174	2009	6	58
PRAKASH C, 2015,	10.1016/j.jmsy.2015.03.001	2015	5	190
GOVINDAN K, 2016,	10.1016/j.jclepro.2015.06.092	2016	4	106
MANGLA SK, 2016,	10.1016/j.jclepro.2016.03.124	2016	3	98

Table 2.5: Most Cited Documents world wide

Document	DOI	Year	Local Citations	Global Citations
ZHANG T, 2011,	10.1016/j.resconrec.2010.09.015	2011	24	143
XIANG W, 2011,	10.1016/j.jclepro.2010.11.016	2011	19	105
IJOMAH WL, 2007,	10.1016/j.rcim.2007.02.017	2007	12	219
WANG Y, 2014,	10.1016/j.jclepro.2014.03.023	2014	11	113
ZHU Q, 2014,	10.1016/j.tre.2014.05.001	2014	10	76
WANG Y, 2013,	10.1108/IJPDLM-01-2013-0011	2013	10	107
KHOR KS, 2017,	10.1080/00207543.2016.1194534	2017	8	55
WEI S, 2015,	10.1016/j.jclepro.2015.02.014	2015	8	79
XIA X, 2015,	10.1016/j.jclepro.2014.09.044	2015	8	221
SAAVEDRA YMB, 2013,	10.1016/j.jclepro.2013.03.038	2013	8	88

2.3.2. Content Analysis

Ravi and Shankar (2005) identified that lack of remanufacturing technology and lack of support of top management are the common barriers in remanufacturing in any sectors. Mukherjee and Mondal (2009) analysed various issues in photocopier remanufacturing in India. They developed an ISM based model and identified that product design, remanufacturing technology, impact of the working environment, return strategies, and lack of maintaining proper database of the customers are the major issues. Govindan et al. (2016) also developed a similar ISM based model. But they focused on the barriers related to automotive product remanufacturing and categorized the barriers into four domains such as business, production, technical and

stakeholders. They highlighted that lack of data related to technical and environmental, lack of specific remanufacturing market, higher replacement cost, and lower customer acceptance are the crucial factors. An empirical study was conducted by Sharma et al. (2016) to identify the barriers in remanufacturing in the Indian context. They observed that the lack of support from the government, quality related issues are the barriers in remanufacturing in India. Bhatia and Srivastava (2018) used DEMATEL based model to identify the cause-effect relationships among the external barriers in remanufacturing of e-waste sector. They prioritised some barriers like channel selection and customer's unwilling to return their product over others. Singhal et al. (2019) proposed a conceptual model to determine the critical factors related to the Indian customer perception towards remanufactured products. They identified that attitude, personal benefits and knowledge of remanufactured product are the critical factors. Ansari et al. (2019) developed a hybrid model where they used FAHP method to identify the critical success factors for remanufacturing and then applied Fuzzy-TOPSIS method to prioritize the performance outcomes.

Zhang et al. (2011) mentioned that regulations, policies, and customer acceptance (Wang et al., 2013) are the critical issues of automotive remanufacturing in China. Xia et al. (2015) developed Grey-DEMATEL based approach to evaluate some major causal barriers in the Chinese automotive remanufacturing business. They gave more weightage on lack of investment, low profit, and unavailability of used products. Wei et al. (2015) also conducted a survey and they evaluated customer's recognition and lack of proper sales channel are the major barriers in machinery remanufacturing. Zhu et al. (2015) developed a DEMATEL based model where they discussed both strategic (lack of adequate availability of used truck, lack of industrial standards and quality evaluation, import of remanufactured parts is outlawed) and operational (lengthy and undependable processing time, non-existence of reasonable pricing system) barriers for

truck remanufacturing in China. Tian et al. (2014) discussed the requirement of technological innovation, equipment updates and financial support for the development of automotive parts remanufacturing business in China, whereas Wang et al. (2014) illustrated the impact of different subsidies in remanufacturing operations, which are expected to motivate both the independent and contracted remanufacturers. Shi et al. (2019) developed a Cause-Effect model among the barriers related to the collection, remanufacturing, and sales of the remanufactured cartridges in China. The aforesaid research papers basically represent the status of remanufacturing in China. Some research reports are also available in literature, which include discussions on the challenges of remanufacturing in other developing countries. Saavedra et al. (2013) conducted an exploratory case study to identify the critical decision-making issues related to automotive remanufacturing in Brazil. Bouzon et al. (2016) developed an AHP based method to identify the critical barriers related to reverse logistics implementation in the Brazilian context. They identified that financial burden on tax and the economic uncertainties are the top-rated barriers. Yusop et al. (2016) showed some overview and challenges of automotive remanufacturing in Malaysia. Chaowanapong et al. (2017) identified the key decision-making factors for remanufacturing related to business feasibility, strategy, and policy. They considered three remanufacturing companies in Thailand (automotive parts, photocopier, and agriculture) for the case-study.

2.4. Summary

From the above discussion and with critically examination it can concluded that the remanufacturing management process can be classified under nine management issues categories. These issues, which are not necessarily unrelated among themselves, are essentially originated from nine areas of concern in remanufacturing business as given as below.

1. Design related issues relevant to remanufacturing process like inclusion of Design for Reuse (DFR) and Design for Disassembly (DFD). These issues not only helps in reducing the cost of remanufacturing process but also leads to higher rate of recovery of useful components and parts.
2. The environment where the used product is being installed and way the users of the product utilize it decides the condition of the used product and hence the proportion of the amount of parts recovered from a used unit.
3. Availability of suitable technology, tools and expertise for remanufacturing of the used product.
4. Used products which form the basic raw material for remanufacturing are being collected from the disposer market. Thus, unlike the normal manufacturing process where availability of raw materials are generally assumed to be deterministic, in case of remanufacturing process acquiring of used products is a difficult task, as uncertainty lies in the timing, quality and quantity of collection of used products.
5. Reverse logistics is one of the unique features of remanufacturing. This involves transportation of used products from the market to the remanufacturing plant. Appropriate designing the transportation network and deciding the activities to be carried out in each of the stages of this transportation network decides the smooth flow of raw material in the process
6. Disassembly and reassembly are the uncommon operations in remanufacturing and these make the production planning of the business highly stochastic. The disassembly time varies with the condition of the used product and thus makes the planning process also highly complex.
7. Role of skill and expertise of workforce required in the remanufacturing operations.

8. Issues related to inventory management of both used parts as well as new parts and components.
9. Marketing of remanufactured products is also an important aspect of remanufacturing. Cheaper price of remanufactured products, quality as good as a new product and green image associated with these products can be used as developing marking strategy for remanufactured products.

Hence, for identifying the critical success factors of any remanufacturing business, it is necessary to center the discussions mainly on these factors.

Chapter 3: Research Methodology

3.1 Target population and sample size covered

Based on literature, the range of products that are remanufacturable must be a durable good; it fails functionally and is repairable; the product is standardized and the parts are interchangeable; the remaining value-added is high; the cost to obtain the failed products is low compared to the remaining value-added; the product technology is stable; and, the consumer is aware that remanufactured products are available. Some of the remanufactured world-wide are automotive parts, locomotives, aircrafts, engines, machine tools, electronic equipment, photocopiers, cellular phones, computers.

In India, remanufacturing is still not well accepted as an organized business sector. Although product recovery practices exist in the Indian market as an unorganized business sector, only a few Indian companies like, Xerox India Limited, Rampur, UP; United Van Der Horst Limited, Mumbai etc. are actually engaged in remanufacturing practices. In fact, there is also non-availability of a concise list of remanufacturing companies in India. Getting the geographical distribution of such companies (state-wise or zone-wise) is highly difficult. The population size of Indian remanufacturers is also very difficult to obtain. Hence, convenience sampling method is adopted in this research project to choose the sampling units. The Indian companies which are engaged in remanufacturing business as organized sector are identified from *Centre for Monitoring Indian Economy (CMIE) Database* and searing in websites for unorganized sectors. A sample of such remanufacturing companies are listed in Annexure I. This research study is based on case studies of 10 to 15 remanufacturing companies

3.2. Method of data collection

Since this research study is based on case studies of 10 to 15 remanufacturing companies from different sectors in India, it includes only primary data from the company.

The study was carried out in the following way:

(viii) From the list of remanufacturing companies identified in Annexure I, all of them were contacted and request letters were send to conduct case studies in their plants. 12 of them initially agreed to the proposal.

(ix) Seven case studies in the following companies are completed

a. Volvo Reman India Pvt. Ltd., Peenya, Bengaluru

b. Printech Solutions India Pvt. Ltd., Jayanagar, Bengaluru

c. 4R recycling Pvt. Ltd., Bengaluru.

d. Reman Infrastructure Pvt. Ltd., Namakkal, Tamil Nadu.

e. Eco Recycling Limited, Andheri (E), Mumbai

f. Texcool Limited, Cuffe Parade Mumbai

g. Bijoy Engineering Works, Dhanbad

Due to COVID-19 and travel restrictions many companies did not agree to further continue with the study, so we finally ended with the 7 case studies.

(x) Each case study is being carried out with one-week visit to the company and understand their process of remanufacturing, labour employment, their financial and other business performance, critical success factors, etc. The primary data is collected through interviews and filling open-ended and unstructured questionnaires.

(xi) Some of the unique operations and technology needed to be given due emphasis, are the *acquisition process of cores*, *reverse logistics*, *disassembly*, *cleaning*,

inspection and testing, *special tools and machines*, *technology*, *design for remanufacturing*, *reassembly* and *marketing*.

(xii) Process flow diagram to be constructed, which will help to summarize various technical and operation issues.

(xiii) From the study, we could identify the issues which are relevant to their remanufacturing process. These issues are listed down and their importance are rated using 5-point Likert scale.

(xiv) The critical ones needs to be identified, based on which the success of the remanufacturing business will depend.

3.3. Demographic profile of sample

The demographic profile of the 7 companies of case studies are shown in the table below.

Company	Location	Year of Establishment	Products Remanufactured	Total Annual Turnover	Number of Employees
VOLVO REMAN India	Peenya, Bengaluru	2009	Pumps and Motors of excavator and road machinery	NA	5
Printech Solutions India Pvt. Ltd.	Jayanagar, Bengaluru	1996	Cartridges (Laser Printer Cartridges)	3 Crores	35-40
4R Recycling Private Limited	Peenya, Bengaluru	2012	All Kinds of Electronic Wastes, Ex: Desktops, Cables etc.	7.5 Crores	25
REMAN Infrastructure Pvt. Ltd.	Namakkal, Tamil Nadu	1989	Bucket Elevators, Conveyors, and Rollers	4 Crores	25-30
ECORECO	Andheri, Mumbai	2005	Metallic Products. Ex: copper, Aluminium etc	12.43 Crores	40
Authentic Implex / Texool Limited	Bhiwandi, Mumbai	2012	Bags and Accessories	3 Crores	50
Bijoy Engineering Works	Bhuli, Dhanbad	1965	Transformer, Motors and Switch Gears	80 Lakhs	9

Chapter 4: Detailed analysis of the Data

4.1. Volvo Reman India Pvt. Ltd., Peenya, Bengaluru

4.1.1. Introduction

Volvo REMAN India is a pure remanufacturing-based company which is situated in industrial area, phase 1, Peenya, Bangalore. With a good amount of annual turnover, the company is having an attractive infrastructure with total number of employees being 5. Volvo has been an inspiration for other remanufacturing based companies in India. The company has set benchmarks time and again with its innovative and environment friendly practices. Currently there are 19 products that are in offering from the Remanufacturing Plant and more are in the process of being included. Based on the concept of remanufacturing, the products which are being remanufactured are pumps, motors of excavators and road machineries. Volvo is turning India's remanufacturing challenge into an opportunity for sustainable business growth. Various operations and different sorts of methods are being deployed in Volvo, which contributes towards the production of good quality of remanufactured products. The reasons why Volvo has started remanufacturing are they found this a profitable business option, they want to create a green image among customers and it is an ethical and moral responsibility of the company towards environment.

4.1.2. The Acquisition Process

This company follows a B2C structure for collecting e-wastes from the market. In Volvo, the customers contact the vendors or dealers and the dealers finally contact the Volvo Reman India regarding the collection of used products.

- All the motors, pumps of excavators or any other road machinery is being transported to Volvo Reman unit/centre.

- The parts are then dismantled, inspected, cleaned, the worn-out products are then discarded, further process of remanufacturing, refurbishing takes place and finally reassembling of used products take place with some new parts being replaced if needed.
- The remanufactured products are then sent for testing to check for the desired specific standards and if the standards are being met the remanufactured products are sent back to the dealers.
- The dealers then contact the customers and hand over them the remanufactured products.
- The value of the return is determined by the product's age, usage and quality.
- The company do not have separate collection centres for collecting the used products.
- The mode of transportation for collecting the used products is trucks.
- The whole used products are being transported and the dealers bear the transportation costs.

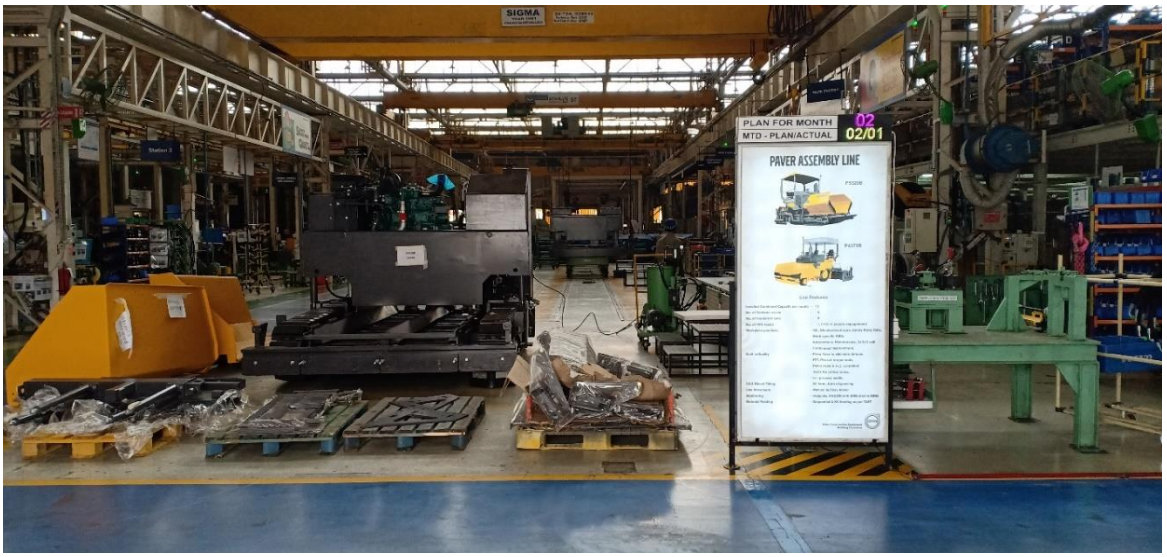


Fig. 4.1.: The remanufacturing plant

Fig. 4.2.: The Volvo remanufactured products

4.1.3. Collection of Cores

The crucial phase of this reverse logistics framework is collecting the cores. The quality, availability and usefulness of the wastes could lead to success in the re-cycling business. Cores are being collected through dealers network. They identified 14 factors which are associated with acquisition of used products including problem of locating the cores, data base of the customers, reverse distribution network, planning complexities, size shape fragility and handling of the cores, collection centre locations, inspection and finalizing the buy-back price of cores.

4.1.4. Disassembly

Once the wastes are collected from the users or some other sources, the next step is to disassemble the product in order to expose the various components of that product. It is a simple and manual process which involves 2 workers. The disassembling time is approximately one hour for dismantling a pump. Tools being used in this process include screw drivers, impact tools. Experienced and skilled workers are required in this process. PULL and PUSH strategies are used in this operation. The source of disassembly technology is reverse engineering and component service method. There could be several issues while following a disassembly operation including sequence, depth of disassembly, lot-sizing, permanent fastening, rust, dirt,

complexity of product design, uses of special tools, worn out fastener heads, size of products and availability of disassembly technology and many others. The team has to look out each and every issues while the disassembly operation.

4.1.5. Cleaning

It is a manual as well as machine automated process. This process is somewhat complex and this process is carried out by only one worker. Manual cleaning process keeps on changing and it takes around 10 minutes for completing the cleaning process. Pressurized cleaning machines like high pressure washers are used. There is a need of skilled workers in cleaning process.

4.1.6. Sorting

This is the second step being performed. The sorting process depends on the colour of the used raw material, quality of used products etc. Indigenously made machines are used for sorting. It is a complex procedure and the workers need to have basic handling and sorting skills. Volvo avoids this sorting step and jumps directly into inspection.

4.1.7. Inspection

It is an initial step of balancing the quality of conformances. The quality of a tiny part from an e-waste could impact the quality of the product at end-users. This process includes eliminating the bad parts, bad materials, removing zips of the pants, buttons etc. After the completion of the sorting process, the materials are then sent to the conveyor belt which is the end of the preparatory stage. It can be considered as the end stage process. It is a complex process and only one worker is involved in this operation. There is a need of highly skilled workers and measuring tools like calibers and micrometers are used in such kind of operation. Tools such as bore gauges are also used here. This is a manual process. The time required for inspection is one hour. The issues arises in the inspection process are generally identified by the knowledge and experience of the inspector.

4.1.8. Issues in Repairing and Replacement Process

Up cycling might be performed which might include refurbishing/repairing. Repairing/ Refurbishing is being performed manually. This process may include simple sewing machines and requires basic sorting and inspecting skills that help in repairing/refurbishing. It is a manual as well as machine automated process. It is a complex process. Three workers are being involved in repairing/refurbishing/replacing. There is a need of skilled and experienced workers in this process. The approximate time required for such operation is 2 hours. Almost 50% of the parts is newly procured for remanufacturing. For replacing any of the used parts, the company keep some parts in stock from Korea. Special machines like grinding, lathe, drilling machines are used.

Fig. 4.3.: Remanufacturing operation

4.1.9. Reassembly

It is a complex process and done manually. Holding fixtures are used for holding the parts of the pumps. This operation is done in approximately one hour. There is a need of skilled workers.

4.1.10. Disposal Procedure

They burn the discarded materials and others they sell to recyclers. The disposal costs depend on current rate of the material like steel or scraped material etc. 30% of the parts are being disposed at VOLVO REMAN.

4.1.11. Design Issues

The design of the product has a critical impact on the recycling stage. The diversity in the designs leads to time taking operations.

4.1.12. Marketing and Sales of recycled products

The customers for the remanufactured products are dealers like ENCORE, BSE's, SVENSKA, SUCHITA etc. The recovered parts are used to remanufacture a new product. There is 50% cost variation when we compare the original and the remanufactured product. The dealers are confident and they full faith on the Volvo Reman Centres.

4.1.13. Inventory Control

The company keeps all the materials in in-house. There is no such separate inventory.

4.1.14. Other Managerial Issues

Few government policies which have a positive impact on the long-term goal of the company including buy-back policies, laws related to environment protections, restriction on the uses of hazardous substances, prevention and control of pollution.

4.2. Printech Solutions India Pvt. Ltd., Jayanagar, Bengaluru

4.2.1. Introduction

Printech Solution is a firm engaged in remanufacturing refurbishing and refilling of printer cartridges located in Jayanagar, Bengaluru. The overall annual turnover of this company is about 3 Crores. It was established in the year of 1996 consisting 35-40 workers and has been a centre of attraction for various new re-cycling/ Remanufactured companies. The company has a beautiful infrastructure and a great working environment, which helps the employees towards motivation. Re-cycling/ Remanufactured is not just a term of profit making, the founders of

Printech solution has a different opinion in it. According to them, re-cycling/ Remanufactured is beyond just the literal meaning i.e. re-cycling/ Remanufactured is "mining above the ground". Printech Solution has emerged as an organization that is not only carrying the already existing business of Re-cycling/ Remanufactured, but also adding values to the Wastes. In order to start a re-cycling/ remanufacturing business, the founders are influenced by several factors including green image among customers and ethical & moral responsibilities. It also aims at protecting the green environment, therefore it was also created for a social and environmental concern. Printech Solutions aims to be fully compliant with all environmental rules and regulations as applicable to cartridges recycling/ Remanufactured, to keep its customers fully aware of the recycling efforts undertaken by it, and also aims to invest in systems and processes to track and provide traceability of disposal to its customers. Based on the concept of re-cycling/ Remanufactured, the products which are being refilled/recycled/ Remanufactured in this company are all kinds of Printer cartridges. Printech solutions is an Eco friendly recycling of cartridges maximum usage of non-biodegradable plastic body of the cartridges thereby minimizing the damage to the environment. Printech solution replace the cartridges by completely changing worn-out parts like OPC Drum, Magnetic roller, primary charger roller, wiper blades and filling new imported toner specially manufactured to suit Indian climatic conditions.

Fig. 4.4.: The remanufactured cartridge

4.2.2. The Acquisition Process

This company follows a B2C structure from collecting the e-wastes to releasing in the market. This is a Reverse Logistics framework, where the material is flowing from the users to the manufacturer. In Printech, the customers contact the vendors or dealers and the dealers finally contact the Printech India regarding the collection of used products.

Process of collection of used products:

- Empty virgin, used cartridges are being collected from customers by digital mode of communication or by all means of communication.
- All these cartridges are brought back to their plant/inventory.
- They are opened, cleaned, and worn out parts are replaced with the new ones.
- They are then reassembled and tested accordingly and they keep the test copy.
- And finally the remanufactured cartridges are handled over to the customers.
- The whole used products are being transported and the dealers bear the transportation costs. The detailed processes are discussed below:

4.2.3. Collection of Cores

The factors which are associated with acquisition of used products including problem of locating the cores, data base of the customers, reverse distribution network, planning complexities, size shape fragility and handling of the cores, inspection and finalizing the buy-back price of cores.

Fig. 4.5.: Testing process

4.2.4. Disassembly

It is a simple and manual process which takes approximately 5-10 minutes for dismantling a cartridge. Tools being used in this process include screw drivers, impact tools. Combination of PULL and PUSH strategies are used in this operation. The source of disassembly technology is reverse engineering.

4.2.5. Cleaning

It is a manual process at Printech. Equipment like, blowers, dryers, compressors are being used. Toner cleaning machine is also used. One worker is involved in the cleaning process. Manual cleaning process keeps on changing and it takes around 5-10 minutes for completing the cleaning process. Pressurized cleaning machines like high pressure washers are used. There is a need of semi-skilled workers in cleaning process. Issues like excessive dirt/oil, corrosion and type of material are important at Printech.

4.2.6. Inspection

The inspection procedure is a manual process where the worker place the remanufactured cartridge in a printer (tester) and check whether the cartridge is working or not. One skilled worker is involved in the process. It takes 10-15 minutes for inspection. Cartridge inspection machine is used for inspection. Defining specifications, identifying defects, inspector's knowledge and section instrument required for inspection are the key factors of this process.

4.2.7. Repairing/Replacement/Reassembly

It is a manual as well as machine automated process. It is a complex process. Three workers are being involved in repairing/refurbishing/replacing. There is a need of skilled and experienced workers in this process. The approximate time required for such operation is 25-30 minutes. When the cartridge is dismantled, the worn out or the damaged parts are repaired or replaced with the same new part. 10-15 % of new components are used in the process. Reassembling is

being done manually by the same workers in the same bench. It takes approximately 10-15 minutes.

4.2.8. Disposal Issues

20 % of the products or spares are disposed off. Printech sells the products to the customers within a minimal cost. The company has EPR certificate for disposing e-wastes as per governmental laws.

4.2.9. Marketing and Sales of recycled products

The customers for the remanufactured products are dealers like hospitals, SMEs, financial sectors, IT sectors etc. There is 50-60% cost reduction when compared to the original cartridges.

4.2.10. Other Managerial Issues

Few government policies which has a positive impact on the long term goal of the company including buy-back policies, land fill restrictions, laws related to environment protections, restriction on the uses of hazardous substances, prevention and control of pollution, disposal costs and few others.

4.3. 4R recycling Pvt. Ltd., Bengaluru.

4.3.1. Introduction

4R is a recycling based company which is located in Peenya Industrial Area, Bengaluru. The overall annual turnover of this company is about 7.5 crores. It was established in the year of 2012 consisting 25 workers and has been a centre of attraction for various new re-cycling companies. The company has a beautiful infrastructure and a great working environment, which helps the employees towards motivation. Re-cycling is not just a term of profit making, the founders of 4R Re-cycling has a different opinion in it. According to them, re-cycling is beyond

just the literal meaning i.e. re-cycling is "mining above the ground". 4R Re-cycling has emerged as an organization that is not only carrying the already existing business of Re-cycling, but also adding values to the E-Wastes. In order to start a re-cycling business, the founders are influenced by several factors including green image among customers and ethical & moral responsibilities. It also aims at protecting the green environment, therefore it was also created for a social and environmental concern. 4R aims to be fully compliant with all environmental rules and regulations as applicable to e-waste recycling, to keep its customers fully aware of the recycling efforts undertaken by it, and also aims to invest in systems and processes to track and provide traceability of disposal to its customers. Based on the concept of re-cycling, the products which are being recycled in this company are all kinds of electronic wastes for example desktops, cables etc. 4R is a waste management enterprise which focuses on Re-cycling, Re-processing, Re-use and Re-create from all kinds of waste and has been established as a company that generates power using waste. Profitable business option, creating green image among customers and ethical and moral responsibility towards society are the prime reasons why the company started the business.

Fig. 4.6.: 4R remanufacturing plant

4.3.2. The Acquisition Process

This company follows a B2B structure from collecting the e-wastes to releasing in the market. This is a Reverse Logistics framework, where the material is flowing from the users to the manufacturer. The detailed processes are discussed below:

- The 4R buys e- wastes with the help of calls, emails, auctions or any form of digital communication.
- The used e-wastes gets collected at the inventory.
- Dismantling and further dismantling of used products is done.
- Finally the metals are extracted from the used e-wastes and non-metals are left behind.
- The policies that are adopted to collect the used products are buy- back policies and from auction centres.
- The value of the return is determined by the age, usage and the quality of the used e-waste product.(If it is a scrap then what is the metal content in it.)
- They are the recyclers but they are having different separate warehouses. They have 3 separate warehouses.
- The mode of transportation for collecting the used products is truck.
- The whole used products are being transported.
- The overall cost involved in transportation of used materials is approximately 7-10%.

4.3.3. Collection of Cores

Factors associated with acquisition of used products including problem of locating the cores, data base of the customers, reverse distribution network, planning complexities, size, shape fragility and handling of the cores, collection centre locations, mode of parts collection, inspection and finalizing the buy-back price of cores.

4.3.4. Disassembly

4R uses manual process of disassembly which involves 5 workers having basic tool handling skills, semi-skilled workers are also preferred. Machines being used in this process include wire granulating machines, PCB granulating machines etc. Further dismantling of materials include machines as mentioned before. The approximate time and cost for dismantling of a unit totally depends on the type of material. The source of disassembly technology is in-house development. There could be several issues while following a disassembly operation including sequence, depth of disassembly, lot-sizing, permanent fastening, rust, dirt, complexity of product design, uses of special tools, worn out fastener heads, size of products and availability of disassembly technology and many others. The team has to look out each and every issues while the disassembly operation. After the disassembly, cleaning and sorting operation is needed to remove the dirt and rusts. 4R usually avoid this steps and jumps directly into inspection.

4.3.5. Inspection

It is an initial step of balancing the quality of conformances. The quality of a tiny part from an e-waste could impact the quality of the product at end-users. No such specific machines are being used here at 4R, sometimes magnets are used in this process. Generally 4- 5 well skilled and experienced workers are involved in this process. Depending on the visuals and colours of the materials, the inspection is done. Time required for inspection totally depends on the volume of the item, its type, its colour. The issues arises in the inspection process are generally identified by the knowledge and experience of the inspector. 4R usually do not repair or replace spare parts.

4.3.6. Extraction

4R uses a semi-automated procedure which involves 5 workers to operate the extraction

process. This is the last step being performed. There are granulating machines. The approximate time and cost involved in extraction totally depends on the type of the material. The granulating machines can handle 2 tons of materials per hour. The important issues in extraction process are skill of employees, design complexities and product diversities.

4.3.7. Disposal Procedure

The percentage of components/parts that are being disposed is approximately 10%. The disposal costs depend on the type of material ex. plastic, silicon etc. E-waste Management Rules 2016 issued by MOEF is being followed by 4R.

4.3.8. Design Issues

The design of the product has a critical impact on the recycling stage. The diversity in the designs leads to time taking operations.

4.3.9. Marketing and Sales of recycled products

4R is basically recyclers and extractors and they contact those users which are involved in working with metals and non- metals through digital communication. The cost of metals and non-metals extracted from the used products is going to cost less in comparison to the original product's cost.

4.3.10. Other Managerial Issues

Few government policies which has a positive impact on the long term goal of the company including buy-back policies, land fill restrictions, laws related to environment protections, restriction on the uses of hazardous substances, prevention and control of pollution, disposal costs and few others.

4.4. Reman Infrastructure Pvt. Ltd., Namakkal, Tamil Nadu.

4.4.1. Introduction

REMAN Infrastructure Private Limited is a Remanufacture based company which is located in S F No. 235/1, 235/2, Auto Nagar Kathapalli, Namakkal Tamilnadu-637019. With an annual turnover of about 4 crores, the company has a beautiful infrastructure, which was established in the year 1989. REMAN Engineering works was taken over by "REMAN Infrastructure Private Limited" in the year 2018 with an intent to peddle, penetrate the market and serve nation & global customers with its quality products and services. The company consists of 25-30 workers. To the founders of REMAN Infrastructure private limited they engaged in remanufacturing or manufacturing of batch machine as per the requirements of the customers. The REMAN Infrastructure Private Limited firm is highly rated for quality work and has an excellent reputation. The REMAN Infrastructure Private Limited innovation auto batching scale machine its help to reduce your batching time. It batches the right quantity and 40% of the feed is premixed which saves times & labour hours for batching.

Based on the concept of remanufacturing, the products which are being remanufactured in this company are all kinds of machine for example Bucket Elevators, Conveyors, mixers, pellet mill dies & rollers. The REMAN Infrastructure Private Limited is a remanufacturing private limited which focuses on Remanufacturing and OEM, Reprocessing, Reuse and Recreate from all kinds of Remanufactured has been established as a company that generates power using Remanufacturing.

The company was established in order to create a profitable business and also thought that it is their ethical and moral responsibility. It also aims at protecting the green environment, therefore it was also created for a social and environmental concern. The REMAN Infrastructure Private Limited aims to be fully compliant with all environmental rules and regulations as

applicable to Remanufacturing, to keep its customers fully aware of the remanufacturing efforts undertaken by it, and also aims to invest in systems and processes to track and provide traceability of disposal to its customers.

Fig. 4.7.: REMAN remanufacturing plant

4.4.2. The Acquisition Process

This company follows a B2C structure from collecting the e-wastes to releasing in the market. This is a Reverse Logistics framework, where the material is flowing from the users to the manufacturer. The detailed processes are discussed below:

- The REMAN Infrastructure Private Limited used products are being collected from with the help of calls, emails, auctions or any form of digital communication.
- Company visit to the customer's factory to know that the Dimension, management, layout, design, make, which parts to be replaced or repair.
- The policies that are adopted to collect the used products are Take- back policies and from auction centres.
- They give quotation to the customers on the basis of replacement and repair of the products.

- They are the Remanufacture and manufacture also but they have not different separate collection centres.
- The value of the return by any quality checking or current value of the steel.
- The mode of transportation for collecting the used products by own trucks.
- The used products are being transported by disassembling or some time whole used products are being transported.
- The overall cost involved in transportation of used materials is approximately 8%.

4.4.3. Collection of Cores

The crucial phase of this reverse logistics framework is collecting the cores. The quality, availability and usefulness of the wastes could lead to success in the re-cycling business. The factors which are associated with acquisition of used products including problem of locating the cores, data base of the customers, reverse distribution network, planning complexities, uncertainty issues in timing, quality and quantity of returns, size, shape, fragility and handling of the cores, collection centre locations, mode of parts collection, and inspection of cores.

4.4.4. Disassembly

Once the wastes are collected from the users or some other sources, the next step is to disassemble the product in order to expose the various components of that product. It is a partial manual and machinery operation which involves 5 workers having basic tool handling skills, semi-skilled workers are also preferred. The disassembling time varies according to the type of material and size of material, approximate one day or two day being disassembled. Machines being used in this process include pullers, manual crane, chain pulley, simple tools, grinders, cutters etc. Further dismantling of materials include machines as mentioned before. The approximate time and cost for dismantling of a unit totally depends on the type of material and size of material. The strategies adopt for disassembly operation is PULL strategy. The source

of the disassembly technology are from OEM and Reverse Engineering. The REMAN Infrastructure Private Limited also required expertise from Design and Layout diagram of the material. There could be several issues while following a disassembly operation including sequence, depth of disassembly, lot-sizing, permanent fastening, rust, dirt, complexity of product design, uses of special tools, worn out fastener heads, size of products and availability of disassembly technology and many others. The team has to look out each and every issues while the disassembly operation.

4.4.5. Sorting

It is manual and machinery process which involves the same 5 workers who are carry the disassembly operations. They have basic tool handling skills, semi-skilled and experience workers are preferred. The sorting time varies according to the type of material that is steel, iron etc. It also depends on bearing, belt, pulley and machine part like shaft, sprocket. The time and cost are depending on material and size of materials. In the sorting process the machine and equipment's are required like pullers, cutting machine, crane.

4.4.6. Inspection

It is a complex process, and operated by manual, machinery and electrically. Very skilled and experienced workers are involved in this process. This process needed specific machines like Gauge machine for measuring main parameters and critical dimensions. Manual and visual inspection are also done. REMAN usually engages 3 workers in this inspection process. The approximate time required for inspection totally depends on the type of the material and size of the material or within a day.

4.4.7. Repair and Replacement Process

It is done by manually and using specific machine for repair/replacement like welding machine, lathe, grinding machine, cutting machine, drilling machine, wrench set, testing set, mugger etc.

It is done by skilled team of 5 workers. The approximate time and cost required for repairing depends on materials and plants. If there is big plants it take one month. The 75% parts/components is newly procured for remanufacturing.

Fig. 4.8.: REMAN remanufacturing process

4.4.8. Reassembly Process

The reassembly process is operated both manually and by using machines. The same team of workers involved in the remanufacturing process do this operation. Also the same tools/machines are used. The issues arises in the reassembly process are generally identified by the knowledge and experience of the worker.

4.4.9. Disposal Procedure

The percentage of components/parts that is being disposed of is approximately 10-20%. The disposal costs depend on current rate of the material like steel or scraped material etc. The disposal costs depend on current rate of the material.

4.4.10. Design Issues

The design of the product has a critical impact on the recycling stage. The diversity in the designs leads to time taking operations.

4.4.11. Marketing and Sales of recycled products

They are remanufacturing, and they contact the customers involved in working with OEM customers like Selvam broilers, Aishwarya feeds, Existing customers and new customers through digital communication and visiting. The cost variation involved while comparing the remanufacturing products cost with the original products cost is 20%.

4.4.12. Inventory Control

REMAN Infrastructure maintains an inventory of parts and components. Shortages in inventory, balancing demand with return, parts matching, lead time variability, requirement of stores are some of the important issues in managing inventory at the plant.

Fig. 4.9.: REMAN Inventory

4.4.13. Other Managerial Issues

Few government policies which has a positive impact on the long term goal of the company including buy-back policies, land fill restrictions, laws related to environment protections, restriction on the uses of hazardous substances, prevention and control of pollution, disposal costs and few others.

4.5. Eco Recycling Limited, Andheri (E), Mumbai

4.5.1. Introduction

Ecoreco is a recycling based company which is located behind Gurunanak pump, Andheri Kurla Road, Andheri, Mumbai. With an annual turnover of about 12.43 crore, the company has a beautiful infrastructure, which was established in the year 2005. The company consists of 40 workers and has been a centre of attraction for various new recycling companies. Eco Recycling Ltd (Ecoreco) is India's first and leading professional E-waste Management Company that has set industry benchmarks time and again with its innovative & environment friendly disposal practices. Based on the concept of recycling, the products which are being recycled/remanufactured in this company are metallic products for example: copper, aluminium etc. Ecoreco is turning India's e-waste challenge into an opportunity for sustainable business growth. The company was established in order to create a profitable business. It also aims at protecting the green environment, therefore it was also created for a social and environmental concern. E-waste poses a serious environment hazard if it is not disposed of in a scientific manner. Ecoreco, commits to the scientific disposal of e-waste. This enables a reduction in the environmental impact and drives responsible environmental stewardship. Towards this goal, the company is committed to exploring new and innovative ways to reduce the ecological footprint of e-waste whilst maximizing its value recovery. As a recognized leader of e-waste recycling, the company aim is to avoid landfill and to leverage best-in-class technologies to reclaim the resources from this valuable waste.

Fig. 4.10.: Ecoreco remanufacturing plant

4.5.2. The Acquisition Process

This company follows a B2B structure from collecting the e-wastes to releasing in the market. This is a Reverse Logistics framework, where the material is flowing from the users to the manufacturer. The detailed processes are discussed below:

- Ecoreco receives requests from corporates or MNC's in the forms of emails or calls or any other digital communication.
- The requests are being sent to the third party logistics or own fleet of vehicles.
- Once the e-wastes being collected, they are brought down to the Ecoreco.
- In Ecoreco, B2B process is being involved. These are major corporates or MNCs who want to dispose of their e wastes. Ecoreco receives requests in the form of emails/calls in B2B segment and then the requests are being sent to the third party logistics or own fleet of vehicles , once the e wastes are being collected they are brought down to the Ecoreco for recycling purpose.

The crucial phase of this reverse logistics framework is collecting the cores. The quality, availability and usefulness of the wastes could lead to success in the re-cycling business. The data which has been collected from the site, has directed the readers to understand the critical

factors in collection of cores. The factors which are associated with acquisition of used products including problem of locating the cores, data base of the customers, reverse distribution network, planning complexities, collection centre locations, inspection and finalizing the buy-back price of cores. The complete acquisition process consists 4 intermediate steps including the communication stage, B2B stage, transportation stage which also done by either own fleet or 3rd party vehicles and lastly arriving to the recycling stage.

Fig. 4.11.: Remanufacturing process

4.5.3. Disassembly

It is both manual and machine operated, which involves 7-10 workers having basic tool handling skills; semi-skilled workers are at least preferred. Tools like, screw drivers, hammers, hinges etc. are used in this process. The disassembling time varies according to the type of material and size of material. The source of the disassembly technology are from OEM or by Reverse Engineering. There could be several issues while following a disassembly operation including sequence, complexity of product design, uses of special tools, size of products and availability of

disassembly technology. The team has to look out each and every issues during the disassembly operation.

4.5.4. Sorting

It is a manual process. Depending on the type of product, sorting operation is performed, that is whether the product is plastic or hazardous wastes or e-wastes. The time and cost involved in sorting operation varies according to the type of equipment being sorted. No special tools required here, it is done manually.

4.5.5. Inspection

This operation totally depends on the technology being used for each and every kind of equipment. No such special tools required for this operation and basic skill sets are required. Skilled and experienced workers are involved in this process. The issues arises in the inspection process are generally identified by the knowledge and experience of the inspector, high product diversity.

4.5.6. Inventory Control

It generally indicates a Push type supply chain where the demand is as per made to stock type. The Inventory control system at Ecoreco maintains a Made to order layout, where the end products are associated with high costs. The Company has incoming equipment's inventory and recycled equipment's inventory.

4.5.7. Marketing and Sales of recycled products

Ecoreco is an end chain company. They sell their by-products (recycled) to the smelters, reprocesses or other facility departments. Parts are being sold to the different facility centres by Ecoreco to remanufacture a new product. The cost variation involved while comparing the recycled product with the original product totally depends upon the type of product being recycled. The observed behavioral patterns of the customers are always aggressive. The cost of

metals and non-metals extracted from the used products is going to cost less in comparison to the original product's cost.

4.5.8. Other Managerial Issues

Few government policies which has a positive impact on the long term goal of the company including buy-back policies, land fill restrictions, laws related to environment protections, restriction on the uses of hazardous substances, prevention and control of pollution, disposal costs and few others.

4.6. Texcool Limited, Cuffe Parade Mumbai

4.6.1. Introduction

Texool limited is a recycling based company which is located in Shree Arihant Complex, Kalher, Bhiwandi, Mumbai. With an annual turnover of about 3 crores, the company was established in the year 2012. The company consists of 50 workers and has been a centre of attraction for various new recycling companies. Texool is one of the few who offer a fully circular model. The company take back clothes and textiles for responsible recycling and up cycling and offer an array of products from their stable of up cycled and recycled products to complete the chain. According to them, Landfills can be reduced dramatically if waste is channelized. Texool has given a new dimension to up cycling on an industrial scale something which has always been considered cottage in operation. Texool pioneered TEXTILE recycling especially industrial up cycling, starting as concessionaires, representing large overseas collectors and graders of Old & Used Clothing for more than 50 years ago. Texool is being considered as one of the most remarkable companies globally where GREEN is a State of Mind and sustainable management with Zero waste is a MANTRA.

Based on the concept of recycling, up cycling (believe in 3R's concept) the products which are being recycled /up cycled in this company are bags and accessories. Every Kilo Texool recycles and up cycles significantly helps the environment due to the implementation of 3 R's, Reduce, Recycle and Reuse. The company endeavour to create and innovate, teach, share and spread the benefits of helping the environment through brands I AM NOT A VIRGIN and I AM SO WASTED. Through their brand, the company also conveys that recycling and up cycling is Fashion, Fun and being Responsible.

The company was established in order to create a profitable business and also thought that it is their ethical and moral responsibility. It also aims at protecting the green environment, therefore it was also created for a social and environmental concern. The company also wanted to maintain green image among the customers. The company totally believes in motivating the society towards the fact that used products can also be recycled and reused and the environment can be kept safe from the materials such as plastics or non-biodegradable materials.

Fig. 4.12.: Texcool Remanufacturing plant

Fig. 4.13.: Texcool Remanufactured products

4.6.2. The Acquisition Process

This company follows a B2C structure from collecting the e-wastes to releasing in the market. This is a Reverse Logistics framework, where the material is flowing from the users to the manufacturer. The collection of used raw materials is done manually which include collecting the raw materials (used) either from retailers (post consumers) or collecting the used products from organised mills or from unorganised textile industries might also include chindi dealers and then finally these products reach the destination and then finally these used products reach the destination Texool Ltd. via trucks or mini vans. The company finally recycles/reproduces the used products into a new product. The detailed processes are discussed below:

- The policies which are adopted to collect the used products are exchange-offer, take-back, buy-back or from auction centres.
- The value is the return is determined by checking the quality of the product.
- The company does not have separate collection centres.
- The mode of transportation for collecting the used products is done via tempos or trucks.
- The whole used products are being transported directly to the location of the plant

- The overall cost being involved in transportation of used materials is 10 Rs./ Kg approximately.

TEXOOL generally imports from the international retailers, Charities, used clothing peelers and bin collections. Those items which have been received from the retailers are directly recycled/ reproduced.

4.6.3. Collection of Cores

The crucial phase of this reverse logistics framework is collecting the cores. The quality, availability and usefulness of the wastes could lead to success in the re-cycling business. The data which has been collected from the site, has directed the readers to understand the critical factors in collection of cores.

4.6.4. Disassembly

This operation is a manual process and it totally depends on the used raw materials, its type, quality and other factors like colour etc. Here more than 50 percent of the employees of the plant are being involved. The approximate time depend upon the type of used raw material being recycled. This process is one of the challenging process among the whole business process. It can be considered as the preparatory process and it is somewhat a complex process. The strategies adopted for disassembly procedure is a combination of PULL and PUSH strategies. The source of disassembly technology is OEM and Reverse Engineering. There could be several issues while following a disassembly operation including uncertain recovery rates, homogeneity of used product range, disassembly sequence, depth of disassembly, lot-sizing, permanent fastening, rust, dirt, complexity of product design, uses of special tools, worn out fastener heads, and availability of disassembly technology.

4.6.5. Cleaning

It is the end stage process done in Texool while recycling the used products. It is not a complex

process. It is done with the help of simple machines such as industrial washing machines, dry cleaning machines etc. It is an automated as well as semi- automated process. Machines like XSONI, INEO etc. are used. The time required for cleaning operation depends on the type of raw material being cleaned. No such expertise is required here.

4.6.6. Sorting

This is the second step being performed. The sorting process depends on the colour of the used raw material, quality of used products etc. Indigenously made machines are used for sorting. It is a complex procedure and the workers need to have basic handling and sorting skills. The approximate time and cost required for sorting depends upon the type of material being sorted and sorting is a time consuming process and therefore the cost also gets affected. It is done both manually and using machines.

4.6.7. Inspection

It is an initial step of balancing the quality of conformances. The quality of a tiny part from an e-waste could impact the quality of the product at end-users. This process includes eliminating the bad parts, bad materials, removing zips of the pants, buttons etc. After the completion of the sorting process, the materials are then sent to the conveyor belt which is the end of the preparatory stage. It can be considered as the end stage process. It is a manual process which involves 50-60% of the staff. It is a simple process in recycling but a complex process when it comes to up cycling. The approximate time required for inspection depends on the type of material being recycled. No such special machines or equipment's are needed here. Skilled manual operators are required to identify the type of material for ex. wool, cotton. The issues arises in the inspection process are generally identified as the knowledge and experience of the inspector, high product diversity, identification of defects, etc.

4.6.8. Upcycling, Repairing and Replacement Process

Upcycling might be performed which might include refurbishing/repairing. Repairing/ Refurbishing is being performed manually. This process may include simple sewing machines and requires basic sorting and inspecting skills that help in repairing/refurbishing. This process involves 5-10% of the employees. It is a simple procedure. The approximate time required for repairing is 2-5 minutes. 5% of the parts is newly procured for repairing/recycling. This process requires simple industrial sewing machines and cleaning washing machines for ex.: SGGEMSY etc.

4.6.9. Reassembly

Carding is a mechanical process that disentangles, cleans and intermixes fibres to produce a continuous web or silver suitable for subsequent processing. It is a crucial process in recycling business. This involves carding machines such as BEFAMA, BENINO, and LAROSH etc. The approximate time and cost required here totally depends on the type of material being processed.

4.6.10. Disposal Procedure

They are themselves the recyclers. No such environmental laws are followed by the company as they are not involved in the disposal process.

4.6.11. Design Issues

The design of the product has a critical impact on the recycling stage. Homogeneity in products, dirt/oil of used products, type of material used, delicate raw materials are some of the issues.

4.6.12. Marketing and Sales of recycled products

The customers for the recycled products include all type of customers basically the export oriented customers and the possible medium to reach the costumers include all sources such as social media, exhibitions, mails, calls etc. There is a minimal slight cost variation when the

comparison is done between the original product's cost and the recycled product's cost. There are trust issues which are being generated from the customer's end and to gain their trust the company provides certification that guarantees the quality of the recycled product.

4.6.13. Inventory Control

The Inventory control system at TEXOOL maintains a Made to order layout, where the end products are associated with high costs. Shortages in inventory, matching demand and supply, capacity planning and scheduling, lead time variability and lot sizing are some of the issues in managing inventory.

4.6.14. Other Managerial Issues

Few government policies which has a positive impact on the long term goal of the company includes laws related to environment protections.

4.7. Bijoy Engineering Works, Dhanbad

4.7.1. Introduction

Bijoy engineering works is a remanufacturing based firm which is located in Bhuli, Dhanbad, Jharkhand. It has approximately an annual turnover of about 80 lakhs. This firm was established in the year 1965 and currently running with 9 workers. Bijoy Engineering works has been engaged in primarily the remanufacturing products like Transformers, Motors and Switchgear as per the requirements of the customers. The Bijoy Engineering Works firm is highly rated for quality work and has an excellent reputation. The Company works with the government or private company. Based on the concept of remanufacturing, the products which are being remanufactured in this company are all kinds of transformer (three phase transformer, single

phase transformer etc.), motors, switchgear. The company was established with the objective that this is a profitable business, creating inventory of spare parts, with a aim of building a green image in the market and also as an ethical and moral responsibility to society. The Bijoy Engineering Works aims to be fully compliant with all environmental rules and regulations as applicable to remanufacturing.

4.7.2. The Acquisition Process

This company follows a B2B structure from collecting the e-wastes to releasing in the market. There is a Reverse Logistics framework, where the material flows from the end users to the manufacturer. The detailed process is discussed below:

- The Bijoy Engineering Works collects used products from the market through calls, emails and E-tendering. Company bids for quotation in many companies for parts to be replaced or repair. They uses buy- back policies, and collects from auction centres.
- They do remanufacturing but have no separate collection centers.
- The value of return is done by quality checking, age of the product and usage the product.
- The mode of transportation for collecting the used products is trucks or mini vans.
- Transportation depends on the size of the used product. For big sizes, they are disassembled at the site and then loaded in trucks. Smaller sizes are transported in whole.
- The overall cost involved in transportation of used materials is approximately 3-4%.

4.7.3. Collection of Cores

The factors associated with acquisition of used products including problem of locating the cores, uncertainty in time of return, size and shape of core, inspection of cores and finalizing the buy-back price of cores.

4.7.4. Disassembly

It is done manually and also machine operated. It involves 6-7 workers having basic tool handling skills, semi-skilled workers are also preferred. The disassembling time varies according to the type of material and size of material, approximate one day or two day is required. Machines used in this process include pullers, manual crane, chain pulley, simple tools, grinders, cutters etc. The strategies adopt for disassembly operation is PUSH strategy. The source of the disassembly technology is from Reverse Engineering. There could be several issues while following a disassembly operation including sequence, depth of disassembly, permanent fastening, rust, dirt, complexity of product design, use of special tools, worn out fastener heads, size of products and availability of disassembly technology and uncertain recovery rates.

Fig. 4.14.: Used transformers for remanufacturing

4.7.5. Cleaning

It is manual and machine operated process, which involves 2 workers having basic tool handling skills. The cleaning time varies according to the type of material, deposit of corrosion/rust, excess dirt/oil/debris etc. It also depends on size of product and machine part like transformer, switchgear and motors. In the cleaning process, the machine and equipment used are Oil filter

machine, Blowers, and Brace and Spray.

4.7.6. Sorting

It is manual and machine operated process, which involves same set of 4-6 workers. The sorting time varies according to the type of material and size of material that is coils, transformer parts, motor parts etc. In the sorting process, machine and equipment required are grinder, cutter and tool set.

4.7.7. Inspection

It is done manually, using tools for electric checking. Specific machines used for inspection includes oil testing, high pressure testing, secondary injection testing, ratio testing, balancing testing etc. Skilled and experienced workers are involved in this process. Same 4 workers are involved here. The approximate time required for inspection is 1-2 days. The overall cost involved in Inspection process is approximately 2%. The issues arises in the inspection process are generally the knowledge and experience of the inspector and defining specifications.

4.7.8. Repair and Replacement Process

It is done manually using tools like winding machine, wrench set, testing set, mugger etc. It is done by skilled team with the help of helpers. Same 6 workers are involved here. The approximate time and cost required for repairing depends on product like, transformers take 15-45 days, motors take 30-60 days and switchgear take 10-15 days. 50% parts/components is newly procured for remanufacturing/repair/replacement. Many parts are not available easily, not available at the same time and same place. The overall cost involved in repair process is approximately 10-15%.

4.7.9. Reassembly Process

It is done manually and using machine like tyfor, chaincupi, basic tools etc. It is done by skilled team with the help of helpers. Same 6 workers are involved here. The approximate time

required for reassemble depends on product like, transformers take 2-4 days, motors take 2 days and switchgear take 2-4 days. The overall cost involved in reassemble process is approximately 2-3%. The issues arises in the reassembly process are generally identified by the knowledge and experience of the worker.

Fig. 4.15.: Remanufacturing process at Bijoy Engineering

4.7.10. Disposal Procedure

The percentage of components/parts that are being disposed is approximately 25-50%. The disposal costs depend on the type of material ex. plastic, silicon etc. E-waste Management Rules 2016 is being followed by Bijoy.

4.7.11. Design Issues

The design issues like complex products, tolerances for wear, assembly/disassembly problems are considered to be critical to the company.

4.7.12. Marketing and Sales of recycled products

Customers are through GeM portal, BCCL, CL, ECL, and Jharkhand Government. New customers are built through digital communication and visiting. The cost variation while comparing the remanufacturing products cost with the original products cost is 30-50%. The observed

behavioural patterns of the customers are always aggressive.

4.7.13. Inventory Control

The Inventory control system at Bijoy Engineering Works is for both new parts/components and for used products. Primary issues involves shortages in material, space constrains for stores, parts matching problems.

4.8. Comparative analysis of the case studies

The seven companies are compared in the following tables with respect to the various factors identified from the literature.

Company	Acquisition of Products	Mode of Transportation
VOLVO REMAN India	B2B Connectivity from customers and other sources	Trucks and Couriers
Printech Solutions India Pvt. Ltd.	B2B Connectivity from customers and other sources	Manually or any form of transportation
4R Recycling Private Limited	B2B Connectivity from customers and other sources	Trucks
REMAN Infrastructure Pvt. Ltd.	B2B Connectivity from customers and other sources	Own Fleet of Vehicles. Ex. Trucks
ECORECO	B2B Connectivity from industries and other sources	Trucks
Authentic Implex / Texool Limited	Imported from outside countries and as well as from other parts of INDIA	Trucks and Mini Vans
Bijoy Engineering Works	B2B Connectivity from industries and other sources	Trucks and Mini Vans

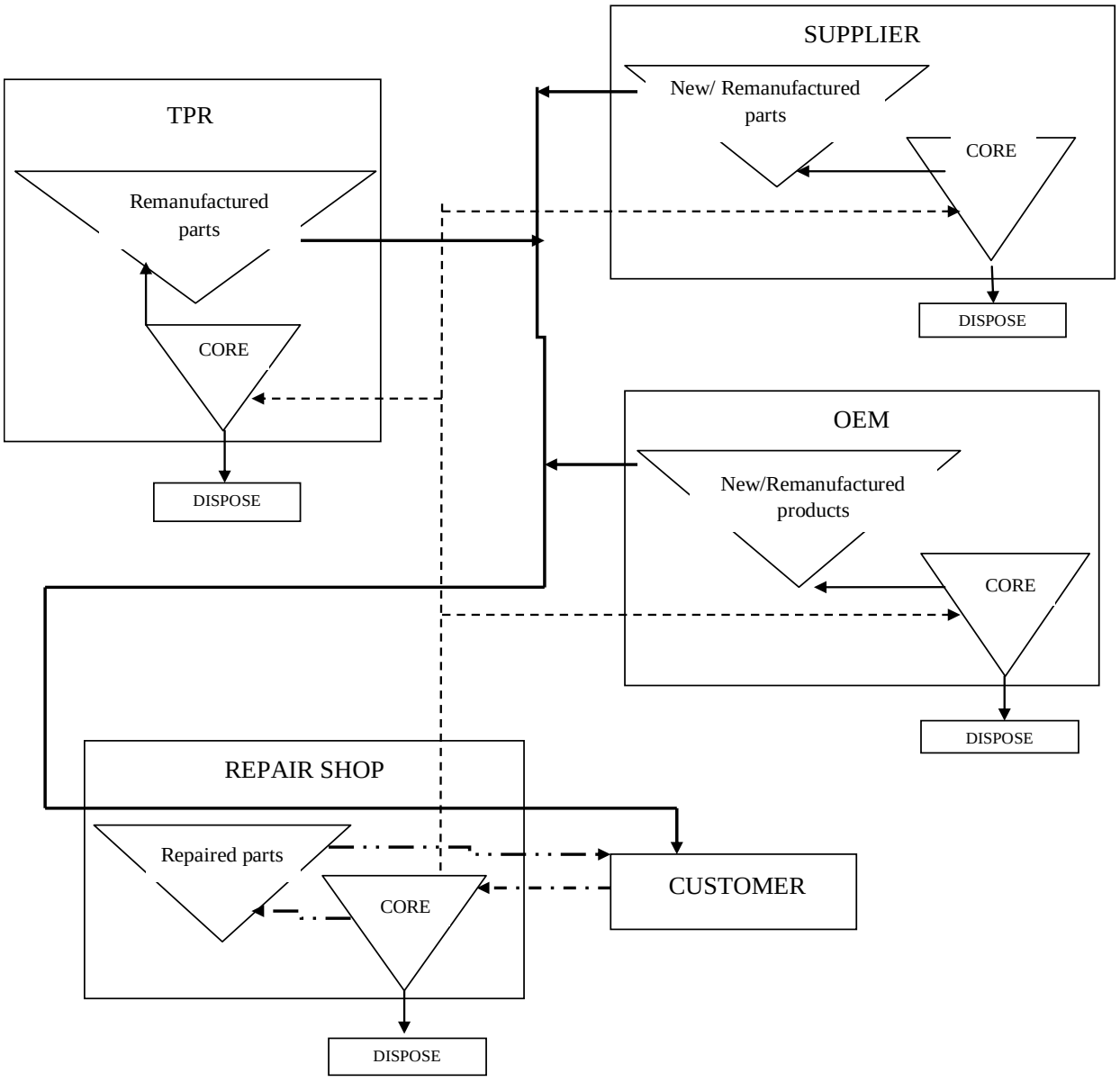
Company	Remanufacturing Processes						
	Disassembly	Cleaning	Sorting	Inspection	Repair/ Replacement	Reassembly/ Extraction	Disposal
VOLVO REMAN India	Manual Process with 2 employees involved	Semi Manual process with 1 workers involved in the process	NA	Manual Process with 1 highly skilled worker involved	Semi Manual Process with 3 highly skilled workers involved	Manual Process with 1 highly skilled worker involved	30%

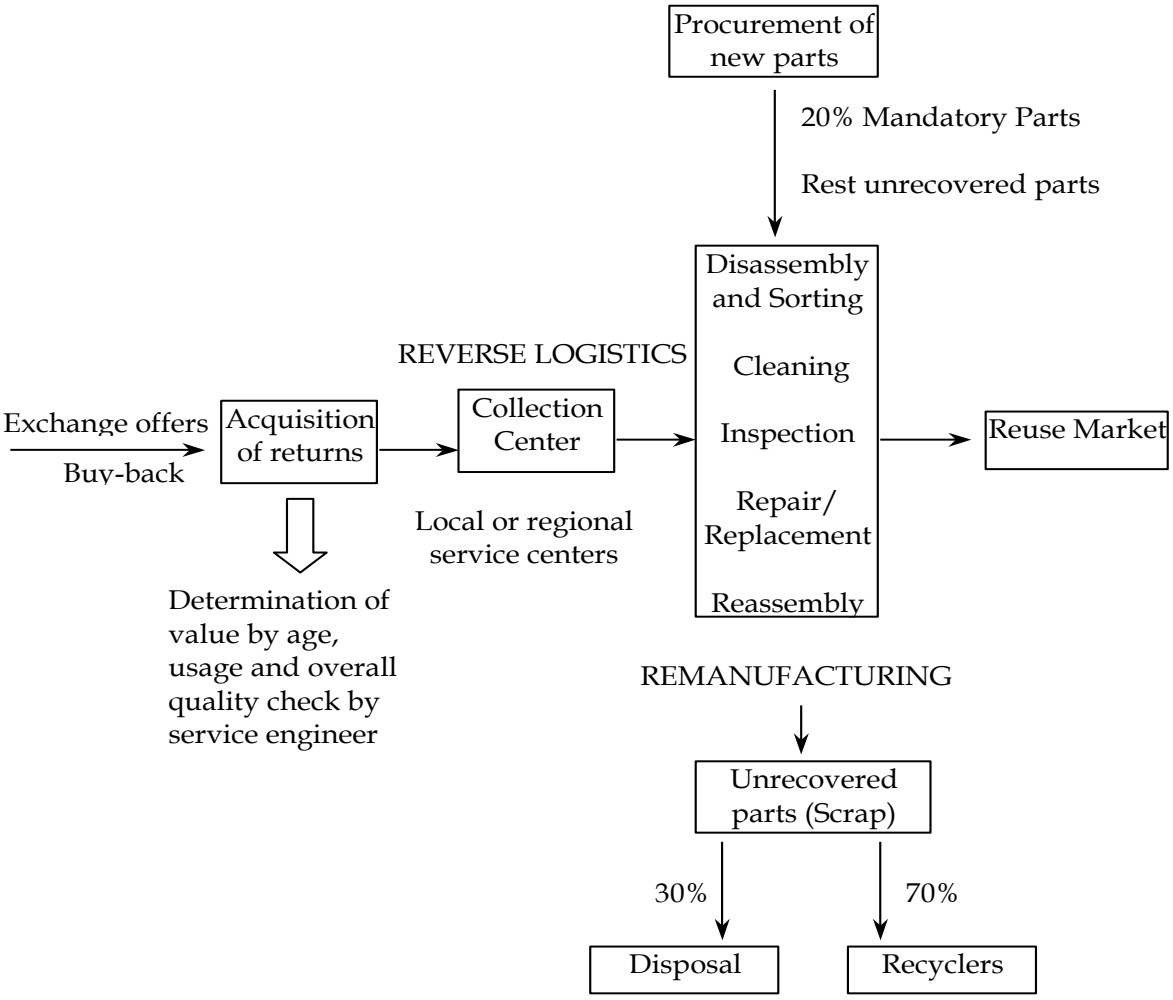
Printech Solutions India Pvt. Ltd.	Manual process.	Manual Process with semi skilled workers	NA	Completely Manual Process	Manual Process with 1 worker involved	Manual Process with 1 worker involved	20%
4R Recycling Private Limited	Semi Manual process. Done with 5 workers	NA	NA	Completely Manual Operation. 4-5 Highly skilled workers are involved.	NA	Semi automated procedure with 5 workers involved in the operation	10%
REMAN Infrastructure Pvt. Ltd.	Semi Manual process. Done with 5 workers	NA	Manual Process	Manual or Visual process with 3 workers involved	Manual Process with 5 worker involved	Semi Manual Process	10-20%
ECORECO	Manual process. Done with 7-10 workers	NA	Manual Process	Completely Automated Process	NA	NA	100%
Authentic Implex / Texool Limited	Manual Process with 50 % employees	Cleaning done by using simple machines like XSONI, INEO etc. are used	Manual Process	Manual Process with 50 % workers involved	Manual process with 5-10 % workers involved	Mechanical process where BEFAMA, BENINO, and LAROSH etc. are used	0%
Bijoy Engineering Works	Semi Manual process. Done with 6-7 workers	Semi Manual process with 2 workers involved in the process	Semi Manual process with 4-6 workers involved in the process	Semi Manual process with 4 workers involved in the process.	Semi Manual process with 6 workers involved in the process	Semi Manual process	25-50%

Company	**Inventory**	**Supply Chain Strategy (PUSH/ PULL)**	**Distribution of Costs**			**Turnover in 2020-2021 (In Lacs.)**	**Consolidated Profit in 2020-2021 (In Lacs.)**
			Technology/ Machine/ Capital	**Used Products**	**Others**		
VOLVO REMAN India	NA	Both	NA	NA	NA	NA	OEM
Printech Solutions India Pvt. Ltd.	NA	Both	10%	5%	85%	214	75
4R Recycling Private Limited	NA	NA	55%	25%	20%	NA	NA
REMAN Infrastructure Pvt. Ltd.	YES	PULL	20%	30%	50%	250	93
ECORECO	YES	NA	NA	NA	NA	1848	605
Authentic Implex / Texool Limited	YES	Both	50-60%	30%	20-10%	2500	85
Bijoy Engineering Works	YES	PUSH	45%	10%	45%	NA	NA

4.9. Process Flow Diagram of the remanufacturing process

Summarizing the various remanufacturing processes of the case study a comprehensive Process Flow Diagram is constructed, as shown in the figure below. The figure shows that there exists basically three types of remanufacturers in the market, one is the OEM himself remanufacturing their products, the Suppliers of OEM who are remanufacturing parts and components to supply remanufactured products to either OEM or spare part market and the Third Party Remanufacturers (TPR) who are independently remanufacturing components or products.




Procurement of new parts
20% Mandatory Parts
Rest unrecovered parts
Disassembly and Sorting
Cleaning
Inspection
Repair/ Replacement
Reassembly
REVERSE LOGISTICS
Exchange offers
Buy-back
Acquisition of returns
Collection Center
Reuse Market
Local or regional service centers
Determination of value by age, usage and overall quality check by service engineer
REMANUFACTURING
Unrecovered parts (Scrap)
30%
70%
Disposal
Recyclers

Chapter 5: Result and Discussions

5.1. Critical Issues in remanufacturing process

From the above seven case studies it is found that the success factors for remanufacturing business in India is centered along the following set of issues.

(i) Remanufacturing issues

- Acquisition of Used products/Returns/Cores
    - Raw material for remanufacturing - collected from the disposer market
    - Unlike normal manufacturing process where availability of raw materials are assumed to be deterministic, in case of remanufacturing process acquiring of used products is a difficult task, as uncertainty lies in the timing, quality and quantity of collection of used products
    - Recovery rate & Collection/acquisition rate
- Reverse logistics
    - Transportation of used products from the market to the plant
    - Appropriate designing the transportation network
    - Deciding the activities carried out in each stage of the transportation network
- Disassembly and reassembly
    - Disassembly time varies with the condition of the used product and thus makes the planning process highly complex

(ii) Design related issues

a. Design for Reuse (DFR) and Design for Disassembly (DFD)

b. Helps in reducing the cost of remanufacturing and leads to higher rate of

recovery of useful components and parts.

(iii) Availability of suitable tools and technology

a. Cleaning technology

b. Disassembly

c. Inspection and assessing the remaining life of used products

d. OEM dependency for Third Party Remanufacturers

(iv) Skill and expertise of workforce required in remanufacturing activities

(v) Marketing of remanufactured products

a. Price of remanufactured products

b. Quality “as-good-as-new” product

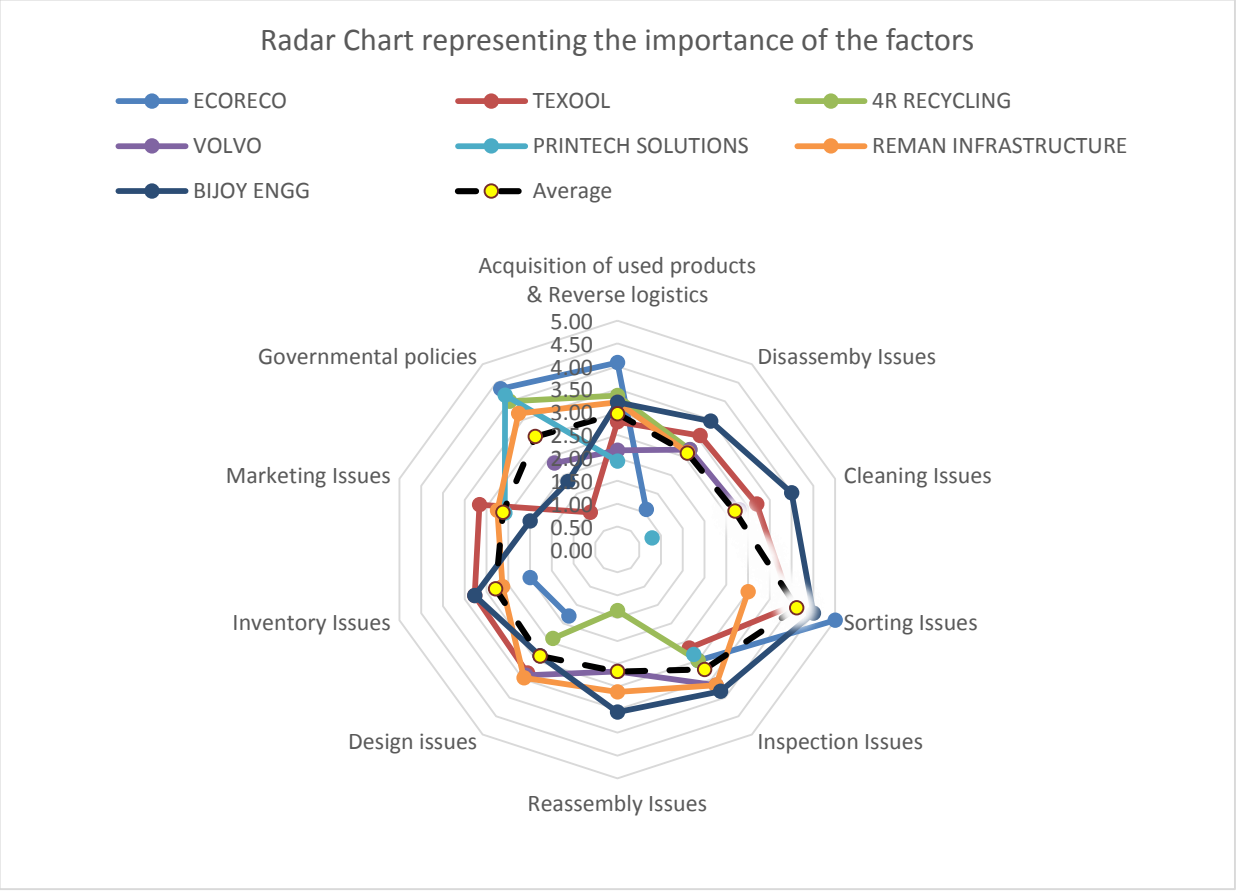
c. Green image associated with these products

Every single issue are grouped into 10 major groups i.e. The Acquisition of Products, Disassembly Issues, Cleaning Issues, Sorting Issues, Inspection Issues, Reassembly Issues, Design Issues, Inventory Issues, Marketing Issues, and different Government Policies. Ten factors are identified from the cases and the items under each of the factors are noted. Importance of each items in the remanufacturing decision making process are rated using 5 point Likert scale. Then the critical items (those items which are having an average value of 2.5 or more in a scale of 5) are presented in the following table.

Acquisition of used products & Reverse logistics	Disassembly
Problem of locating the cores Data base management of customers Reverse distribution network design Complexity in planning for return flow Uncertainty in time of return Uncertainty in quality of return Uncertainty in quantity of return Size and shape of cores Special tools required for handling Collection Centre location Mode of parts collection Inspection of cores Deciding buy back price of cores	Uncertain recovery rates Homogeneity of product range Disassembly sequence Depth of disassembly Lot-sizing Permanent fastening Corrosion/Rust Dirt/Oil Complexity in product design Special tools required Worn out fastener heads Size of products Availability of disassembly technology
Cleaning	**Design**
Excess Dirt/Oil/Debris Corrosion/Rust Fragility of parts The type of material	Homogeneity in product Complexity in product design Design for remanufacturing Corrosion/rust on used products Dirt/oil on used products Testing and inspection Tolerances for wear Permanent fastening Type of material used Defining specification Fragility of parts Destructive disassembly required Assembly/disassembly problem Reliability of product Skill of employees
Sorting	
Identification of similar components Expertise needed to recognize similar groups	
Inspection	
Inspector's knowledge Defining specifications Identifying defects Special instrument required for inspection Product diversity Tolerances for wear	
Reassembly	**Inventory**
Skill of employee Complexity in design Product diversity Fastening problem Special tooling Lighter duty materials Serial No. of specific parts/components Uncertainty of demand of remanufactured products Parts matching problem	Shortages of inventory Balancing demands with returns Special handling methods required Parts matching problem Mismatch between demand & supply Complex scheduling Capacity planning Lead time variability Storage facility location Space required for storage Lot sizing problem
Marketing	**Governmental policies**
Segmentation of the market Green image used as marketing element Cheaper price of remanufactured product Level of demand for remanufactured goods Target markets and their potential for growth Customer’s attitude towards remanufactured product Existence of disorganized business sector OEMs perception about remanufacturing Second hand market is thriving Trade barriers	Take-back policies/buy back system Land fill & Incineration restrictions Laws related to environmental protection Restriction on use of hazardous substances Prevention & control of pollution Disposal cost

The average importance of various factors for the seven companies are presented in the table below.

Sl. No	FACTORS	VOLVO	PRINTECH SOLUTIONS	4R RECYCLING	REMAN INFRASTRUCTURE	ECORECO	TEXOOL	BIJOY ENGG	*Average*
1	Acquisition of used products & Reverse logistics	2.17	1.93	3.36	3.21	4.08	2.79	3.21	**2.97**
2	Disassembly	2.69		2.69	2.62	1.08	3.08	3.46	**2.60**
3	Cleaning	2.80	0.80				3.20	4.00	**2.70**
4	Sorting				3.00	5.00	4.00	4.50	**4.13**
5	Inspection	3.67	2.83	3.00	3.67	3.00	2.67	3.83	**3.24**
6	Reassembly	2.67		1.33	3.11			3.56	**2.67**
7	Design	3.40		2.40	3.47	1.80	3.33	2.87	**2.88**
8	Inventory				2.64	2.00	3.27	3.27	**2.80**
9	Marketing		2.58		2.75		3.17	2.00	**2.63**
10	Governmental policies	2.33	4.17	4.00	3.67	4.33	1.00	1.83	**3.05**
	Average	**2.82**	**2.46**	**2.80**	**3.13**	**3.04**	**2.94**	**3.25**	



From the table, it can be identified that in Acquisition of used products or Reverse Logistics, the critical issues are: The Problem of locating the cores, Database management of customers, Reverse distribution network design, Complexity in planning for return flow, Uncertainty in time of return, Uncertainty in quality of return, Uncertainty in quantity of return, Size, and shape of cores, Fragility of the cores, Special tools required for handling, Collection Centre location, Mode of parts collection, Inspection of cores, Deciding the buyback price of cores. To rate each of the above 14 different issues, we used an importance scale, where the least point has been given to least important issues and the highest point has been given to most important issues. We analyzed these issue wise ratings among each companies we visited. The above study indicates the factors related to the acquisition of used products and Inspection issues are primary topics of concern in all of the cases. How the used products are returning back to the remanufacturing industries, the buy-back policies, finding the customers, and their databases are major factors in the reverse logistics chain. Once the products are collected, it has to be inspected. This process helps in identifying which parts are needed to be replaced and which are needed to be retained. The design of the old product helps in disassemble and reassemble processes. The more complex the design of the product is, the harder it is to disassemble it towards changing the spares. Similarly, there are several government policies like Take-back policies/buyback system, Landfill & Incineration restrictions, Laws related to environmental protection, Restriction on use of hazardous substances, Prevention & control of pollution, Disposal costs. These are also making an impact on the supply chain of remanufacturing industries. Among the 7 cases discussed above, it is very clear that in the remanufacturing reverse logistics chain, the acquisition process, Inspection Process, Design of the products, and Government policies are impacting the overall supply chain efficiency.

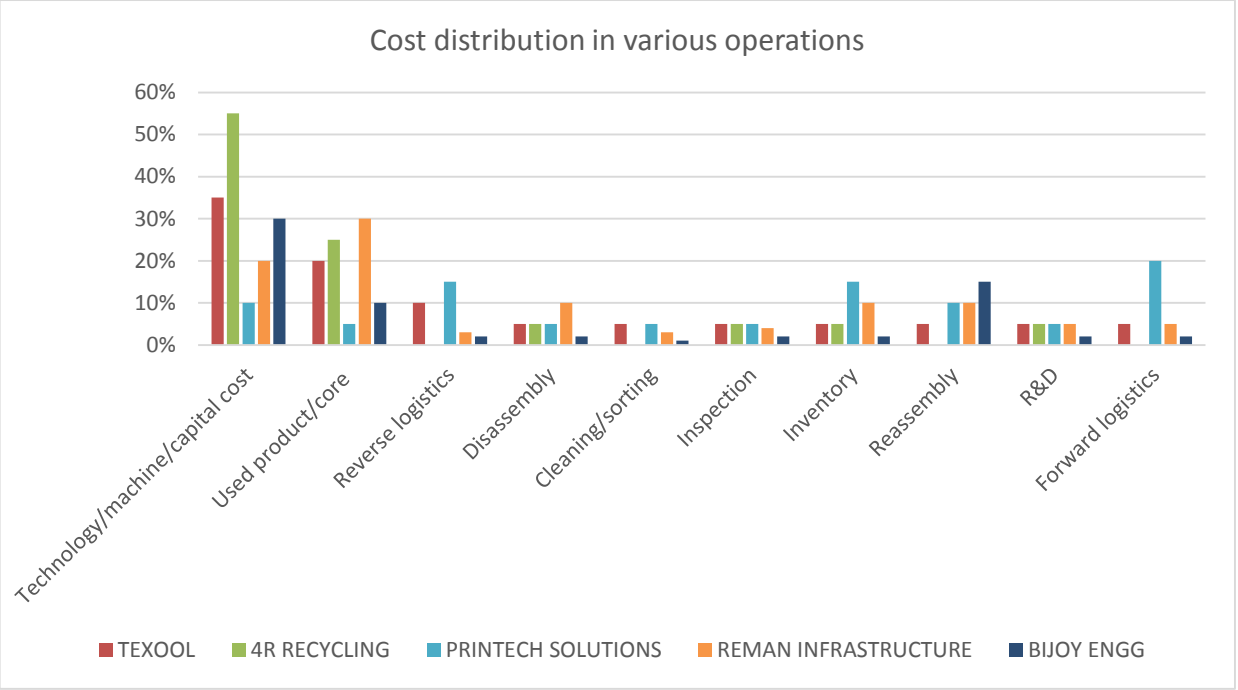
Among all the critical issues Sorting and Inspection operations are considered to be the

most important remanufacturing operations (as the mean score is more than 3). This is perhaps due to the fact that they are quite unique to the remanufacturing process. As the basic raw material for the remanufacturing process is used parts and components, they need to pass through a severe inspection procedure. It needs to be ensured that the reliability of the parts and components meets the specifications so that they can perform for another product life cycle. Further, categorization or sorting of used components depending on their usability is also a critical activity in the remanufacturing process. Hence, for inspection and sorting operation there is a requirement of specialized equipments and skilled personnel. The technical support for these operations can be build indigenously by the company or through OEM's support.

5.2. Cost distribution in various remanufacturing activities

In the cost distribution analysis, all the crucial expenditures are counted and analyzed among all the case studies. The cost distribution is given in the table below.

	Cost Distribution	TEXOOL	4R RECYCLING	PRINTECH SOLUTIONS	REMAN INFRASTRUCTURE	BIJOY ENG G
1	Technology/machine/capital cost	35%	55%	10%	20%	30%
2	Used product/core	20%	25%	5%	30%	10%
3	Reverse logistics	10%	0%	15%	3%	2%
4	Disassembly	5%	5%	5%	10%	2%
5	Cleaning/sorting	5%	0%	5%	3%	1%
6	Inspection	5%	5%	5%	4%	2%
7	Inventory	5%	5%	15%	10%	2%
8	Reassembly	5%	0%	10%	10%	15%
9	R&D	5%	5%	5%	5%	2%
10	Forward logistics	5%	0%	20%	5%	2%



One of the biggest portions of the total expenditure that every remanufacturing industry invests in New Technology/Machine/Capital. This reverse logistics chain requires investing new technologies, new machines, or capital to buy back the used products and as per requirements, the defective parts have to be replaced. This reassembly or recycling process has to be done with maximum accuracy. Manual faults could lead to a complete waste of that particular product. It is very clear from the Distribution of Cost Figure, where the 2 point moving average of the cost structure of 4R Recycling Company invests approximately 55 % of its total capital in purchasing new machines and technologies. And the curve steeps down for the other costs. Similarly purchasing used products or cores is also capturing a bigger portion of the total working capital. The after-use life of the used products are among one of the vital issues that have to be considered before purchasing from the retailers or customers. The buy-back value to after-life quality of a particular product could reduce the total cost in remanufacturing, as well as guarantees the quality of the new product also. There are other costs in a remanufacturing business includes reverse logistics costs, disassembly costs, cleaning/sorting

costs, inspection costs, inventory costs, reassembly costs, R&D costs, forward logistics costs, and many others. A calculated investment in remanufacturing industry not only helps in assuring the revenue but also takes care of many more years of the remanufactured product.

Chapter 6: Global Remanufacturing Practices

6.1 List of success global remanufacturing companies

A list of 39 global remanufacturing companies are listed in the table below. All the information has been extracted from Remanufacturing Industries Council. The Remanufacturing Industries Council (RIC) is a strategic alliance of businesses and academic institutions that works across industry sectors to support the entire remanufacturing industry through a combination of collaboration, education, advocacy, and research. (http://www.remancouncil.org/). They are committed to promoting the growth of all sectors of the remanufacturing industry, providing a forum for members to identify and address issues of common interest, benchmark and share best practices, building a strong network to stay informed of developments in remanufacturing technology, providing education and training to the industry, working to increase awareness of the benefits of remanufacturing in governments and the general public, continuing to advocate with policy-makers and government regulators to minimize barriers to US markets and foreign trade, and increasing RIC effectiveness by expanding RIC membership to include new businesses and business sectors.

Sl No	Name of the company	Location/ Country	Products/ Remanufacturing operations	Year of establishment	Profits/ Annual Turnover	No. of Employee	Reasons for starting the company/Business activities
1	GE Goldseal Refurbished Systems	USA	Computed tomography, X-ray, MRI, nuclear medicine, PET/CT, mammography, surgical imaging and ultra sound equipment.	2000	$18B	50000	https://www.gehealthcare.in/products/goldseal---refurbished-systems Hospitals and imaging centers must provide safe, reliable, advanced, and cost-effective imaging and ultrasound solutions for their communities—even when budgets are tight. When facing competing capital priorities, they can still access technology that

							offers peace of mind afforded by a comprehensive warranty and a GE Healthcare field service team they know and trust.
2	ARC Augusta	USA	Floor Care, Small Appliances, Micro waves, Heating and cooling, Power Tools, O.P.E, Generator and Compressor	2002	NA	250	http://arcaugusta.com/ The founding partner, Mark Branum, was invited to a TTI Technologies factory and noticed that all the returned Dirt Devil vacuums were being tossed in a large dumpster for landfilling. Mark is a entrepreneur and saw an opportunity. He negotiated to take the Dirt Devil vacuums to his facility – which saved TTI landfill costs and was the genesis of America's Remanufacturing Company.
3	Amazon Renewed	USA	Pre-owned products on Amazon Renewed have been inspected and tested by qualified suppliers to work and look like new, and come with the Amazon Renewed Guarantee. Smartphones, laptops and desktops, tablets, home and kitchen appliances, game consoles, office products, and more.	1996		More than 1 Lakh people	https://www.amazon.com Renewed products have been professionally inspected and tested to work and look like new by an Amazon qualified and performance managed supplier. If we source products from a third-party vendor, the third-party vendor tests and inspects the product. The inspection and testing process usually includes a full diagnostic test, replacement of any faulty parts, and a thorough cleaning. The product may have minimal scratches or dents. Boxes may be generic. Accessories may not be original, but will be compatible and fully functional. Wireless devices don't come with headphones. Batteries will have at least 80% capacity. Any exceptions will be stated on the product detail page.
4	Advanced	USA	They are insulated case circuit breaker experts with the				https://www.aeamc.com/

	Electrical & Motor Controls		largest inventory and the experienced, skilled engineers and technicians capable of extending the life of breakers by repairing, retrofitting or retrofilling existing breakers utilizing the latest technology, instrumentation and test equipment. They have an extensive inventory of repair parts and components, and skilled technicians provide expert service utilizing the latest tools, instruments, and test equipment.				To keep the electrical equipment's of the customers active using minimal downtime.
5	AMBAC International	USA	Focused on supplying new and remanufactured fuel injection systems and related components to engine OEM's, militaries, remanufacturers, and a global network of service dealers. They are a full service, ISO 9001:2015 OE manufacturer with engineering and production based in the Columbia South Carolina area.	1910			https://www.ambacinternational.com Fluid innovation, Solid Performance Innovative provider of critical power and fluid components. Engineering, Manufacturing, Remanufacturing, Distribution
6	Camso	USA	The certified remanufacturing program lets used Camso wheels and tracks, in exchange for remanufactured products, at a lower cost than new ones. Similar to rebuilding an old engine, track carcass and wheel cores can be remanufactured to OEM standards and perform like new replacement parts.	2015			https://camso.co/en/blog/product-insight/remanufacturing-explained Trade in Old tracks and save on next set
7	Caterpillar	USA	Around the world, Caterpillar is driving positive, sustainable change through advanced processes and product innovation. As the world leader in remanufacturing, Cat Reman is making progress possible finding new ways to reduce, reuse, recycle, and reclaim materials which once would have gone into a landfill. Rebuild programs include Cat® Certified Rebuilds, component overhauls at Cat® dealers, Solar Turbines rebuilds and Progress Rail Services rebuilds. A complete Cat Certified Rebuild includes more than	1900	$ 41.7 B (2020)		http://www.caterpillar.com/en/company/sustainability/remanufacturing.html Once a returned core arrives at a Reman facility, it is disassembled down to the smallest part, losing its original identity. Each element goes through a cleaning process and is inspected against strict engineering specifications to determine if it can be effectively salvaged. Accepted worn out components are then converted into production ready material through

			350 tests and inspections, automatic replacement of approximately 7,000 parts and a like-new machine warranty. In addition, trained dealer service professionals perform this work using genuine equipment and parts. Caterpillar provides information, data, training and service tools to help dealers make the most appropriate decisions on which parts to reuse in order to achieve expected longevity of rebuilt components. Reuse of components helps us use materials and energy more efficiently.				advanced salvage techniques which use the same rigorous engineering process that goes into new Cat machines. These world-class salvage techniques make it possible for Cat Reman to return otherwise unusable core parts to the latest performance specifications, a key differentiator when looking at remanufacturing at Caterpillar versus the competition. Cat Reman is just one way Caterpillar is developing new solutions to grow the business and help create a more sustainable world.
8	CNH Industrial	USA	CNH Reman is a joint venture between CNH Industrial (CNHI) and Springfield Remanufacturing Corp (SRC). The partnership brings together CNH Parts & Service product expertise, access to equipment and dedicated dealer networks with SRC's remanufacturing operations, capabilities and expertise. Engines, Driveline, Hydraulics	2009			http://www.whyreman.com Remanufacturing gives customers the opportunity to purchase replacement assemblies and components that are just like new, sometimes better than new due to engineering enhancements, at a reduced price and with a competitive warranty. Reman assemblies mean increased efficiencies and productivity due to reduced repair times. This is something that both customers and dealers can appreciate, especially during peak seasons when downtime is especially costly. Reman is also an important way to support sustainable development, which aligns with CNH's commitment to environmental responsibility.
9	Cummins	USA	Cummins engines, Electronic Control Modules, PT/STC Injectors, CELECT Injectors & Actuators, High Pressure Injection (HPI) Injectors &	1910	$ 19.8 B	58000	https://www.cummins.com/ Genuine Cummins ReCon engines and parts provide with a cost-effective, environmentally friendly,

			Actuators, CAPS Pumps & Modules, Bosch Mid-range Injectors and Common Rail Pumps				no-surprise solution that quickly puts Cummins powered equipment back to work.
10	Davies Office	USA	Refurbished Office Furniture – Cubicles, Workstations, Panel Systems, Modular Furniture and More from Davies Office	1948			http://www.daviesoffice.com/ They are the largest independent office furniture remanufacturer in the United States and have one of the widest inventories in the nation, which includes refurbished cubicles, workstations, desks, tables, chairs, credenzas, and more. They remanufacture all major OEM lines, and offer highly customized options like ergonomic enhancements and retrofits that other office furniture providers simply cannot. Their remanufactured office furniture is also more affordable than offerings from the big OEMs, and it's also a greener option because reuse core components and employ environmentally friendly refurbishing practices.
11	National Switchgear	USA	National Switchgear is an industry leader in power distribution equipment and services, offering a broad line of new and repurposed electrical equipment from an extensive inventory and network of suppliers. National also provides service shop, engineering and on-site services for critical power systems, including remanufacturing of circuit breakers, switchgear and related components. The company's on-site services consist of maintenance, testing, power system studies and disaster recovery operations. Circuit Breaker Repair, Rebuilding, Testing and	1986			https://nationalswitchgear.com National Switchgear is committed to the delivery of first-class solutions and is mindful of the benefits of environmentally responsible practices. The company strives to meet the needs of today's world without compromising the needs of future generations.

			Troubleshooting, Rental Exchange Breakers, Emergency Repairs, Solid-State Retrofitting, Solid-State Programmer Upgrades and Repairs, Power Factor and High Potential Testing, Protective Relay Testing and Protection, Switchgear Services, Large Breaker Parts and Inventory, Vintage Switchgear, Bus Manufacturing				
12	Hydraulex	USA	Repairs and provides Remanufactured, Aftermarket, and OEM hydraulic units and components. Specialized in industrial applications like paper mills, saw mills, steel mills, recycling plants, oil & gas applications and mobile applications, including construction, utility, mining, agricultural and marine equipment.				http://www.hydraulex.com Hydraulex Reman™ is the premier global hydraulics remanufacturing brand, providing comprehensive reman/maintenance solutions to virtually every OE hydraulic product. Stocking the one of the world's largest inventory of reman hydraulic pumps and cores, customers are assured of the quickest component replacement. Hydraulex Reman delivers unparalleled in-house technical, reverse-engineering and manufacturing expertise to service current and out-of-production products. All-makes, all-models of hydraulic units and components, are 100% tested to meet or exceed OEM standards and are backed by industry-defining customer service, performance and warranty coverage.
13	John Deere Reman	USA	John Deere Reman has an extensive product portfolio of remanufactured parts and components including engines, engine components, fuel, starters/alternators, axles, transmissions, hydraulic pumps/motors, and electronic components for use on John Deere equipment.	1830	$ 35.54 B	69000	https://www.deere.com/en/parts-and-service/parts/remanufactured/ John Deere Reman has a well-trained, experienced, and highly-skilled work force solely dedicated to producing John Deere Reman products. Remanufactured parts and components are distributed around the globe through an extensive parts

							distribution network, and through John Deere Dealers. Reman products deliver the same level of performance and reliability as new components. Remanufactured components provide customers with cost-effective service solutions while minimizing equipment downtime through component exchange programs. Remanufacturing supports John Deere's Eco-Efficiency goals by reducing the raw materials and energy that go into component production and through reducing waste at the end of a product's useful life.
14	ROMAC	USA	ROMAC is a 55 year old company supplying electrical equipment to industry in support of new construction of or maintenance of industrial electrical infrastructure. Products include Switchboards, Switchgear, Circuit Breakers, Motor Controls and all of the parts and components to maintain them.	1958			http://www.romacsupply.com Entry into this business was originally through salvage acquisition at demolition sites, purchases from investment recovery lots and from new material liquidations of never built out projects. Initially a dealers dealer, ROMAC learned early how to validate material for its capacity to be rebuilt becoming a well-known provider of electrical cores, then growing into one of the more capable reconditioners in the industry. Stock and routinely engages in design and build to order, with customers often being provided the option of Reconditioned systems. ROMAC is promoting safety, standards and professionalism in the reconditioning and remanufacturing businesses.
15	WABCO Reman Solutions	USA	WABCO is a leading innovator and global supplier of technologies that improve the safety and efficiency of commercial vehicles. WABCO				http://www.am.wabco-auto.com/reman/home They work to create comprehensive, flexible answers to remanufacturing

			Reman Solutions provides tailored remanufacturing solutions to automotive and commercial vehicle OEMs and their Tier 1 electronic components suppliers.				challenges and to support long term strategies for sustainable aftermarket businesses
16	Lifecycle Specialties	USA	Lifecycle Specialties' fully equipped machine shop, provides the ability to remanufacture a variety of mechanical components.	1970			https://www.lifecyclespecialties.com Reuse parts for cost reduction and less waste for the environment.
17	Nokia	USA	Remanufactured Product are available as: Circuit packs, shelves, configured cabinets, systems, or kits restored to original factory condition. Tested, quality approved and warranted same as New. Remanufactured products can be Integrated with new products to build equipment configured to specific customer requirements.	1970	$ 21.9 B		https://networks.nokia.com/ For 26 years Nokia's Circular Supply Operations has provided remanufactured equipment solutions. Remanufactured Products provide flexible solutions to help customers decide what best fits their needs, and deliver the most from their existing network infrastructure.
18	Techbuyer	USA	Techbuyer helps businesses maximize their IT budgets by supplying cost-effective new and quality remanufactured and refurbished servers, storage, memory, and networking equipment from over 150 brands including HPE, Dell, IBM, and Cisco.	2005	$ 10 M		https://www.techbuyer.com efficient solutions for IT upgrade cycle at a significantly lower cost than buying new servers. Selling new and certified refurbished IT parts and have worked with thousands of organisations worldwide and have partnerships with leading manufacturers such as HPE, Dell and Lenovo.
19	Air France Industries KLM Engineering & Maintenance	Europe	The range of products is from airframes to engines of Airbus, Boeing as well as regional Aircraft (e.g. Bombardier, Embraer)	2018		14000	https://www.afiklmem.com/en In this case, the remanufacturing process is termed as "Overhaul". The process steps are ranging from the disassembly to the repair of components and the reassembly which is followed by various validation tests.
20	Advanced	UK	Refrigeration and air conditioning compressors.	2000	$ 15 M	20	https://uk.globaldatabase.com/company/advanced-

	Compressor Engineering Services Ltd (ACES)		Remanufacturing Process: 1) Complete strip down, 2) Inspection of parts, 3) Replace and recycle, 4) Re-winding, 5) Cleaning, 6) Reassembly, 7) Testing.				compressor-engineering-services-limited
21	Siemens Industrial Turbomachinery AB	Sweden	Gas Turbines, Cores are retrieved from customers (i.e. turbine users), and cores with the same quality (or the same entities) are returned to the customers after overhaul/repair. The overhaul/repair is often a planned activity (e.g. after a predefined length of operation). Advanced materials, such as low-maintenance materials, high-temperature resistance materials, super alloys, and coated materials, are recovered.	2001			https://smartcitysweden.com/companies/1405/siemens-industrial-turbomachinery-ab/ The company's key resources are its product knowledge and facility. In particular, the company utilizes its OEM (Original Equipment Manufacturer) knowledge of operating parameters (ambient conditions, operating mode, operated fuel, etc.) and of component design, manufacturing parameters and tolerances.
22	Toyota Material Handling Sweden	Sweden	Forklift trucks	2003	$ 8.3 B	33000	https://toyota-forklifts.eu/ Most of the forklift trucks are deriving from the market from different kinds of rental models. These rental contracts run from one month up till 10 years. The advantage of having this kind of business model is mainly that the company keeps the control of the forklift trucks while being used and reused several times. It keeps a good relation to the customers. By providing the market remanufactured forklift trucks the company reaches new customer segments i.e. those who are not willing to buy new forklift trucks.
23	Nayco Motor	Spain	Engines. They retrieve cores by two methods: → Direct order: it is their main way of sourcing. If the cores are in good condition, the customers receive their own engine back in few days. → Buy-back: buying cores from core dealers is more	2007			https://www.naycomotor.es/ Nayco Motor has been remanufacturing engines since 2007. Their main market is in Spain although in the last years they have been working in France, Belgium and Cuba.

			expensive than the other option thus is the least used source				
24	Hitachi Construction Machinery Europe (HCME)	The Netherlands	Hydraulic main pumps of construction machines. Cores are sourced via the dealers who sell Hitachi machinery to customers in Europe. HCME uses a core charge at the time of sale of a remanufactured component, to make sure the core is returned. HCME offer their customer the option of replacing their pump with a remanufactured one and take back the used core.	2009		500	https://www.hitachicm.eu/ HCME's remanufacturing business model is based on the knowledge and craftsmanship of its employees, the economic and environmental advantage of remanufacturing cores, and the availability of used cores.
25	Linde Material Handling GmbH	Germany	Forklift trucks. Cores are typically retrieved directly from customers (i.e. truck users) under rental contracts both in a long term (3-6 years) and a short term, where Linde keeps ownership of the trucks. The company utilizes its own sales channels for both refurbished and new trucks. The refurbishment process includes: 1.) control of truck conditions, 2.) Check and, if needed, replacement of components (e.g. batteries), 3.) repaint, and 4.) quality control.	2001		13000	https://www.linde-mh.com/en/About-us/Company/ Linde Material Handling GmbH carries out thorough refurbishment and provides Approved Used Trucks to meet market demands, especially from users with a medium or low utilization level. The main advantage of the Approved Used Trucks is at lower prices (approximately half of the price of new trucks), while the main disadvantage is shorter remaining lifetimes. The rental contracts utilized with the refurbishment are provided in order to meet the market demands for quick, simple and easy access with cost-effectiveness, and with the widest choice of materials handling equipment available on the market today.
26	Daimler	Germany	Remanufacturing engine, transmission, clutch, propeller shaft, moving parts such as starters, but also electronic components such as engine control units. Recondition used Mercedes-Benz genuine parts from all three divisions, i.e. passenger cars, vans and trucks, in such a way that they correspond to a new part with regard to their	2000			https://www.daimler.com/sustainability/closeup/remanufacturing.html The remanufacturing process conserves resources and is highly efficient. It makes a valuable contribution to the sustainability of business model. Remanufacturing not only makes it possible to

			function, safety and quality. Reconditioning the parts according to series production standards.				reduce costs, it also requires less energy and fewer raw materials compared with producing new parts. It makes a contribution to a positive eco-balance.
27	Leapp	Nether lands	Leapp recovers all types of Apple products. Leapp has two types of core sourcing streams. 80% of the used Macbooks comes from business users, besides this 20% comes from Apple resellers. For the customer segment, by returning an old Macbook a discount is applied to the new product which can be seen as a credit-based way to collect cores. The biggest sourcing stream comes from collector companies that focus on businesses customers in Europe. Most of the Macbooks are collected in Germany and the United Kingdom. After collecting Macbooks, the used products are screened on quality. After screening and classification of the Macbooks, they are decomposed and all hardware pieces are checked and repaired or replaced if needed. Afterwards, the original user data is wiped and the software is being updated. Finally, the products go through a thorough cleaning procedure. Employees are trained by Apple to be able to guarantee quality of the remanufactured products. Around 8% of components cannot be re-used, these once will be recycled at a waste disposal. The iron parts are brought to a metal scrap collector. After cleaning, the Macbooks are packed and ready to be sold to a new customer. The remanufactured products are sold on the website and in the offline shops with a warranty of 24 months. This remanufacturing process is possible because to the quality of the materials used in a	2011		100	Leapp's business model is based on the difference between economic redemption and technical redemption of a Macbook. Leapp has a long-term contract with these collector companies to buy Macbooks after three years of usage, then the economic value is written off while the lifetime of a Macbook is much longer. Because of this Leapp can use this value.

			Macbook and the timeless design. A recent model is sold for 90% of the initial price of a new Macbook, an older version is sold for 70% of the initial price.				
28	Lizarte	Spain	Lizarte has four remanufacturing product lines for steering racks, steering pumps, air conditioning compressors and diesel injection. They retrieve cores mostly by: → Surcharge model: the 80-85% of the cores are collected in this way. A deposit is charged to the customers when they buy the product, which can be recovered as long as the item is returned in good conditions so that it can be remanufactured. → Direct order: since all the cores collected by surcharge cannot be remanufactured, they buy a small percentage of cores to core dealers, approximately the 15-20%.	1973		85	Lizarte has been remanufacturing automotive spares since 1973, when they became the first company in Europe to remanufacture mechanical steering racks. Today they remanufacture more than 1100 models of steering racks and AC compressors, over 1000 models of steering pumps and around 700 models of diesel injection. To get to this point, they count on 85 employees and a manufacturing facility and central warehouse in Pamplona that supplies their logistic centres spread across Spain, France and Germany. The mission of Lizarte is to offer high quality solutions to cover the needs in the automotive repair Market.
29	Replay Golf	Spain	Replay Golf is Europe's leading remanufacturer and recycler of golf balls. They provide their customers with a wide range of products: new, recycled and refurbished balls which can also be personalized to cover the needs of every client. Used golf balls Cores are retrieved from two methods: → Service contract: deal with several Golf Clubs → Buy-back: the company buys used golf balls from the suppliers, which can be the golf clubs, the end users or other companies.	2009			https://replay-golf.co.uk/ Replay Golf is owned and run by a team of PGA Professionals. They buy, sell and trade-in golf's top brands and stock a huge range of pre-owned and clearance items. Cost advantage and environment consciousness.
30	robotif GmbH	Germany	Industrial robots from Adept, Bosch, Denso and Staubli. Most industrial robots (around 90%) that come in for	2009		20	Best economical solution for the customer. The result is an individual, customized offer.

			remanufacturing are remanufactured on-demand of an industrial robot user who is in need of remanufacturing. The rest (10%), is bought from the market through E-bay, customers etc. After receiving the order, robotif starts disassembly, cleaning and overhaul or repair of the robot and defective components. The robot will be assembled, measured and a 24h test run is made. After the successful completion of the test run, a final inspection takes place. At last, robotif organizes the packaging in special robotif safety-boxes and freight				
31	Robert Bosch GmbH	Germany	Starters, Diesel Systems and Batteries Bosch series remanufacturing is subject to the same production standards as the production of new parts High reliability of Bosch eXchange products are subject to stringent functional and quality tests.	1959	71.5 B Euros	395000	https://www.boschoffhighway.com/xc/en/product-portfolio/remanufactured/ Outstanding price-performance ratio: up to 30% cheaper than comparable new parts with the same warranty Long service life: replacement of all critical components and wear parts as well as professional remanufacturing of all other components
32	BORG Automotive A/S	Denmark	Starters, Alternators, Compressors, Brake Calipers, EGR valves, Steering Racks, Steering Pumps, Turbochargers	1976	1 B DKK	1500	https://www.borgautomotive.com/corporate-responsibility/ Responsibility towards the environment. Grow our business using a model that significantly reduces CO2 emissions.
33	Schmitz + Krieger GmbH	Germany	Engines, transmissions, and other components for automotive assemblers. Injection equipment and high-pressure pumps. Service exchange: the customer returns the used product to the remanufacturer, the product is remanufactured and the customer gets the same quality of the same product	1911			https://www.gmi-ev.de/index.php?article_id=64 Benefits for customers are a lower price, increased availability of products (although some remanufactured products are not always available), and an image about environmental

			model back (if it is possible to perform a remanufacturing operation). The remanufacturing process consists of: 1.) reception of cores, 2.) visual check of the cores' quality, 3.) stock, 4.) disassembly, 5.) cleaning, 6.) check of quality, 7.) machining (e.g. grinding), 8.) mounting, 9.) testing, and 10.) shipment. Key resources are the company's remanufacturing personnel.				sustainability. The main driver for Schmitz + Krieger is economic, which is followed by environmental sustainability and customer demands. There are neither customer groups nor sales channels specifically for remanufactured products. Schmitz + Krieger directly deals with its customers in most cases, and collaborates with logistics providers and spare part providers.
34	Desko	Nether lands	In-house remanufacturing of office desks: Duo Slinger Table. The majority of desks are retrieved from customers through a buy-back scheme. For their own Duo Slinger table, Desko employs a three-tier buy-back scheme and usually remanufacture cores twice during their life-time. Desko buys newly manufactured products back from customers at roughly 10% of the product's initial price. After in-house remanufacturing at Desko's headquarters, desks are sold to a different market segment at roughly 50% of the initial product price. The customers of these remanufactured products are able to sell the desks back to Desko after use. These already once remanufactured are bought back by Desko at roughly 5% of the product's initial price. Desko remanufactures the desks once more and resells the product for the last time to a third customer segment at 25% of the original price. Desko offers a free take-back for these customers and scraps the desks for parts.	1950		50	Economic benefits and environmental responsibility.
35	Inrego AB	Swede n	Computers and smart phones. Inrego buys used professional IT-equipment from private and public organisations for reuse purposes. Inrego pays the seller for the product value	1995	230 MSEK	80	Resells or leases it to the next user.

			and charges for the asset disposition services handling, data wiping and transportation.				
36	FARAL	France	FARAL remanufactures automotive parts (around 2000 engines per year, 6000 turbos, 1200 gear boxes and 2000 cylinder heads). The company has developed its own patented remanufacturing process for cylinder heads. More than 300 types of engines, cylinder heads and turbos can be remanufactured by the company.	1932	9 M Euros	75	The main motivations for remanufacturing are its technical know-how (the company is engaged in these activities since 1965), environmental (availability of raw material and environmental benefits of remanufacturing), and economic benefits.
37	A and B Automative Remanufacturing Pl	Australia	Motor Vehicle Parts; Automotive Repair and Maintenance.	1999	$ 7.73 M	25	https://www.dnb.com/business-directory/company-profiles.a__b_automotive_remanufacturing_pty_ltd.c33170e6b0aa894a303019f7c91b9e38.html
38	Australian Automotive Distribution	Australia	Brake, Clutch Kit, Cooling Components, Engine Components, Steering and Suspensions, Brake Controllers, Trailer Brakes, AAD has a long history in the reconditioning industry. With state of the art testing facilities and equipment, they repair and rebuild parts to original specifications. Designed for 'as-new' performance and durability, they make it possible to extend the value of your investment by bringing new life to damaged or used parts. Our leading-edge technology includes the latest testing facilities and equipment.	1995			https://www.aad.com.au/remanufacturing/ The AAD range of Reconditioned units is second to none in Australia.
39	Fuji Film Co., Ltd.	Japan	Digi Cameras, Instant Cameras, Skincare, Binoculars	1934	JP¥ 2.32 trillion	73906	https://www.fujifilm.com/about/history/

6.2 Summary of best global practices

As per the global reports and above examples, remanufacturing business models operate basically on three types on the basis of the role of Original Equipment Manufacturer (OEMs) in this business process.

a) The OEM is managing all the activities of the remanufacturing supply chain. Some OEMs like Xerox Corporation are directly involved in remanufacturing their own products.

b) The OEM is managing the basic remanufacturing operations, while acquisition of the used products, reverse logistics and/or some activities related to remanufacturing, like disassembly, cleaning and sorting are done by Third Party Logistics Providers (TPLPs) This makes the OEM outsource some of the recovery activities to outside agencies, although the OEM controls the activities of remanufacturing. Many TPLPs like NetReturn, FedEx, ASTRA and GENCO are aiding reverse logistics process for remanufacturing.

c) The OEM does not play any role in remanufacturing. Remanufacturing activities are done by Third Party Remanufacturers (TPRs). Hence, there is the possibility of market competition among the manufactured products by OEM and remanufactured products/components by TPRs. Such type of remanufacturing is common for automotive parts/components.

On the basis of the above it can be observed most of the remanufacturing companies in India are of TPRs engaged in parts/components remanufacturing for spare part market. Interestingly, study shows that India should initiate the remanufacturing business with spare parts remanufacturing instead of going for product remanufacturing. This can be justified by the fact that Indian consumer market is still not much aware about the benefits of remanufactured products, so companies feel that they may at least do some business by selling remanufactured spare parts to industrial and commercial markets or through service centers for repair or part replacement. Moreover, since there is nonexistent of any governmental policies regarding remanufacturing, the OEMs are hesitant for remanufacturing at product level.

Chapter 7: Findings and recommendations

7.1. Findings of the study

This is a study of remanufacturing companies in India that focuses on the scope of development in remanufacturing or recycling industry towards a green future. This study comprises 7 different companies of different sectors. The objective of this study is to understand, analyze the critical factors among the reverse logistics supply chain, the technical or ethical issues during the processes, and the distribution of costs in each company to understand the requirement of technological facilities in adding a new life to an old product. We have identified several issues in a reverse logistics supply chain that directly or indirectly impacts the efficiency of the network and those are grouped together to accordingly their nature of issues into 10 different groups i.e. The Acquisition of Products, Disassembly Issues, Cleaning Issues, Sorting Issues, Inspection Issues, Reassembly Issues, Design Issues, Inventory Issues, Marketing Issues, and different Government Policies. The data from all of the 7 case studies indicate few major findings which are discussed in the below section.

- It has been seen that most of the companies operate in small scale businesses with an annual turnover from Rs. 1 to 10 crores. These companies generate employment of 10 to 50 employees. These workers range from skilled to semi-skilled persons.
- The products which are popularly remanufactured are automotive parts and components, machine tools, industrial machines, transformers, pumps, printer cartridges and recycling of e-wastes.

- All the seven companies have responded that remanufacturing is a profitable business option in India. The profit percentage range from 3% to 37%. However, they also responded that building green image among customers is also a secondary reason.
- All the companies mention that the remanufacturing business decisions are mainly centred around 10 prime factors as, Acquisition process of used products, disassembly issues, cleaning issues, sorting issues, inspection issues, reassembly issues, design issues, inventory issues, marketing issues, and government policies. Further these ten factors are sub-divided into several items, so that a detailed decision-framework can be established. The success of the remanufacturing business lies in how the company efficiently manages these set of decision issues.
- The Average Importance Scale is the average value of importance of each issue among all the cases for a particular group. Generally, those issues are taken on critical importance which is selected and highly rated by most of the companies. It helps in identifying the important parameters among Remanufacturing Industries.
- Sorting and Inspection activities are found to be the most critical activities in remanufacturing business. Hence, requirement of skilled work force and special technology is the prime requirement.
- This Average Importance Scale indicates Inspecting the cores, Deciding Buyback price of the cores and Problem Locating the cores are three major issues in Acquisition of Products or Cores. A reverse logistics industry entirely depends on the quality and buyback price of used products.
- Excess Dirt/Oil/Debris, The type of Material and Corrosion/Rust are the three highly important issues in Cleaning. After collecting the used products from the industries, customers, or from any other sources, it has to be cleaned thoroughly. There could be a

high amount of unnecessary things which must have to be removed before proceeding to the next stage.

- In disassembly stage, the used product needed to be dismantled. This process requires the requirement of special tools. It is a semi-automatic process. Similarly few other highly important issues in disassembly are uncertain recovery rates and disassembly sequence.
- The next stage is inspection and it is one of the highly skilled process in the entire supply chain. Identifying defects, Inspector's knowledge and Defining specifications are three highly important issues marked by 90 % industries.
- In Reassembly, Skill of the employees is the highly important issue marked by 100% of industries. A highly skilled employee works efficiently and can help in making quality products. Other important issues are complexities in design, special tooling, and lighter duty materials, etc.
- Design of the product has a major contribution to the remanufacturing industry. A complex designed product could have been raising several problems in the disassembly process. Similarly type of material being used in manufacturing the product and Skill of employees are important issue in the design stage.
- Lot sizing problem is one of the most important issues in the Inventory category raised by 60 % of the industries.
- The remanufactured product needed more marketing to reach the maximum sales value in the market. Simultaneously, the manufacturer has to assure the customer of its best-in-class quality. To capture the remanufacturing market, the major issues are the target market and their potential growth and customer's attitude towards a remanufactured product.

- Intervention of Government and other managerial policies are also impacting the remanufacturing industries. Prevention and control of pollution are one of the crucial issues that have to be considered not only among the remanufacturing industries but also in every sector. Similarly, laws related to environmental protection and the restriction of the usage of hazardous products are also important issues marked by 90 % of the industries.
- One of the biggest portions of the total expenditure that every remanufacturing industry invests in New Technology/Machine/Capital. It is on an average of 25-30%.
- Most of these companies operate as a small scale business.

7.2. Recommendations

1. Most of the remanufacturing companies are operating as a small scale business, with an annual turnover of Rs. 1 to 10 crores. The number of employees range from 10 to 50. Moreover, we found that the technology/capital cost of these companies contributes on an average of 30%. Thus, under such a situation governmental support of soft loans can boost such industry.
2. Since, sorting and inspection activities are found to be the most critical activities in remanufacturing business, skilled manpower requirement is more. Training and skill development programs may be initiated in these areas. Moreover, in remanufacturing determination of remaining life of used products is one of the difficult task. Special technology is required for determination of residual life and inspection due to safety and reliability issues of the product design. Research initiatives in this area is highly recommended.

3. Most of these companies abide by all the governmental laws related to Environmental Protection Act, but they put forward a point that they are not allowed participate in governmental contracts due to the fact that they are selling remanufactured product.
4. A social awareness program is required from the end of the government, as most of the company feels that though they are contributing to the society in reducing environmental pollution by reuse of waste material, they are still not considered as the mainstream business or not a part of organised business sector. Government should think of initiating a separate policy for promoting a healthy remanufacturing business.

Research Summary/annotation of project (for website uploading only)

"Developing a framework of critical indicators for success of remanufacturing in India", Sandeep Mondal, Indian Institute of Technology (ISM), Dhanbad, 2021.

Remanufacturing is a form of product recovery option, where used and discarded products are subjected to a sequence of value-additive operations, so as to convert them into reusable ones. The increasing concern over environmental issues, rise in disposal costs, economic benefits and demand for spare parts during post Product Life Cycle period are found to be the prime reasons, which motivated the industry towards reuse and remanufacturing of used products. Although remanufacturing has been accepted as an alternative business practice for value recovery of used products in USA, Europe, Japan, China, Taiwan and other developed countries, this practice still remains in adolescence stage in many African, South American and some of Asian countries including India. In India remanufacturing is yet to get its acceptance as an organized business sector. Several research studies have been studied in developed countries on establishing decision frameworks, analyzing production plans, inventory plans, strategic issues etc. But they are based on either opinion from experts or research framework meant for other countries. In fact, we require an exclusive study that addresses Indian business environment and identify the success factors for Indian remanufacturing business. This research project is a maiden attempt to initiate such a study for developing a framework of critical success factors of Indian remanufacturing business. The study is based on case studies of seven profitable remanufacturing companies in India. All the companies responded that the remanufacturing business decisions are mainly centered on 10 prime factors as, acquisition of used products, disassembly, cleaning, sorting, inspection, reassembly, design, inventory, marketing, and government policies. Further these ten factors are sub-divided into several items, so that a detailed decision-framework can be established. The success of the remanufacturing business lies in how the company efficiently manages these set of decision issues. Moreover, it is found that these companies are operating as a small scale business, with an annual turnover of Rs. 1 to 10 crores and with 10 to 50 employees. Technology/capital cost of these companies contributes to the maximum and is on an average of 30%. Thus, under such a situation governmental support of soft loans can boost this industry. This would further generate employment in the country. A social awareness program is required from the end of the government, as most of the company feels that though they are contributing to the society in reducing environmental pollution by reuse of waste material, they are still not considered as the mainstream business or not a part of organized business sector. Government should think of initiating a separate policy for promoting a healthy remanufacturing business.

End project deliverables

This research project lead to the identification of a framework of factors and sub-factors from seven successful remanufacturing companies in India. These factors and sub-factors are observed in the companies that are regularly addressed by the company to operate the business smoothly. This exhaustive framework is very helpful for a remanufacturing company for efficient decision-making and operating a profitable business.

How the outcome of this project will be beneficial to various stakeholders

(i) The decision-making framework of critical success factors and sub-factors from seven successful remanufacturing companies is very helpful for the company managers and guide them to operate a profitable business.

(ii) The project also suggest some guidelines to the policy makers and government, how growth of this business sector can be made.

(iii) Researchers can use the decision framework as a base and extend it by including more case-studies and also develop frameworks for various industry sectors.

References

Autry C.W. (2005), “Formalization of reverse logistics programs: A strategy for managing liberalized returns”, Industrial Marketing Management, Vol. 34, pp. 749-757.

Bouzon, M., Govindan, K., Rodriguez, C. M.T., and Campos, L.M.S., 2016. Identification and analysis of reverse logistics barriers using fuzzy Delphi method and AHP. Resources, Reservations and Recycling, 108, 182-197.

Chaowanapong, J., Jongwanich, J., and Ijomah, W., 2018. The determinants of remanufacturing practices in developing countries: Evidence from Thai industries. Journal of Cleaner Production. 170(1), 369-378.

Daugherty P.J., Richey R.G., Genchev S.E. & Chen H., (2005), “Reverse logistics: superior performance through focused resource commitments to information technology”, Transportation Research Part E, Vol. 41, pp. 77-92.

Doppelt, B. and Nelson, H., (2001), Extended producer responsibility and product take-back: application for Pacific Northwest, The Center for Watershed and Community Health, Portland State University, Portland, Oregon.

Gerrard J & Kandlikar M., (2007), “Is European end-of-life vehicle legislation living up to expectations? Assessing the impact of the ELV Directive on ‘green’ innovation and vehicle recovery”, Journal of Cleaner Production, Vol. 15, pp. 17-27.

Guide, V.D.R.Jr. (2000) “Production planning and control for remanufacturing: industry practice and research needs”, *Journal of Operations Management*, Vol. 18, pp. 467-483.

Hammond, R., Amezquita, T. and Bras, B. (1998) “Issues in the automotive parts remanufacturing industry – a discussion of results from surveys performed among remanufacturers”, *International Journal of Engineering Design and Automation*, Vol. 4(1), pp. 27-46.

Lund, R. (1998), “Remanufacturing: an American resource”, Proceedings of the Fifth International Congress Environmentally Conscious Design and Manufacturing, June 16 and 17, Rochester Institute of Technology, Rochester, NY, USA.

Mondal S. & Mukherjee K., (2006) “An Empirical Investigation on feasibility of Remanufacturing activities in Indian economy”, *International Journal of Business Environment*, Vol. 1, No. 1, pp. 70-88.

Mondal S. & Mukherjee K., (2006), “Buy back Policy Decision in managing Reverse Logistics’, *International Journal of Logistics Systems and Management*, Vol. 2, No. 3, pp. 255-264.

Mukherjee K. and Mondal S., (2004), “Remanufacturing – Issues and current Indian practices”, *Productivity*, Vol. 45, No. 1, pp. 85-95.

Mukherjee K., (2003), “Reverse Logistics for Product Recovery - Issues and Models”, *Vision* (Special Issue on Supply Chain Management), Vol. 7, pp. 141-149.

Mukherjee, K and Mondal S. (2009), “Analysis of issues relating to Remanufacturing Technology – a case of an Indian Company”, *Technology Analysis and Strategic Management*, Vol.21, No. 5, pp. 639-652.

Mukherjee, K. and Mondal, S. (2007), “Management of remanufacturing business – a critical study of a photocopier remanufacturer”, *Productivity*, Vol. 48, No. 1, pp. 80-90.

Mukherjee, K. and Mondal, S. (2008), “Some studies on remanufacturing activities in India”, In: *Environment Conscious Manufacturing*, edited by Gupta, S.M. & Lambert A.J.D.(Fred), CRC Press, Taylor and Francis Group, New York, pp. 445-471.

Ravi V. & Shankar V, (2005), “Analysis of interactions among the barriers of reverse logistics”, Technological Forecasting and Social Change, Vol. 72, pp. 1011-1029.

Saavedra, Y.M., Barquet, A. P., Rozenfeld, H., Forcellini, F.A., and Ometto, A. R. 2013. Remanufacturing

in Brazil: case studies on the automotive sector. Journal of Cleaner Production, 53, 267-276.

Schultmann F., Zumkeller M. & Rentz O., (2006), “Modeling reverse logistic tasks within closed-loop supply chains: An example from the automotive industry” European Journal of Operational Research, Vol. 171, pp. 1033-1050.

Shi, J., Zhou, J., and Zhu, Q. 2019. Barriers of a closed-loop cartridge remanufacturing supply chain for urban waste recovery governance in China. Journal of Cleaner Production. 212, 1544-1553.

Spicer, A.J. and Johnson, M.R., (2004), Third party demanufacturing as a solution for extended producer responsibility, *Journal of Cleaner Production*, Vol. 11, pp. 445-458.

Thierry, M.C., Salomon, M., Van Nunen, J.A.E.E. and Wassenhove, L.N.V., (1995), Strategic production and operations management issues in product recovery management, *California Management Review*, Vol. 37, No. 2, pp. 114-135.

Tian, G., Chu, J., Hu, H., and Li, H. 2014. Technology innovation system and its integrated structure for automotive components remanufacturing industry development in China. Journal of Cleaner Production. 85, 419-432.

US Automotive Parts Industry Annual assessment, Office of Aerospace and Automotive industries, International Trade administration, US Department of Commerce, April 2006.

Wang, Y., Chang, X, Chen, Z, Zhong, Y., and Fan, T. 2014. Impact of subsidy policies on recycling and remanufacturing using system dynamics methodology: a case of auto parts in China. Journal of Cleaner Production, 74, 161-171

Wang, Y., Wiegerinck, V., Krikke, H., and Zhang, H. 2013. Understanding the purchase intention towards remanufactured product in closed-loop supply chains: An empirical study in China. International Journal of Physical Distribution & Logistics Management, 43(10), 866-888

Wells P.E. & Seitz M.A. (2004), “Business Models and Closed-Loop Supply Chains: An Analysis of the Automotive Industry”, Second World Conference on POM and 15th POM Conference, Cancun, Mexico, April 30 – May 3, 2004.

Xia, X., Govindan, K., and Zhu, Q. (2015). Analyzing internal barriers for automotive parts remanufacturers in China using grey-DEMATEL approach. Journal of Cleaner Production. 87, 811-825.

Yusop, N.M., Wahab, D.A. and Saibani, N. 2016. Realising the automotive remanufacturing roadmap in Malaysia: challenges and the way forward. Journal of Cleaner Production. 112(3), 1910-1919

Zhang, T., Chu, J., Wang, X., Liu, X. and Cui, P. 2011. Development pattern and enhancing system of automotive components remanufacturing industry in China. Resources, Conservation and Recycling, 55(6), 613-622.

Zhu, Q., Sarkis, J. and Lai, K.H. 2015. Reprint of 'Supply chain-based barriers for truck-engine remanufacturing in China. Transportation Research Part E: Logistics and Transportation Review, 74, 94-108.

Annexure I

List of Remanufacturing companies

A. Automotive sector
    a. Cummins India, Satara, Maharashtra.
    b. Volvo India Pvt. Ltd, Peenya, Bangalore.
    c. Timken India Limited, Jamshedpur and Raipur.
    d. Timken Engineering and Research India Private limited, Nattam Chengalpatt, Tamil Nadu.
    e. M. S. AUTOMOBILES, Adityapur, Jamshedpur.
B. Industrial machinery
    a. United Van Der Horst, Raigad, Navi Mumbai, Maharashtra
    b. Caterpillar India Private Limited, Thiruvallur, Tamil Nadu.
    c. REIL Electricals India Limited, Pondicherry.
    d. Godrej Precision Engineering, Vikhroli West, Mumbai.
    e. Komatsu India Pvt. Ltd, Kancheepuram Dist. Tamil Nadu.
    f. Aditya Engineering Company, Hadapsar, Pune
    g. Aditya Vidyut Appliances Ltd., Thane, Mumbai.
    h. Track Engineers, Mumbai.
    i. Gravita India Ltd, Jaipur
    j. Reman Infrastructure Pvt. Ltd., Namakkal, Tamil Nadu
    k. Bijoy Engineering Works, Dhanbad
C. Photocopiers
    a. Modi Xerox Limited, Rampur, Moradabad, U.P.
D. Locomotives
    a. Diesel Locomotive Modernization Works, Patiala,
    b. EMD Locomotive Technologies Pvt. Ltd, Phase II, Extension, NOIDA.
E. Toner Cartridge
    a. India Toners & Developers, Rampur- Bareily Road, Rampur. U.P.
    b. Printech Solutions India Pvt. Ltd., Jayanagar, Bengaluru
F. E-waste/Recyclers
    a. 4R recycling Pvt. Ltd., Bengaluru.
    b. Eco Recycling Limited, Andheri (E), Mumbai
    c. Texcool Limited, Cuffe Parade Mumbai

Annexure II

"DEVELOPING A FRAMEWORK OF CRITICAL INDICATORS FOR SUCCESS OF REMANUFACTURING IN INDIA"

A research project sponsored by Department of Science and Technology, Ministry of Science and Technology, Government of India

All information provided by you would be kept confidential and will not be shared with anyone. I really appreciate to share your valuable time with us.

While carrying out each of the case study, the following objectives are to be addressed.

- Study the various business operations of the company and develop a process flow diagram of the existing operations.
- Study the technological infrastructure required for its implementation.
- Identification of the key issues which are relevant to the remanufacturing business.
- Identification of the critical indicators for a successful remanufacturing business.

Some instructions for filling up the questionnaire

There are three type of questions found in this survey.

a) Ticking the appropriate option(s)
b) Open question type
c) Rating of the issues in terms of degrees of importance (1 indicates least important and 5 indicates most important).

General information about the Company

Name of the company _____

Location _____

Year of Establishment _____

Products remanufactured _____

Total annual turnover _____

Number of employees _____

Reasons to start the remanufacturing business _____

Factors	(Please tick)	**Factors**	(Please tick)
Governmental legislation		Green image among customers	
Profitable business option		Ethical & moral responsibility	
Creation of inventory of spare parts			
Any other			

Respondent Profile

(All the personal information provided would be confidential)

(i) Name
(ii) Designation
(iii) Total Industry Experience
(iv) Your Expertize
(v) Official E-Mail:
(vi) Contact Number:

A. Product Recovery Practices

1. What are the critical decision areas of your remanufacturing business?

Decision areas	(Please tick)	**Decision areas**	(Please tick)
Availability of used products/cores		Disassembly	
Pricing of used products/cores		Cleaning & sorting	
Quality of used products/cores		Inspection	
Reverse Logistics network design		Reassembly	
Inventory of used products		Special tools and equipment	
Availability of technology		Production planning	
Design for remanufacturing		Identifying potential markets	
Pricing decisions for remanufactured product		Strategies for selling remanufactured product	
Any others			

Since used products (cores/returns) form the basic raw materials in this set of activity, the process begins with acquiring returns from the disposer market (returns acquisition management), which is then followed by transporting these returns to the remanufacturing plant through a logistics chain (Reverse Logistics). Further, at the remanufacturing site, these returns are completely disassembled to the level of parts and components. The parts/components are thoroughly inspected, defective and worn out parts are repaired or replaced by new ones and then reassembled to build up the remanufactured product. With respect to the quality, a remanufactured item is 'as-good-as-new'. Technological upgradation of some parts or modules is also possible during the remanufacturing process. The case study is adopted to follow the same sequence of activities.

I. ACQUISITION OF RETURNS / REVERSE LOGISTICS

1. Process of collection of used products (Process Chart):

2. What policies are adopted to collect the used products?

	(Please tick)		(Please tick)
Exchange Offer		Take – Back	
Buy – Back		From auction centers	
Off – Lease			
Any other (please mention)			

3. How do you determine the value of the return?

(Please tick)

Age of the product		Usage of the product		Any quality checking	
Any other (please mention)					

4. Does your company have separate take-back or collection centers that are responsible for collecting reusable returns? _____
   If yes, then how many centers are there? _____

5. What is the mode of transportation for collecting the used products?

6. How these used products are being transported, either by disassembling the used products into smaller parts or only the whole used products are being transported?

7. What is the overall cost involved in transportation of used materials?

8. Please rate the following factors as per their importance in collection of cores.

(Please Tick)

Sl. No	**Acquisition of used products & Reverse logistics**	Least important	Somewhat important	Important	Very important	Most important
01.	Problem of locating the cores					
02.	Data base management of customers					
03.	Reverse distribution network design					
04.	Complexity in planning for return flow					
05.	Uncertainty in time of return					
06.	Uncertainty in quality of return					
07.	Uncertainty in quantity of return					
08.	Size and shape of cores					
09.	Fragility of the cores					
10.	Special tools required for handling					
11.	Collection centre location					
12.	Mode of parts collection					
13.	Inspection of cores					
14.	Deciding buy back price of cores					

II. REMANUFACTURING PROCESS

1. *Disassembly*

(i) Discuss the disassembly process

(ii) Which of the following strategies you adopt for disassembly operations?

(Please tick)

PUSH Strategy	
PULL Strategy	
Combination of PUSH and PULL Strategies	

PUSH: Disassemble as and when used products are returned.
PULL: Disassemble only when demand is known

(iii) What is the approximate time and cost for disassembly of a unit?

(iv) What is the source of disassembly technology?

(Please tick)

From OEM	
Reverse Engineering	
Any other sources	

(v) How important are the following issues for the disassembly process?

(Please tick)

Sl. No.	Issues	Not Important	Least Important	Somewhat Important	Important	Very Important	Most Important
1	Uncertain recovery rates						
2	Homogeneity of product range						
3	Disassembly sequence						
4	Depth of disassembly						
5	Lot-sizing						
6	Permanent fastening						
7	Corrosion/Rust						
8	Dirt/Oil						
9	Complexity in product design						
10	Special tools required						
11	Worn out fastener heads						
12	Size of products						
13	Availability of disassembly technology						
14							
15							

(vi) What are the other required expertise needed?

2. *Cleaning*

(i) Discuss the cleaning process

(ii) What is the approximate time for cleaning operation?

(iii) How much man power is required for cleaning of used parts?

(iv) What is the approximate cost for cleaning operation?

(v) What are the special machines/equipments/tools required for cleaning operation?

(vi) Any other expertise required?

(vii) How important are the following issues in the cleaning process?

(Please tick)

Sl. No.	Issues	Not Important	Least Important	Somewhat Important	Important	Very Important	Most Important
1	Excess Dirt/Oil/Debris						
2	Corrosion/Rust						
3	Size and shape of parts/orifices						
4	Fragility of parts						
5	The type of material						
6							
7							

3. ***Sorting***

(i) Discuss the sorting process

(ii) What is the approximate time and cost required for sorting?

(iii) What are the special machines/equipments/tools required for sorting operation?

(iii) How important are the following issues for the sorting of parts/ components?

(Please tick)

Sl. No.	Issues	Not Important	Least Important	Somewhat Important	Important	Very Important	Most Important
1	Identification of similar components						
2	Expertise needed to recognize similar groups						
3							
4							

4. ***Inspection***

(i) Discuss the inspection procedure

(ii) What is the approximate time required for inspection?

(iii) What are the special machines/equipments/tools required for inspection operation?

(iv) Any other expertise required?

(v) How important do you think are the various issues in the inspection process?

(Please tick)

Sl. No.	Issues	Not Important	Least Important	Somewhat Important	Important	Very Important	Most Important
1	Inspector's knowledge						

2	Defining specifications						
3	Identifying defects						
4	Special instrument required for inspection						
5	Product diversity						
6	Tolerances for wear						
7							
8							

5. ***Repair/Replacement***

(i) Discuss the process of repair/remanufacturing/refurbishing

(ii) What is the approximate time and cost required for repairing? _____

(iii) What percentage of the parts/components is newly procured for remanufacturing? ___

(iv) Is there any difficulty in availability of new parts / components? YES / NO.
If yes, what may be the possible reason? _____

(v) What are the special machines/equipments/tools required for refurbishing operation?

(vi) Any other expertise required?

6. ***Reassembly***

(i) Discuss the process of reassembly

(ii) What is the approximate time and cost required for reassembly?

(iii) What are the special machines/equipments/tools required for reassembly operation?

(iv) Any other expertise required?

(v) How important are the following issues in the reassembly process?

(Please tick)

Sl. No.	Issues	Not Important	Least Important	Somewhat Important	Important	Very Important	Most Important
1	Skill of employee						
2	Complexity in design						
3	Product diversity						
4	Fastening problem						
5	Special tooling						
6	Lighter duty materials						
7	Serial No. of specific parts/components						
8	Uncertainty of demand of remanufactured products						
9	Parts matching problem						
10							

7. ***Disposal***

(i) What is the approximate percentage of parts/components that is
   a) Disposed of? _____
   b) Sold to recyclers? _____
   c) Disposal Costs. _____

(ii) Is there any environmental law for disposal of some of the materials? _____

III. Design issues

Please rate the following factors as per their importance.

(Please Tick)

Sl. No.	**Design issues**	**1**	**2**	**3**	**4**	**5**
01.	Homogeneity in product					
02.	Complexity in product design					
03.	Design for remanufacturing					
04.	Corrosion/rust on used products					
05.	Dirt/oil on used products					
06.	Testing and inspection					
07.	Tolerances for wear					
08.	Permanent fastening					
09.	Type of material used					
10.	Defining specification					
11.	Fragility of parts					
12.	Destructive disassembly required					
13.	Assembly/disassembly problem					
14.	Reliability of product					
15.	Skill of employees					
16.						
17.						

IV. INVENTORY CONTROL

1. Whether there is (a) inventory for parts/components, or ☐ (Please tick)
   (b) Inventory for used products, or ☐
   (c) Both (a) & (b) above. ☐

2. How important are the following issues in inventory control?

(Please tick)

Sl. No.	Issues	Not Important	Least Important	Somewhat Important	Important	Very Important	Most Important
1	Shortages of inventory						
2	Balancing demands with returns						
3	Special handling methods required						
4	MRP based						
5	Parts matching problem						

6	Mismatch between demand & supply						
7	Complex scheduling & capacity planning						
8	Lead time variability						
9	Storage facility location						
10	Space required for storage						
11	Lot sizing problem						
12							

3. Any other expertise required?

V. MARKETING AND SALES OF REMANUFACTURED PRODUCTS

1. Who exactly are the customers for the remanufactured products?

2. How the recovered parts are used?

(Please tick)

Parts used to remanufacture a new product	
Used as spare parts	
Any other (please mention)	

3. How important are the following issues for marketing of the remanufactured product?

(Please tick)

Sl. No.	Issues	Not Important	Least Important	Somewhat Important	Important	Very Important	Most Important
1	Segmentation of the market						
2	Green image used as marketing element						
3	Cheaper price of remanufactured product						
4	Level of demand for remanufactured goods						
5	Target markets and their potential for growth						
6	Facility location related to market						
7	Customer's attitude towards remanufactured product						
8	Existence of disorganized business sector						
9	OEMs perception about remanufacturing						
10	OEMs fear of loosing market share						
11	Second hand market is thriving						
12	Trade barriers						
13							
14							

4. How much is the cost variation involved while comparing the remanufactured product's cost with the original products cost?

5. What are the observed behavioral patterns of the customers?

VI. SOME MANAGERIAL ISSUES

1. How important are the following issues with respect to government policies?

(Please tick)

Sl. No.	Governmental policies	1	2	3	4	5
01.	Take-back policies					
02.	Land fill & Incineration restrictions					
03.	Laws related to environmental protection					
04.	Restriction on use of hazardous substances					
05.	Prevention & control of pollution					
06.	Disposal cost					

2. What is the distribution of costs in various operations of remanufacturing?

Operations	Cost
Technology/machine/capital cost	
Used product/core	
Reverse logistics	
Disassembly	
Cleaning/sorting	
Inspection	
Inventory	
Reassembly	
R&D	
Forward logistics	

Please mention any other information you want to share with us and we would be really happy if you can contact us at the following address.

Dr. Sandeep Mondal, Department of Management Studies, Indian Institute of Technology (Indian School of Mines), Dhanbad (Jharkhand). PIN – 826 004, E-mail: sandeepmondal@iitism.ac.in

Any other information

NSTMIS Division
Department of Science & Technology
Ministry of Science & Technology
Technology Bhawan, New Mehrauli Road, New Delhi – 110016
Phone: 91-011-26567373
Website:www.nstmis-dst.org/

About NSTMIS:
The National Science and Technology Management Information System (NSTMIS), a division of Department of Science and Technology (DST) has been entrusted with the task of building the information base on a continuous basis on resources devoted to scientific and technological activities for policy planning in the country.

Citation:
The report may be cited as DST (2021): Report on Developing a framework of critical indicators for success of remanufacturing in India; Sandeep Mondal, IIT(ISM), Dhanbad. New Delhi, Govt. of India.

Disclaimer:
Every care has been taken to provide the authenticated information. However, the onus of authenticity of data rests with the PI of the project.