Analysis of issues controlling the feasibility of automobile remanufacturing business in India

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Abstract: In the last three decades, remanufacturing has grown into a significant business sector in developed countries. Take-back obligations, disposal bans, economic benefits, creation of stock of components/parts from disassembly and demand for spare parts during post product life cycle period are key enablers of growth for this business sector. In India, the remanufacturing business is mostly practiced as a disorganised sector. Though Indian automobile industry holds the tenth position in the entire world, second in two wheelers and fourth in commercial vehicles, there are no significant initiatives either from the government or from the industry to pursue remanufacturing as a separate business entity. This paper presents an empirical investigation of the Indian automobile industry and explores the reasons behind the slow growth of remanufacturing as a profitable business option. The survey identifies critical issues that impact the feasibility of automobile remanufacturing in India. It also identifies the differences in perception on remanufacturing by different players in the automobile supply chain, that is, heavy commercial vehicles (HCVs), light commercial vehicles (LCVs), car, two wheeler or original equipment manufacturers (OEMs) and suppliers.

Keywords: remanufacturing; automobile; empirical study; India.

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1 Introduction

Human-caused climate change has placed significant pressure on both governments and firms to conserve our natural resources. Remanufacturing is one of the options which can indirectly preserve our ecosystem by avoiding incineration and land filling by waste

materials. It is defined as a series of processes which makes the condition of the old product functionally equivalent or better than new (Mok et al., 2013; Jung, 2013). Remanufactured products use less energy (about 10%~20% of new product); are cheaper to manufacture (50%~60% of new product) with a well-established closed-loop recovery system (Mok et al., 2011); and can provide the customer with a significantly lower cost of ownership.

The growth in remanufacturing is motivated by multiple factors – take-back obligations, disposal bans, economic benefits, creation of stock of components/parts from disassembly and demand for spare parts after the end of the life of the product. Remanufacturing is currently prevalent in many industrial sectors, with the automobile sector accounting for two-third of the total remanufacturing activities worldwide (Steinhilper, 2006; Williamson et al., 2012). According to Automotive Parts Remanufacturers Association (APRA), the remanufactured auto parts market is estimated to be $85–100 billion world wide. In the USA, the automobile parts remanufacturing is worth around $34 billion. There are about 150 engine remanufacturers and 1,000 automotive parts remanufacturers in USA alone. Automotive components that are currently remanufactured include clutches, brake shoes, engine blocks, starters, alternators, water pumps and carburetors (Lund et al., 1998).

The Indian automobile industry is the tenth largest in the world. The two-wheeler industry in India ranks second globally and the commercial vehicles industry is the fourth largest in the world. As of 2014, the Indian automobile industry produced about 21 million vehicles. Twelve out of every thousand Indians own an automobile and sales are projected to grow at the rate of 9% per year. The projected size of Indian automotive industry in 2016 will vary between $122 million to $159 million (*Automotive Mission Plan Report 2006–16*). It is estimated that between 2020 and 2025, 5.1 million cars and two-wheelers would be ready for disposal after the end of their useful life. Coupled with the fact that Indian customers value low cost of ownership, remanufacturing holds significant potential for the Indian market.

Despite the potential, automobile remanufacturing in India is in its nascent stage. This research reports on how automobile companies (OEMs) and their ancillary suppliers perceive remanufacturing and the challenges and stumbling blocks in pursuing a viable remanufacturing business sector in India. Specifically, we seek the answer to the following questions:

1 What are the factors considered critical by OEMs and suppliers for the viability of automobile remanufacturing business in India?

2 How are these factors perceived by different classes of automobile manufacturers – Car, LCV, HCV, two-wheelers?

2 Background literature and identification of issues in remanufacturing

We classify the set of issues related to automobile remanufacturing into seven different categories: economic issues, environmental policies, marketing issues, acquisition and reverse logistics, inventory management, production planning and control, and design issues. A detailed literature review is available in Sinha (2013) – we highlight key ideas in the ensuing narrative.

2.1 Economic issues

The economic benefits from the remanufacturing activities are prime drivers that motivate many companies in the Organization for Economic Cooperation and Development (OECD) countries to pursue it alongside traditional manufacturing processes (Thierry et al., 1995). Regulations and the wide-spread awareness on remanufacturing significantly increase the availability of used parts. High profit margins as a result of lower cost of manufacture makes remanufacturing attractive [see e.g., Amelia et al. (2009), Ayres et al. (1997), Ferrer and Whybark (2000), Guide (2000) and Geyer et al. (2007) for many successful remanufacturing implementation].

However, the economic feasibility of remanufactured product depends on multiple factors (Ferrer et al., 2003):

1 infrastructure of the reverse logistics network

2 the market for remanufactured products

3 the design of the product.

As the infrastructure to collect products and parts improve; as customer's perception of remanufactured products improve; and as products are designed for ease of remanufacturability, the business case for remanufacturing also increases (Hammond et al., 1998; Gungor, 2006).

2.2 Governmental policies

In OECD countries, environment protection laws indirectly act as a driver for the remanufacturing process. For example, waste from electrical and electronics equipment (WEEE), take-back programs, end-of-life vehicles (ELVs) directives, extended producer responsibility (EPR) law and restriction of hazardous waste substances (RoHS) directives drive remanufacturing and impact the operations of firms under the jurisdiction of these laws (Guide, 2000; Gray and Charter, 2006).

In European Union (EU) countries, for example, the ELVs directive has passed laws to the member countries to reuse and recover 95% by weight of the average vehicle by the year 2015 (Eurostat, 2013). The ELVs directives of Denmark, Germany, Netherlands and France compel the auto makers to collect the used cars for the purpose of remanufacturing (Doppelt and Nelson, 2001). In USA, as of May 2010, twenty one states had passed laws making OEMs responsible for taking back and reusing and/or disposing electronic products at end-of-life. In India, the relevant laws include The Environment (Protection) Rules (1986) and The Batteries (Management and Handling) Rules (2001). These laws currently do not compel auto manufacturers to reuse or remanufacture on a large scale.

2.3 Marketing factors

Marketing strategy depends upon the 'type' of company, that is, whether the company is remanufacturing spare parts or the complete product. The strategy further depends on whether the remanufactured product is used by the company itself or by its customers or suppliers in the supply chain (Thierry et al., 1995). Market segmentation clearly identifies the potential customers for the remanufactured products. Since such products are cheaper,

they can be attractive to lesser-developed markets (Debo et al., 2005). Companies are also trying to attract environmental conscious customers by advertising the remanufactured products as 'green'. It is very challenging for the companies to decide the selling price for the remanufactured product as the recovery rate varies from product to product (Liang et al., 2009; Morley et al., 2006). Further, customers are not aware of remanufactured products or the products carry a negative connotation, and therefore not willing to buy them (Steinhilper, 2006). In some cases, especially in automobile remanufacturing, the existence of second hand market discourages OEMs from remanufacturing. As the customer's attitude towards remanufactured product is not mature in India, the OEM is very reluctant to initiate the remanufacturing business. Third party quality certification programs in India are still evolving; the customer still perceives the remanufactured product as 'used'. This perception, despite the high population, has led to a lack of customer base which further reduces the incentives to remanufacture. Finally, customers also expect a significant discount on products they perceive as lower in quality than the new vehicles; the pricing of the remanufactured product is also a key issue for OEMs.

2.4 Acquisition and reverse logistics

Reverse logistics is the area that primarily focuses on inbound supply and distribution of used products (Fleischmann et al., 1997). Designing an effective reverse logistics network is challenging, especially, given the uncertainty involved in managing the remanufacturing process (Krumwiede and Sheu, 2002; Guide and Srivastava, 1997; Srivastava, 2008). These uncertainties include uncertainty in the timing of returns, uncertainty in the quantity of returns and uncertainty in the quality of returns. In India especially, an organised supply base is absent; so the sources of supply for OEMs are uncertain. Second, recovered cores need to be transported to the remanufacturing facility in a timely fashion without damaging the product. So managing these supply networks requires significant planning (Schultmann et al., 2006). Third, many of the cores that are recovered will need significant processing or in some cases have to be thrown away, making inventory and production planning challenging. The management of acquisition may either be done in-house or via a third party. Finally, the cost related to acquisition of returns is uncertain and difficult to control due to uncertainty involved in the quality and quantity of the used products (Savaskan et al., 2004).

2.5 Inventory management

Determining lot-sizes and the resultant cycle inventory of component parts are challenging due to the uncertainty in supply quantities and increased variation in supply lead times (Teunter, 2001; Fleischmann and Kuik, 2003). Integrating recycled or remanufactured component parts into traditional material requirement planning (MRP) systems is challenging due to the uncertainties involved in the acquisition process. Many OEMs, even in OECD countries manage this either manually or independent of the MRP system. The uncertain flows can create an imbalance between supply (returns/used product) and demand of remanufactured product (Dekker et al., 2000; Inderfurth, 2004). This necessitates an inventory control mechanism that accommodates the uncertain returns process while balancing demand and supply (Guide, 2000). A 'reverse MRP' is

recommended which can effectively control the stochastic and hybrid nature of supply of returns (Inderfurth, 2004; Kiesmuller, 2003).

2.6 Production planning and control

The production process of remanufacturing starts with the disassembly operation. Disassembly is defined as a systematic method of disintegrating a product into its constituent parts, components and sub-assemblies. The disassembly process could be either destructive (constituent parts may be damaged) or non-destructive; or the product could be partially or fully disassembled inducing a source of uncertainty (Lambert and Gupta, 2002). One of the challenges is to decide if the collected cores should be remanufactured or recycled (see Tharanga et al., 2013) for a model on the trade-offs).

Furthermore, not all cores that are recovered are usable – many have to be discarded due to quality considerations. These uncertainties in the disassembly operation could lead to uncontrolled release of parts (or have no parts at all) which may cause long queues (or starving) at machine centres. This situation may increase lead time and its variability in processing the parts, which in turn may impact customer service (Guide, 1996). New approaches like reverse MRP alleviate some of the uncertainty by better matching the demand of the remanufactured product with that of supply of used parts.

2.7 Design issues

Design for remanufacturing (DFR) refers to product design that enables the product to be used for multiple life cycles as the original product or at end-of-life, makes it easier to be used as parts into remanufactured products (Ramani et al., 2010; Ishii et al., 1995; Gungor and Gupta, 1999). DFR strategies include design for core collection, design for disassembly, design for multiple life cycles, and design for upgrade and evaluation (Amezquita et al., 1995; Gray and Charter, 2006). Automobiles are complex in design and often other design considerations – such as safety – make it difficult to recover at end-of-life (Hammond et al., 1998).

3 Methodology

To identify the factors that hinder automobile remanufacturing in India, a survey instrument consisting of a set of questions related to each of the issues discussed above was implemented (see Appendix for the survey instrument).

The respondents were asked to rate each of the issues on a five-point Likert scale, (1 as the least important and 5 as the most important) based on their importance to initiating automobile remanufacturing business. 204 Indian automobile companies were chosen to be part of the study. The sample included OEMs and automotive component suppliers. We compiled the list from various sources: capital line data base (2009), automobile directory (2010) and automobile companies' websites. OEMs consisted of cars, LCVs, HCVs and two-wheeler manufacturers. Questionnaires were sent to these 204 companies. Sixteen companies responded by e-mail. Personal visits to various companies around the country were also arranged. We interviewed company representatives from manager to the supervisor level. Some of the companies responded through mail. A total of 72 responses were obtained which forms the sample size for the

present study. The sample comprises of 33 OEMs and 39 suppliers. Further, the OEMs are classified into four classes that is, passenger cars (eight), HCV (13), LCV (four) and two-wheeler manufacturers (eight).

4 Data analysis

4.1 Analysis of critical issues

The responses of automobile companies were collected and statistically analysed. The analysis is first performed for two echelons of the automotive supply chain that is, OEM and supplier to understand their perceptions on automobile remanufacturing. We classify responses that had a survey rating of four or above as 'critical'. A total of 14 issues come under the critical category for OEM and 13 for the supplier. The critical issues for OEM and the supplier are given in Table 1.

Table 1 Descriptive statistics of critical issues for the class, OEM/supplier

Issues	*OEM (33)*			*Supplier (39)*		
	Mean	*Std. dev.*	*t-values**	*Mean*	*Std. dev.*	*t-values**
Economic						
Technology/machine/capital cost	4.33	0.78	2.46	4.41	0.72	3.58
Governmental policies						
Take-back policies	4.12	1.11	0.63	4.44	0.82	3.32
Land fill and incineration restrictions	3.85	0.80	–1.09	3.97	0.67	–0.24
Reverse logistics						
Reverse distribution network design	4.18	0.77	1.36	4.51	0.64	4.98
Uncertainty in quality of return	3.88	0.65	–1.07			
Uncertainty in quantity of return	3.91	0.63	–0.83	3.92	0.70	–0.68
Deciding buy back price of the used product	3.82	0.73	–1.44	4.10	0.60	1.07
Inventory management						
Balance of demand with returns	3.94	0.70	–0.49	3.90	0.64	–1.00
Prod. planning and control						
Complex scheduling and capacity planning	3.94	0.83	–0.42	3.92	0.93	–0.52
Design issue						
Complexity in product design	4.45	0.51	5.16	4.28	0.51	3.45
Marketing issue						
Price of remanufactured product	4.18	0.64	1.64	4.15	0.74	1.29
Relatively few customers in the market	3.91	1.13	–0.46	3.77	1.09	–1.33
Identification of potential customers	4.09	0.84	0.62	4.21	0.77	1.67
Green image as marketing element	4.21	0.89	1.37	4.21	0.80	1.60

Note: *Decision criteria, if $t \geq -1.6939$ (OEM) and -1.6860 (Supplier) then the factors have mean significantly greater than or equal to 4 (at 5% level of significance).

Table 2 Descriptive statistics of critical issues for different class of OEMs

Issues	*Car (8)*			*HCV (13)*			*LCV (4)*			*Two-wheeler (8)*		
	Mean	*SD*	*t**	*Mean*	*SD*	*t**	*Mean*	*SD*	*t**	*Mean*	*SD*	*t**
Economic												
Cost of reverse logistics				3.77	1.01	–0.82	4.00	0.82	0.00			
Collection of used product/cores							3.50	0.58	–1.73			
Cost of product and process design							3.00	1.15	–1.73			
Technology/machine/capital cost	4.25	0.71	1.00	4.31	0.85	1.30	4.25	0.96	0.52	4.50	0.76	1.87
Governmental policies												
Take-back policies	4.13	0.99	0.36	3.92	1.44	–0.19	4.25	0.96	0.52	4.38	0.74	1.43
Land fill and incineration restrictions				3.69	1.03	–1.08	4.50	0.58	1.73	4.00	0.53	0.00
Prevention and control of pollution	3.88	0.35	–1.00				3.25	0.96	–1.57			
Disposal cost	3.50	0.76	–1.87				3.75	0.50	–1.00	3.38	1.06	–1.67
Reverse logistics												
Problem of locating the used products	3.50	1.07	–1.32							3.75	0.89	–0.80
Reverse distribution network design	4.13	0.83	0.42	4.00	0.91	0.00	4.50	0.58	1.73	4.38	0.52	2.05
Complexity in planning for return flow	3.50	0.76	–1.87				3.75	1.26	–0.40	3.75	0.71	–1.00
Uncertainty in time of return							3.50	1.00	–1.00	3.75	0.89	–0.80
Uncertainty in quality of return	3.88	0.35	–1.00	3.77	0.83	–1.00	4.00	0.82	0.00	4.00	0.53	0.00
Uncertainty in quantity of return	3.88	0.64	–0.55	3.92	0.76	–0.37	3.75	0.50	–1.00	4.00	0.53	0.00
Deciding buy back price of the used product	3.88	0.35	–1.00	4.00	0.71	0.00	3.50	1.00	–1.00	3.63	0.92	–1.16
Inventory management												
Balance of demand with returns	3.88	0.83	–0.42	3.92	0.76	–0.36	3.50	0.58	–1.73	4.25	0.46	1.53
Uncertainty in demand							3.25	0.96	–1.57	3.75	1.04	–0.68
Push/pull strategies				3.92	0.76	–0.37						
MRP-based system				3.85	0.69	–0.81						
Serial number mismatch	3.63	1.06	–1.00	3.69	0.85	–1.30	3.75	0.50	–1.00			

Notes: *Decision criteria, if $t \geq -1.8946$ (car), –1.7823 (HCV), –2.3534 (LCV) and –1.8946 (two-wheeler) then the factors have mean significantly greater than or equal to 4 (at 5% level of significance).

Table 2 Descriptive statistics of critical issues for different class of OEMs (continued)

Issues	*Car (8)*			*HCV (13)*			*LCV (4)*			*Two-wheeler (8)*		
	Mean	*SD*	*t**	*Mean*	*SD*	*t**	*Mean*	*SD*	*t**	*Mean*	*SD*	*t**
Prod. planning and control												
Homogeneity of product range				3.69	0.85	–1.30	3.75	0.50	–1.00			
Disassembly sequence							3.50	0.58	–1.73			
Lead time variability							3.50	0.58	–1.73			
Mismatch between demand and supply				3.92	0.86	–0.32	4.25	0.50	1.00	3.50	0.76	–1.87
Complex scheduling and capacity planning	4.13	0.83	0.42	3.62	0.96	–1.44	4.50	0.58	1.73	4.00	0.53	0.00
Design issue												
Homogeneity in product				3.85	0.80	–0.69	3.00	1.15	–1.73			
Complexity in product design	4.50	0.53	2.65	4.62	0.51	4.38	4.25	0.50	1.00	4.25	0.46	1.53
Design for remanufacturing				3.85	0.80	–0.69	3.00	1.15	–1.73			
Corrosion/rust on used products							3.75	0.50	–1.00			
Assembly/disassembly problem				3.62	0.87	–1.59	3.25	0.96	–1.57			
Skill of employees				3.62	0.96	–1.44	3.25	0.96	–1.57			
Marketing issue												
Price of remanufactured product	4.13	0.64	0.55	4.31	0.63	1.76	4.25	0.96	0.52	4.00	0.53	0.00
Existence of disorganized business sector							3.25	0.96	–1.57			
OEMs perception about remanufacturing				3.62	0.96	–1.44	3.25	0.96	–1.57			
Relatively few customers in the market	3.88	0.83	–0.42	3.69	1.38	–0.81	4.25	0.96	0.52	4.13	1.13	0.31
Identification of potential customers	4.00	0.76	0.00	4.15	1.07	0.52	3.75	0.50	–1.00	4.25	0.71	1.00
Green image as marketing element	4.00	0.93	0.00	4.15	1.07	0.52	4.25	0.50	1.00	4.50	0.76	1.87
Remanufactured product promotion through offers				3.54	1.20	–1.39	3.50	1.00	–1.00			

Notes: *Decision criteria, if t ≥ –1.8946 (car), –1.7823 (HCV), –2.3534 (LCV) and –1.8946 (two-wheeler) then the factors have mean significantly greater than or equal to 4 (at 5% level of significance).

The analysis was further extended to four different classes of OEMs: passenger cars, HCV, LCV and two wheelers manufacturers. We were interested to find whether there are any differences in perception among these four classes of OEMs in initiating remanufacturing business. Table 2 shows the descriptive statistics of the factors for remanufacturing for each class of OEMs.

Critical are shown in Table 3.

Table 3 The critical issues for various classes of OEMs and suppliers

		OEM	*Supplier*	*Car*	*HCV*	*LCV*	*Two-wheeler*
Economic issue	$\mu \geq 4$	8	8	8	1, 8	1, 2, 6, 8	8
Governmental policies	$\mu \geq 4$	1, 2	1, 2	1, 5, 6	1, 2	1, 2, 5, 6	1, 2, 6
Reverse logistics	$\mu \geq 4$	3, 6, 7, 14	3, 7, 14	1, 3, 4, 6, 7, 14	3, 6, 7, 14	3, 4, 5, 6, 7, 14	1, 3, 4, 5, 6, 7, 14
Inventory management	$\mu \geq 4$	3	3	3, 9	3, 5, 8, 9	3, 6, 9	3, 6
Prod planning and control	$\mu \geq 4$	11	11	11	4, 10, 11	4, 6, 8, 10, 11	10, 11
Design issue	$\mu \geq 4$	2	2	2	1, 2, 3, 14, 16	1, 2, 3, 4, 14, 16	2
Marketing issue	$\mu \geq 4$	1, 6, 9, 10	1, 6, 9, 10	1, 6, 9, 10	1, 4, 6, 9, 10, 11	1, 3, 4, 6, 9, 10, 11	1, 6, 9, 10

Notes: The numbers in each cell correspond to the line item under that category in the survey instrument (see Appendix). For example, technology/machine/capital cost #8 under economic issues were considered critical by OEMs, suppliers, and car manufacturers).

4.2 Description of critical issues

4.2.1 Economic issues

All classes of automobile manufacturers considered that technology/machine/capital cost is the biggest stumbling block when deciding to pursue remanufacturing business. The reason may be due to the non-existence of a vibrant remanufacturing business sector in India. They may have the common perception that the operations involved in remanufacturing specially the disassembly, inspection, and the eventual integration into the manufacturing process may involve very high degree of technological investment. OEMs perceive that they have to take the initiative to start such closed loop networks. The second important issue considered by HCV and LCV manufacturers is the cost of reverse logistics. They perceive that managing reverse logistics is very crucial to overall cost due to the uncertainty involved in the procurement of the used product/cores.

4.2.2 Governmental policies

Among all classes of automobile manufacturers, take-back policies, land fill and incineration issues are considered to be the most important. In western countries, governments have taken the initiative and have enforced rules and regulations related to land filling and environmental pollution. This compels the automotive companies in

those countries to initiate remanufacturing business in many sectors – especially in the automotive business – where the infrastructure for reverse supply chains is well-developed. The second most important issue was the disposal cost. Most of the OEMs have the perception that the government should impose a cost for disposal of automotive waste. It indirectly compels the manufacturer as well as the customer to think carefully about used automotive waste and may drive impetus towards remanufacturing. The third most important issue was the prevention and control of pollution – an issue that can be addressed by regulation and/or voluntary standards. In India there is a lack of governmental laws regarding extended producers responsibility. Moreover, there is no penalty associated with disposal or incineration, thereby reducing the incentives for remanufacturing. Overall, the perceptions are that governments must play a vital role in enabling the remanufacturing business.

4.2.3 Reverse logistics

The issues of reverse distribution network design, uncertainty in quantity and quality of return, and deciding the buy-back price of the used product are found to be the most important factors under this category. These issues are considered important by all classes of automobile manufacturers. Demand for remanufactured product is uncertain. It is compounded by the fact that rate of returns, their quality, and quantity are also not known due to lack of organised closed loop structures. OEMs and suppliers will have to mitigate this uncertainty in both the supply and the demand side of the reverse logistics network for the viability of remanufacturing in India.

4.2.4 Inventory management

The most important issue under inventory management category is the balance of demand with returns. The main reason may be due to the uncertainty involved in the procurement of the used product. It can be further amplified by the uncertainty in quality, quantity and timing of the returns. Automobile manufacturers also point to tracking of inventory (‘serial number mismatch’) as a critical issue. There are multiple generations of products; compatibility with parts from previous generations needed to be maintained and inventory of such compatible parts needs to be tracked accurately. Finally, due to the lack of a potential customer base, forecasting of the remanufactured product and the inventory required to support it are also challenging.

4.2.5 Production planning and control

Under production planning and control category, the most critical issue is the complexity in scheduling and capacity planning. The uneven rate of product core arrival, the uncertain quality and quantity of the parts coupled with the uncertain forecast of end product are key determinants in capacity allocation and utilisation. It affects the entire remanufacturing process due to uneven lead times and processing times. In addition, traditional MRP techniques may not be applicable here. Overall, the entire remanufacturing process gets ‘perturbed’ due to the lack of synchronisation between demand and supply.

4.2.6 Design issues

The issues which are most critical under design category involve the complexity in product design. Component parts and semi-finished products need to be designed in such a way that it can be used for multiple times and at end-of-life it can be disassembled easily with the ability to recover as many parts as possible. These parts must then withstand the rigor of transportation and remanufacturing. The type of material used, disassembly process, tolerances, and employee skills, all play a major role in the viability of the remanufacturing business.

4.2.7 Marketing issues

The most important issues under marketing category are the price of the remanufactured product, identification of potential customer, green image as marketing element and relatively few customers in the market. The reason behind these are lack of an organised market for remanufactured items, fewer numbers of potential customers and possibly the lack of environmental awareness among Indian customers. These could be possibly countered by offering discounts and promotions on remanufactured products.

5 Conclusions and future directions of research

The concept of remanufacturing is quite new in the Indian business environment. Automobile manufacturers are reluctant to initiate remanufacturing and customers are not aware of the benefits associated with it. Despite the enormous benefits that remanufacturing can bring, it still exists as a disorganised sector. In this research, we have explored the factors considered critical – from the perspective of OEMs and suppliers – for viability of automobile remanufacturing business as an organised sector in India.

The research has identified the following key factors that are inhibiting the growth of automobile remanufacturing business in India:

1 Technology, machining and capital costs are high. Remanufacturing processes include cleaning, sorting, disassembly/reassembly and require non-conventional inspection methods and specialised tools. Moreover, as market for remanufactured products is unknown, it is difficult to set up facilities with the right capacity. Estimating the capital cost is therefore challenging.

2 Used products are the basic raw material for remanufacturing process. Firms in the remanufacturing business have to design an efficient reverse distribution network for its collection and transportation. Lack of organised reverse logistics networks in India, and the difficulty of acquiring raw materials of sufficient quality and at the right price make it challenging.

3 Sustainable design of a product makes it usable for multiple lives. The complexity in automotive design complicates the disassembly process and hence entire remanufacturing process gets perturbed.

4 The lack of potential consumer base due to reduced awareness of remanufacturing among Indian customers is one of the prime road blocks for the demand of

remanufactured product. This should be promoted through consumer education and possibly price discounts.

5 The lack of strong EPR laws in India coupled with the low barriers of disposal discourage remanufacturing business. Government agencies need to initiate take-back policies and disposal regulations to kick start remanufacturing.

In summary, the general perception of automobile companies that we present can be used as a basis for framing strategies for the viability of automobile remanufacturing business in India. Our survey also identifies critical factors for different classes of automobile manufacturers – policies can further be fine-grained for these classes of automobile manufacturers.

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Appendix

A survey on automobile remanufacturing in India

Please rate the following factors as per their importance in automobile remanufacturing business.

Rate	*Description*
1	Least important
2	Somewhat important
3	Important
4	Very important
5	Most important

(*Please tick*)

Sl. no.	*Economic factors*	*1*	*2*	*3*	*4*	*5*
01	Cost of reverse logistics					
02	Collection of used product/cores					
03	Storage & inventory					
04	Inspection cost					
05	Disassembly operation cost					
06	Cost of product& process design					
07	Cost of cleaning & sorting					
08	Technology/machine/capital cost					
Sl. no.	*Governmental policies*	*1*	*2*	*3*	*4*	*5*
01	Take-back policies					
02	Land fill and incineration restrictions					
03	Laws related to environmental protection					
04	Restriction on use of hazardous substances					
05	Prevention and control of pollution					
06	Disposal cost					

A survey on automobile remanufacturing in India (continued)

Sl. no.	*Acquisition of used products and reverse logistics*	*1*	*2*	*3*	*4*	*5*
01	Problem of locating the used products					
02	Database 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 product					
09	Fragility of the used products					
10	Special tools required for handling					
11	Collection centre location					
12	Mode of parts collection					
13	Inspection of used products					
14	Deciding buy back price of the used product					
Sl. no.	*Inventory management*	*1*	*2*	*3*	*4*	*5*
01	Storage facility location					
02	Space required for storage					
03	Balance of demand with returns					
04	Lot sizing problem					
05	Push/pull strategies					
06	Uncertainty in demand					
07	Problem in buffer stock maintenance					
08	MRP-based system					
09.	Serial number mismatch					
Sl. no.	*Production planning and control*	*1*	*2*	*3*	*4*	*5*
01	Location of remanufacturing facility					
02	Technology for manufacturing					
03	Uncertainty in quality and timing of parts return					
04	Homogeneity of product range					
05	Uncertain demand rate					
06	Disassembly sequence					
07	Depth of disassembly					
08	Lead time variability					
09	Parts matching problem					
10	Mismatch between demand and supply					
11	Complex scheduling and capacity planning					
12	Uncertain processing time					
13	Skill of employee					

A survey on automobile remanufacturing in India (continued)

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	Serial number specific parts					
13	Destructive disassembly required					
14	Assembly/disassembly problem					
15	Reliability of product					
16	Skill of employees					
Sl. no	*Marketing factors*	*1*	*2*	*3*	*4*	*5*
01	Price of remanufactured product					
02	Customer's attitude towards remanufactured product					
03	Existence of disorganised business sector					
04	OEMs perception about remanufacturing					
05	OEMs fear of losing market share					
06	Relatively few customers in the market					
07	Second hand market is thriving					
08	Trade barriers					
09	Identification of potential customers					
10	Green image as marketing element					
11	Remanufactured product promotion through offers					