IOSR Journal of Business and Management (IOSR-JBM)
e-ISSN: 2278-487X, p-ISSN: 2319-7668. Volume 21, Issue 11. Series. II (November. 2019), PP 85-94
www.iosrjournals.org

Analytical approach to evaluate potential automobile remanufacturers in India

Ajay Kumar Sinha
National Institute of Construction Management and Research, Hyderabad

Abstract: *Remanufacturing is basically a business option where used and discarded products are converted to a usable product or component after a series of value additive operations. It has grown into a popular business sector among developed countries during the last three decades. 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 found to be the key enablers for the growth of this business sector.In this paper, an empirical investigation is carried out among the Indian automobile companies to explore the reasons behind non-acceptance of remanufacturing as a profitable business option. Analysis revealed identification of critical factors which controls the feasibility of automobile remanufacturing in India. Further, the study has been extended to find out whom among the key players like OEMs, suppliers or third party remanufacturers could be the initiator of this business in India.*

Keywords: *Remanufacturing, Automobile, Analytic Hierarchy Process*

Date of Submission: 01-11-2019 Date of Acceptance: 16-11-2019

I. Introduction

Remanufacturing is a concept of strategic importance that enables a significant part of the value added to a product during its initial production to be retained. It is no longer acceptable to dispose continually of strategically important materials in landfill sites or waste the energy associated with their processing. Remanufacturing is the process by which used products and assemblies are returned to their new state with minimum waste and expenditure on materials and energy. Parts that do not wear out are reused in a rebuilt product that incorporates the technological advances deemed necessary to ensure that repairs can be carried out in a timely manner and the item returned to functionality in an efficient manner (APRA., 2016).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 (Dekker et al., 2000; Guide et al., 2003, Wei et al., 2015). The increasing concerns over environmental issues, 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 periodare found to be the prime reasons,which motivated the industry towards reuse, remanufacturing and recycling of used and discarded products (Thierry et al., 1995, Sharma et al., 2016).

Remanufacturing is currently practiced in numerous industry sectors, namely the automotive, aerospace,engines, machine tools, electronic equipment, photocopiers, cellular phones, computers, consumer durables, etc. The automotive industry is one of the leading sector which practices remanufacturing globally. The remanufacturing of automotive products in current state accounts for two third of all remanufacturing business (*Steinhilper et al., 2001*). Considering automotive sector, the remanufacturing business estimates around $ 85 – 100 billion worldwide as per US Automotive Parts Rebuilders Association and in US it worth $ 35 – 40 billion.Automotive components that are currently remanufactured include clutches, brake shoes, engine block, starters, alternators, water pumps and carburetors (*Lund et al.., 1998*).There are around 150 engine remanufacturers and 1000 automotive parts remanufacturers in US alone. One such example is Caterpillar who remanufactures engine for Ford's Truck. Its annual revenue generation is over $ 1 billion (*Gray et al., 2006, Caterpillar., 2010*).

In India, automobile remanufacturing business is mostly practiced as disorganized sector. The growth of automobile remanufacturing business has tremendous potential if weconsider the huge population base of India. Moreover, Indian automobile industry is the fifth 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 2017, the Indian automobile industry produced about 25 million vehicles.The projected turnover of Indian automotive sector in 2026 will be around$300 billion with 15% CAGR (*Society of Indian Automobile Manufacturers, Automotive Mission Plan Report 2016–26*).Despite the potential, automobile remanufacturing in India is in its nascent stage.

This research work is an effort to explore and analyze the perception of automobile supply chain players on issues relevant to remanufacturing business Indian. This study will perhaps lead to identification of issues which are possibly hindering automotive sector in taking up remanufacturing as an organized business in India. Further, we also intend to identify prospective business initiators who may take the initiative to start automobile remanufacturing business in India. Specifically, we seek the answer to thefollowing questions:

I. *To explore the critical issues which avert automobile supply chain players from carrying out remanufacturing business in India*
II. *To identify the prospective automobile remanufacturing player in India.*

1.2 Issues in Automobile Remanufacturing

The remanufactured products are comparatively cheaper than new one (*Amezquita et al., 1995, Xiong et al., 2014*) in lesser developed market. The economic feasibility of remanufactured product depends upon infrastructure of reverse logistics network, market for remanufactured products, and design of the product (*Ferrer et al., 2003*). The basic raw material for remanufacturing operation is used product/return/cores. The uncertainty (timing, quantity and quality) involved in the acquisition process complicates the planning and design of reverse logistics which indirectly makes the production process very complex (*Huang et al., 2017*). Hence, an efficient network design is essential for location, collection and transportation of cores to the remanufacturing plant. Beside this, there are many other issues involved in the acquisition and reverse logistics which indirectly contribute to the profitability.These are mode of parts collection, handling and packaging of parts, and non-homogeneity in shape and size of collected parts(*Hammond et al., 1998*). Thus acquisition and reverse logistics activities should be given prime importance before the starting-off the remanufacturing business. The second important factor is the market for the remanufactured products. The customer's attitude towards remanufactured product is pretty flimsy. They perceive the difference in quality of remanufactured product on the basis of cost (*Steinhilper et al., 2006, Khor et al., 2017*).This results in the loss of sale of remanufactured products.Hence, for successful remanufacturing the existence of proper market and demand management is an essential requirement. The third important factor for economic feasibility of remanufactured product is the design of the product.The design of the product should be so flexible that it can be easily assembled/disassembled on numerous occasions. Additionally, the parts fragility should be least while transporting and disassembling of the parts. The work on design for disassembly (DFD) and design for remanufacturing are very crucial to make the remanufacturing operations technically feasible (*Hammond et al., 1998, Gungor et al., 2006, Yang et al., 2013*).

In western countries, the laws regarding environment protection and land-fill are very stringent. These laws indirectly act as a driver for the remanufacturing process. The various laws and policies which are prevalent worldwide especially in western countries basically include; Waste from Electrical and Electronics equipment (WEEE), Take-back programs on reuse of products, The End–of-Life vehicles (ELV) directives, Extended producer responsibility (EPR) law and Restriction of hazardous waste substances (RoHS) directives. In India, the laws which are prevalent include; The Environment (Protection) Rules, 1986 and The Batteries (Management and Handling) Rules, 2001.The impact of environmental legislation on remanufacturing activities is considered very important while taking-up the feasibility of automobile remanufacturing business (*Thiery et al., 1995,Doppelt et al., 2001*).

The marketing factors related to remanufacturing process basically include the market related issues and customer's attitude towards the remanufactured product. Under marketing issues, the main challenge exists in finding the market for the remanufactured product. As the customer's attitude towards remanufactured product (*Steinhilper et al., 2006*) is not mature, the manufacturer is very skeptical to initiate the remanufacturing business. Besides that, the remanufacturing in automobile sector is highly capital intensive which makes this business very critical. In countries like US and UK there exists an organized market for remanufactured product from where the demand could be fulfilled. But in India the existence of spare parts market is pretty disorganized. From these outlets the demand for spare parts are fulfilled with very little or without any consideration on quality aspect of the product. These issues considered as one of the prime hindrance for auto parts remanufacturing in the perception of OEM. Besides that, the chances of existence of market competition for remanufactured product also exist between different players (*Majumdar et al., 2001*).

The importance of acquisition management issues in remanufacturing is distinctive. Its uniqueness lies due to the uncertainty in the acquisition of returns (*Guide et al., 1999, Yang et al., 2016*). These uncertainties span three areas namely, uncertainty in the timing of returns, uncertainty in the quantity of returns and uncertainty in the quality of returns. The depth and width of the uncertainty makes the process of remanufacturing very complex. These complexities lie in the location of customer base for procuring the returns and managing the transportation of returns from the customer to the remanufacturing plant (*Xiong et al., 2013*). The management of reverse flow of used product requires a composite network design.The decision regarding

the management of returns depends upon the degree of return rate. If the rate of return is high, companies will manage the acquisition process by itself otherwise, they will outsource it to some external agencies (Third Party Logistics Provider).The selection of external agencies is done by considering various operational parameters like cost, quality, timing, and flexibility of the service (*Meade et al., 2002*).The rate as well as the quality of return is very high in automobile parts. 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*).

Inventory management issues in remanufacturing process comprises of wide-range of new challenges in the areas of material requirement planning (MRP), PUSH-PULL strategies, lot-sizing strategies, and maintenance of safety stock. These difficulties arise basically due to the uncertainties involved in the acquisition process. Due to these uncertainties there arises the problem in integration of returns flow which ultimately complicates the producer's MRP system. Furthermore, it leads to create imbalance between supply (returns/used product) and demand of remanufactured product (*Dekker et al., 2000; Inderfurth et al., 2004*). Thus, an effective inventory control mechanism is required which can create the balance between the demand and supply (*Guide et al., 2000*). Here, reverse MRP is required which can effectively control the stochastic and hybrid nature of supply of returns (*Inderfurth et al., 2004; Kiesmuller et al., 2003*).In case of automobile parts recovery, the rate of return as well as the depth of disassembly operation is very high which results in complexity in maintenance of proper lot-sizing and necessary safety stock during production (*Minner et al., 2001; Golany et al., 2001*).

The design issues in context of remanufacturing literally cover the area of product and process (business model) design which enables the remanufacturing operations (*Sundin et al., 2004*). The product design should be such that it can be used numbers of times as an original product or parts for remanufactured product. These characteristics are coined under a particular name i.e., design for remanufacturing (DFR) (*Ishii et al., 1995; Gungor et al., 1999*). Detailed product design for remanufacture consists of an interrelated group of design strategies, which ultimately build the strategies for eco-design to capture the commercial opportunities of multiple lives and upgrading. These basically include design for core collection, design for disassembly, and design for multiple-life cycle, and design for upgrade and evaluation (*Gray et al., 2006*).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 subassemblies. The planning for disassembly is very complex due to the nature of additive material used as fastener in the original component. The disassembly process to be adopted for separation could be either destructive or non-destructive in nature. In destructive disassembly, the parts will be disassembled into component level by the application of force which results in breaking of some obsolete units. In contrary, in non-destructive disassembly entire unit will be separated into component level without any breakage of parts. In remanufacturing, the decision for performing complete or partial disassembly is very challenging. In complete disassembly, the used product is fully disassembled, where as in partial disassembly, only certain parts or assemblies are recovered (*Lambert et al., 2002, Caner et al., 2013*). These uncertainties in disassembly operation lead to uncontrolled release of parts which may cause long queues at machine centers. This situation may increase lead time and their variability in processing the parts which may affects the customer service cycle level (*Guide etal., 1996*).

II. Methodology

To identify the critical issues related to automobile remanufacturing, a survey instrument was prepared in the form of questionnaire consisting of 77 closed ended questions and 2 open ended questions from various categories like, economic issues, governmental policies, acquisition & reverse logistics, inventory management, production planning & control, design issues, and marketing issues. The respondents were provided to rate each of the questions in a five-point likert scale, based on theircriticality while initiating automobile remanufacturing business. A total of 204 companies were considered for survey which include OEMs and suppliers. Questionnaire was sent to all 204 companies. Overall 72 responses were received through various sources which form the sample size for the present research. The sample consists of 33 OEMs and 39 suppliers.

2.1 Analysis of issues for overall class of Automobile:

As the first step of data analysis, the responses were statistically analyzed. The analysis is first performed on overall class of automobile companies to understand their perception about remanufacturing. A total of 13 issues were identified undercritical categoryfor overall class of automobile companies in India. Alist of critical issues is given in table-1.

Table-1: Descriptive statistics of critical issues for the overall class of automobile company

Issues	**Notation**	**Mean**	**Std. Dev.**	**t-values**** $\mu \geq 4$
Economic				
Technology/machine/capital cost	V8	4.375	0.740	4.300
Governmental policies	V9			

Take-back policies		4.292	0.971	2.550
Land fill & Incineration restrictions	V10	3.917	0.727	-0.973
Reverse Logistics				
Reverse distribution network design	V17	4.361	0.718	4.267
Uncertainty in quantity of return	V21	3.917	0.666	-1.062
Deciding buy back price of the used product	V28	3.972	0.671	-0.351
Inventory management				
Balance of demand with returns	V31	3.917	0.666	-1.062
Prod. planning & control				
Complex scheduling & capacity planning	V48	3.931	0.877	-0.672
Complexity in product design	V52	4.361	0.512	5.985
Marketing Issue				
Price of remanufactured product	V67	4.167	0.692	2.044
Relatively few customers in the market	V72	3.833	1.101	-1.285
Identification of potential customers	V75	4.153	0.799	1.623
Green image as marketing element	V76	4.208	0.838	2.109
** Decision criteria, If t≥ -1.6666 (at 5% significance level) then the factors have mean significantly greater than or equal to 4 (at 5% level of significance).				

III. Results and discussion

Both OEMs and supplier considered technology/machine/capital cost is the most critical issue while considering remanufacturing business. This may be due to the non-existence of remanufacturing business in India. They may have the common perception that the operations involved in remanufacturing specially, disassembly, inspection, testing may involve very high degree of technological investment. Among government regulations, take-back policies and land fill & incinerations issues are considered to be critical. This may be due to the fact that in western countries it is the government who has taken initiative and implemented many rules and regulations related to land filling and environmental pollution. Due to this the automotive companies are compelled and initiated remanufacturing business in many sectors especially in automotive which is quite successful. The issues, namely, reverse distribution network design, uncertainty in quantity of return, deciding the buy-back price of the used product are found to be the critical under acquisition management. The prime reason behind this may be the uncertainty involved in procurement of the used parts. The forecasting of the raw material i.e., used part as well as the finished product is not certain in remanufactured product which is considered the main reason for the imbalance between demand and supply of return. The allocation of capacity is very uncertain in remanufacturing operation. This is because the rate of cores arrival as well as the demand of remanufactured product is very uncertain. Accordingly, the lead time and processing time gets affected. The general MRP system is not applicable here rather some reverse MRP should be designed for this system. This may create the problem related to complex scheduling & capacity planning. Another issue which iscritical for remanufacturing is complexity in product design. The reason behind this is the fact that during disassembly operation most of the product gets damaged which is of great hindrance to this operation. So, the design of the product should be such that it can be assembled/disassemble for multiple life usages. The issues which are most important among marketing category are price of remanufactured product, identification of potential customer, relatively few customers in the market, and green image as marketing element. The prime reason behind these may be that there are not enough customers in the market for remanufactured product. Beside that it's also a very crucial issue to decide the price of the remanufactured product to make it more salable. Obviously, the price should be lesser than the new product but how it will be decided is another big challenge. Moreover, it should be promoted through some offers or discounts. In addition to this some environmental related issues are needed to be highlighted and could be used as the marketing advertisement so that environmental conscious customers will get attracted to it. As the companies are skeptical about the selling of remanufactured product the OEMs should take initiative for starting remanufacturing business in India.

IV. Application of Analytical Modeling: AHP

4.1 Identification of Remanufacturing Players

The United States is the leader in automobile remanufacturing activities. It has headquarters of many leading automotive Parts remanufacturer as well as home for many small remanufacturer. There are around 15000 remanufacturing firms presently operating in US (Automotive Parts Remanufacturers Association). Remanufacturers of automotive parts include original equipment manufacturers (OEMs, the vehicle manufacturers), original equipment suppliers (OESs, auto parts suppliers), and independent remanufacturing firms (TPRs, third party remanufacturers). OEMs manufacture new auto product, parts as well as remanufactured parts for their original products for resale. They have their dealer networks to sell their remanufactured product. OESs produce new auto parts and also remanufacture them to sell the OEMs. Independent remanufacturers have no relation either with OEMs or OESs and sell their remanufactured products

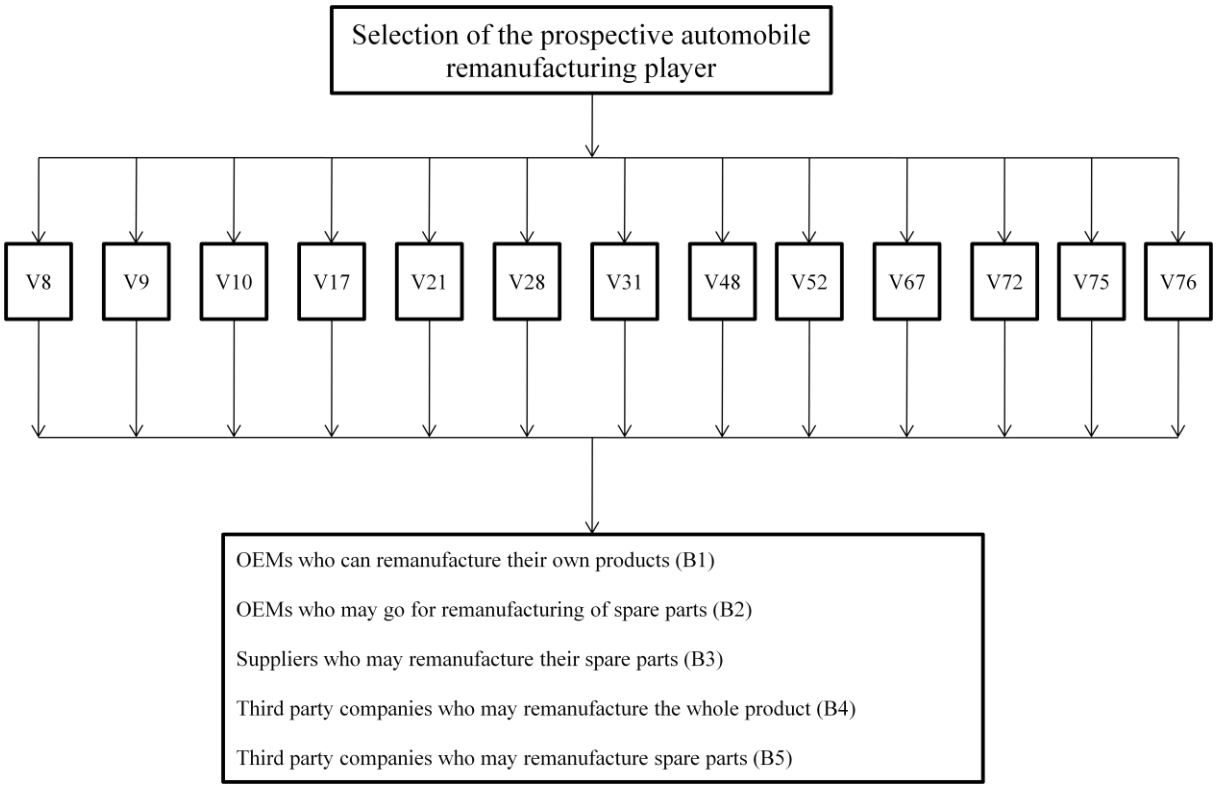
independent distribution networks (*Hauser et al., 2008*). Moreover, OEMs and OESs are able to produce the parts as per the design specifications based on original design and product parameter whereas Independent remanufacturers uses the reverse engineering to replicate the original design of the product to carry out remanufacturing.

From the questionnaire, literature and from the empirical investigation, five different remanufacturing players are identified who can probably initiate automobile remanufacturing business in India. They are (*i*) P1: OEMs who can remanufacture their own products, (*ii*) P2: OEMs who may go for remanufacturing of spare parts, (*iii*) P3: Suppliers who may remanufacture their spare parts, (*iv*) P4: Third Party companies who may remanufacture the whole product, and (*v*) P5: Third Party companies who may remanufacture spare parts.

In India, automobile remanufacturing business is in a very nascent stage and mostly practiced as a disorganized business sector. As per the statistics, there are tremendous potential for the growth of remanufacturing business, especially in automobile sector in India. So we further tried to find out the most economical player who could take up the automobile remanufacturing business in India in future. The issues identified in preceding section will form the basis for selection of most economical player in automobile remanufacturing business. For this purpose Analytic Hierarchy Process (AHP) is applied to assess the relative priorities among the players. The critical issues identified in previous section are considered as a set of criteria for pair wise comparison among identified remanufacturing players.

4.2 Analytic Hierarchy Process Model (AHP)

The hierarchy for selection of the prospective player for automobile remanufacturing is shown in Figure-1.



(**Figure-1:** Hierarchy for selection of the best automobile remanufacturing player)

Further,pair wise comparison between various elements in the hierarchy is performed with a group of experts from automobile sector and research personnel to obtain consistency in the result. The scale chosen for comparing the various criteria is given in Table-2. The scale indicates the level of difficulty for a particular criterion as compared to the other for initiating the remanufacturing business.

Table-2: Comparison Scale for the level of difficulty for criteria

Verbal comparative judgment	Numerical Rating
Extremely more difficult	9
	8
Very strongly more difficult	7
	6
Strongly more difficult	5

	4
Moderately more difficult	3
	2
Equally difficult	1

The pair-wise comparison matrices were constructed among the thirteen criteria and then for each criterion among the five different remanufacturing players. This resulted in fourteen pair-wise comparison matrices as given below.

Pair wise comparison matrix among issues:

	V8	V9	V10	V17	V21	V28	V31	V48	V52	V67	V72	V75	V76
V8	1	2	3	4	5	6	7	6	5	4	3	2	1
V9	1/2	1	2	3	4	5	6	5	4	3	2	1	1/2
V10	1/3	1/2	1	2	3	4	5	4	3	2	1	1/2	1/3
V17	1/4	1/3	1/2	1	2	3	4	3	2	1	1/2	1/3	1/4
V21	1/5	1/4	1/3	1/2	1	2	3	2	1	1/2	1/3	1/4	1/5
V28	1/6	1/5	1/4	1/3	1/2	1	2	1	1/2	1/3	1/4	1/5	1/6
V31	1/7	1/6	1/5	1/4	1/3	1/2	1	1/2	1/3	1/4	1/5	1/6	1/7
V48	1/6	1/5	1/4	1/3	1/2	1	2	1	1/2	1/3	1/4	1/5	1/6
V52	1/5	1/4	1/3	1/2	1	2	3	2	1	1/2	1/3	1/4	1/5
V67	1/4	1/3	1/2	1	2	3	4	3	2	1	1/2	1/3	¼
V72	1/3	1/2	1	2	3	4	5	4	3	2	1	1/2	1/3
V75	1/2	1	2	3	4	5	6	5	4	3	2	1	½
V76	1	2	3	4	5	6	7	6	5	4	3	2	1
SUM	**5.04**	**8.73**	**14.37**	**21.92**	**31.33**	**42.50**	**55.00**	**42.50**	**31.33**	**21.92**	**14.37**	**8.73**	**5.04**

The priority for the thirteen identified criterion are computed as per the given steps.

Step 1. Division of each column element with their corresponding sum value

	V8	V9	V10	V17	V21	V28	V31	V48	V52	V67	V72	V75	V76	**Priority (Level of difficulty)**
V8	0.20	0.23	0.21	0.18	0.16	0.14	0.13	0.14	0.16	0.18	0.21	0.23	0.20	**0.18**
V9	0.10	0.11	0.14	0.14	0.13	0.12	0.11	0.12	0.13	0.14	0.14	0.11	0.10	**0.12**
V10	0.07	0.06	0.07	0.09	0.10	0.09	0.09	0.09	0.10	0.09	0.07	0.06	0.07	**0.08**
V17	0.05	0.04	0.03	0.05	0.06	0.07	0.07	0.07	0.06	0.05	0.03	0.04	0.05	**0.05**
V21	0.04	0.03	0.02	0.02	0.03	0.05	0.05	0.05	0.03	0.02	0.02	0.03	0.04	**0.03**
V28	0.03	0.02	0.02	0.02	0.02	0.02	0.04	0.02	0.02	0.02	0.02	0.02	0.03	**0.02**
V31	0.03	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.02	0.03	**0.02**
V48	0.03	0.02	0.02	0.02	0.02	0.02	0.04	0.02	0.02	0.02	0.02	0.02	0.03	**0.02**
V52	0.04	0.03	0.02	0.02	0.03	0.05	0.05	0.05	0.03	0.02	0.02	0.03	0.04	**0.03**
V67	0.05	0.04	0.03	0.05	0.06	0.07	0.07	0.07	0.06	0.05	0.03	0.04	0.05	**0.05**
V72	0.07	0.06	0.07	0.09	0.10	0.09	0.09	0.09	0.10	0.09	0.07	0.06	0.07	**0.08**
V75	0.10	0.11	0.14	0.14	0.13	0.12	0.11	0.12	0.13	0.14	0.14	0.11	0.10	**0.12**
V76	0.20	0.23	0.21	0.18	0.16	0.14	0.13	0.14	0.16	0.18	0.21	0.23	0.20	**0.18**

Step 2. Multiplication of each column with corresponding priorityelement

	V8	V9	V10	V17	V21	V28	V31	V48	V52	V67	V72	V75	V76	SUM
V8	0.18	0.24	0.24	0.21	0.17	0.13	0.11	0.13	0.17	0.21	0.24	0.24	0.18	**2.47**
V9	0.09	0.12	0.16	0.16	0.14	0.11	0.10	0.11	0.14	0.16	0.16	0.12	0.09	**1.65**
V10	0.06	0.06	0.08	0.10	0.10	0.09	0.08	0.09	0.10	0.10	0.08	0.06	0.06	**1.07**
V17	0.05	0.04	0.04	0.05	0.07	0.07	0.06	0.07	0.07	0.05	0.04	0.04	0.05	**0.69**
V21	0.04	0.03	0.03	0.03	0.03	0.04	0.05	0.04	0.03	0.03	0.03	0.03	0.04	**0.44**
V28	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.03	**0.29**
V31	0.03	0.02	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.02	0.03	**0.21**
V48	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.03	**0.29**
V52	0.04	0.03	0.03	0.03	0.03	0.04	0.05	0.04	0.03	0.03	0.03	0.03	0.04	**0.44**
V67	0.05	0.04	0.04	0.05	0.07	0.07	0.06	0.07	0.07	0.05	0.04	0.04	0.05	**0.69**
V72	0.06	0.06	0.08	0.10	0.10	0.09	0.08	0.09	0.10	0.10	0.08	0.06	0.06	**1.07**
V75	0.09	0.12	0.16	0.16	0.14	0.11	0.10	0.11	0.14	0.16	0.16	0.12	0.09	**1.65**
V76	0.18	0.24	0.24	0.21	0.17	0.13	0.11	0.13	0.17	0.21	0.24	0.24	0.18	**2.47**

Step 3. Divide each row's sumvalue with corresponding priorityelement

Issue	**V8**	**V9**	**V10**	**V17**	**V21**	**V28**	**V31**	**V48**	**V52**	**V67**	**V72**	**V75**	**V76**
Value	13.56	13.58	13.45	13.25	13.11	13.11	13.20	13.11	13.11	13.25	13.45	13.58	13.56

Step 4. Calculation of the average of above values

Average, λ=(13.56+13.58+13.45+13.25+13.11+13.11+13.20+13.11+13.11+13.25+13.45+13.58+13.56) /13

= 173.35/13 = 13.33

Step 5. Consistency index

CI = (λ – n)/(n-1) = (13.33 – 13) / (13 – 1) = 0.33/12 = 0.0275
Step 6. Consistency ratio
CR = CI/RI = 0.0275 / 1.55 = 0.0177 < 0.1
(Since the value is less than 0.1, it is considered that the comparison matrix is a consistent one)
Similarly, the pair-wise comparison matrices were calculated for each criterion among the five players. Pair wise comparison matrix for players with respect to each criterion is computed below.Pair wise comparison matrix among players with respect to complexity in product design (V52):

	P1	P2	P3	P4	P5
P1	1	1	3	6	6
P2	1	1	3	6	6
P3	1/3	1/3	1	4	4
P4	1/6	1/6	1/4	1	1
P5	1/6	1/6	1/4	1	1
SUM	2.67	2.67	7.50	18.00	18.00

Step 1. Division of each column element with their corresponding sum value

	P1	P2	P3	P4	P5	Priority (Level of difficulty)
P1	0.38	0.38	0.40	0.33	0.33	0.36
P2	0.38	0.38	0.40	0.33	0.33	0.36
P3	0.13	0.13	0.13	0.22	0.22	0.17
P4	0.06	0.06	0.03	0.06	0.06	0.05
P5	0.06	0.06	0.03	0.06	0.06	0.05

Step 2. Multiplication of each column with corresponding priority element.

	P1	P2	P3	P4	P5	SUM
P1	0.36	0.36	0.50	0.32	0.32	1.87
P2	0.36	0.36	0.50	0.32	0.32	1.87
P3	0.12	0.12	0.17	0.22	0.22	0.84
P4	0.06	0.06	0.04	0.05	0.05	0.27
P5	0.06	0.06	0.04	0.05	0.05	0.27

Step 3. Divide each row's sumvalue with corresponding priority element

Players	P1	P2	P3	P4	P5
Value	5.15	5.15	5.07	5.02	5.02

Step 4. Calculation of the average of above values
Average, λ = (5.15 + 5.15 + 5.07 + 5.02 + 5.02) / 5 = 5.08
Step 5. Consistency index
CI = (λ – n)/(n-1) = (5.08 – 5) / (5 – 1) = 0.08 / 4 = 0.02
Step 6. Consistency ratio
CR = CI/RI = 0.02 / 1.12 = 0.02< 0.1
(Since the value is less than 0.1, it is considered that the comparison matrix is a consistent one)
Similarly, the pair-wise comparison matrices were calculated for each criterion among the five players. The table of pair wise comparison matrix among players with respect to each criterion is given below.

	V8	**V9**	**V10**	**V17**	**V21**	**V28**	**V31**	**V48**	**V52**	**V67**	**V72**	**V75**	**V76**
P1	0.06	0.16	0.44	0.51	0.49	0.38	0.34	0.56	0.36	0.40	0.44	0.37	0.05
P2	0.06	0.04	0.04	0.04	0.11	0.33	0.15	0.22	0.36	0.40	0.35	0.38	0.04
P3	0.14	0.12	0.12	0.15	0.15	0.19	0.07	0.11	0.17	0.10	0.11	0.13	0.15
P4	0.52	0.44	0.06	0.04	0.06	0.06	0.27	0.07	0.05	0.05	0.06	0.06	0.06
P5	0.54	0.06	0.06	0.04	0.10	0.04	0.16	0.05	0.05	0.05	0.05	0.06	0.23

Similarly, the priority for criterion and the priority for each player with respect to each criterion are summarized below.
Priority for criterion:

Criteria	**Priority (Level of difficulty)**
Technology/machine/capital cost (V8)	0.18
Take-back policies (V9)	0.12
Land fill & incinerations (V10)	0.08

Reverse distribution network design (V17)	0.05
Uncertainty in quantity of return (V21)	0.03
Deciding buy-back price of the used product (V28)	0.02
Balance of demand with returns (V31)	0.02
Complex scheduling & capacity planning (V48)	0.02
Complexity in product design (V52)	0.03
Price of remanufactured product (V67)	0.05
Relatively few customers in the market (V72)	0.08
Identification of potential customers (V75)	0.12
Green image as marketing element (V76)	0.18

The overall priority ranking for different players are computed as,
P1 = (0.18)(0.06) + (0.12)(0.16) + (0.08)(0.44) + (0.05)(0.51) + (0.03)(0.49) + (0.02)(0.38) + (0.02)(0.34) + (0.02)(0.56) + (0.03)(0.36) + (0.05)(0.40) + (0.08)(0.44) + (0.12)(0.37) + (0.18)(0.05) = **0.2504**
P2 = (0.18)(0.06) + (0.12)(0.04) + (0.08)(0.04) + (0.05)(0.04) + (0.03)(0.11) + (0.02)(0.33) + (0.02)(0.15) + (0.02)(0.22) + (0.03)(0.36) + (0.05)(0.40) + (0.08)(0.35) + (0.12)(0.38) + (0.18)(0.04) = **0.1497**
P3 = (0.18)(0.14) + (0.12)(0.12) + (0.08)(0.12) + (0.05)(0.15) + (0.03)(0.15) + (0.02)(0.19) + (0.02)(0.07) + (0.02)(0.11) + (0.03)(0.17) + (0.05)(0.10) + (0.08)(0.11) + (0.12)(0.13) + (0.18)(0.15) = **0.1301**
P4 = (0.18)(0.52) + (0.12)(0.44) + (0.08)(0.06) + (0.05)(0.04) + (0.03)(0.06) + (0.02)(0.06) + (0.02)(0.27) + (0.02)(0.07) + (0.03)(0.05) + (0.05)(0.05) + (0.08)(0.06) + (0.12)(0.06) + (0.18)(0.06) = **0.1898**
P5 = (0.18)(0.54) + (0.12)(0.06) + (0.08)(0.06) + (0.05)(0.04) + (0.03)(0.10) + (0.02)(0.04) + (0.02)(0.16) + (0.02)(0.05) + (0.03)(0.05) + (0.05)(0.05) + (0.08)(0.05) + (0.12)(0.06) + (0.18)(0.23) = **0.1758**

The Priority Ranking for players are summarized as:

Remanufacturing Players	Priority	Rank
P1 : OEMs who can remanufacture their own products	0.2504	**5**
P2 : OEMs who may go for remanufacturing of spare parts	0.1497	**2**
P3 : Suppliers who may remanufacture their spare parts	0.1301	**1**
P4 : Third party companies who may remanufacture the whole product	0.1898	**4**
P5 : Third party companies who may remanufacture spare parts	0.1758	**3**

On the basis of the above analysis it can be observed that P3, i.e., Suppliers who may remanufacture their spare parts and P2, i.e., OEMswho may go for remanufacturing of spare parts are considered to be the two most preferred classes of remanufacturing playersin India for initiating this business. Interestingly, it can be observed that Indian companies 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 the expert feels that the companies may at least do some business by selling remanufactured spare parts to industrial and commercial markets or through automobile service centers for the vehicle repair or parts replacement. Moreover, since there is non-existent of any governmental policies regarding automobile remanufacturing, the OEMs are hesitant for remanufacturing at product level.

V. Conclusion

As the empirical research about the feasibility of automobile remanufacturing in India is based on the exploratory study, the detailed investigation is essential before applying its outcome directly into practice. Moreover, the result of the analysis is limited to the eastern, western and northern region of India. The outcomes of this research project are reflected on the following comments.

- The result of the exploratory study clearly represents the critical factors which are considered on prior basis before initiating the automobile remanufacturing business in India. The companies who are willing to take this business in future should frame the strategies based on these factors.
- The outcome of the study reveals the perception of overallclass of automobile companies about the remanufacturing business. The government should consider this information while framing some policies regarding product recovery or remanufacturing activities in India.
- The research analysis shows the possible automobile remanufacturing players who can take up this business in India.
- The second part of the research i.e., analytical modeling shows the step to be taken as a starting stair towards automobile remanufacturing in Indian scenario.

VI. Future directions of research

The concept of remanufacturing is quite new in Indian business environment, automobile manufacturers as well as customers (as experienced from questionnaire survey) are not much aware about the activities of remanufacturing and the benefits associated with it. Moreover, it was observed that a few companies are practicing remanufacturing as a disorganized sector in India. In this research an attempt was made to explore the reasons of non-entry of remanufacturing as an organized business sector in India, which is quite popular and well accepted economic activity globally. The outcomes of the research analysis show the general perception of the overall class of automobile companies. In this research the common trend in their perception are explored and accordingly the strategies are framed for the viability of automobile remanufacturing business in India. These factors may pave the way for framing the strategies distinctly for different class of automobile business units who can take up remanufacturing activities in future.

References

[1]. Amezquita, T., Hammond, R., Salazar, M., and Bras, B. (1995),"Characterizing the remanufacturability of engineering systems", *Proceedings 1995 ASME, Advances in design Automation conference, Boston, Massachusetts*, DE-82, 271-278.

[2]. Automotive Parts Remanufacturers Association (2016),*http:// apra.org*

[3]. Caner, S., Zhu, S.X., and Teunter, R. (2013),"Capacity and production decisions under a remanufacturing strategy",*International Journal of Production Economics*, 145 (1), 359–370.

[4]. Caterpillar.(2010),"The Remanufacturing Process", *Available at http://unitedkingdom*.

[5]. Dekker, R., Vander Laan, E., andInderfurth, K. (2000), "A review on inventory control for joint manufacturing and remanufacturing", *Conference in management and control of production & logistics, IEEE,* July 5-8, France.

[6]. Doppelt, B., and Nelson, H. (2001),"Extended producer responsibility and product take-back- application for pacific northwest", *Thecentre for watershed and community health, Portland State University, Portland, Oregon.*

[7]. Ferrer, G., and Whybark, D.C.(2003),"The economics of remanufacturing, Business aspects of closed-loop supply chains", Guide, V.D.R., Jr., and Wassenhove, L.N.V. (Ed), *Carnegie Bosch Institute, Carnegie Mellon University Press, Pittsburg, Pennsylvania.*

[8]. Golany, B., Yang, J., and Gang, Yu. (2001),"Economic lot-sizing with remanufacturing options",*IIE Transactions*, 33, 995-1003.

[9]. Gray, C., and Charter, M. (2006),"Remanufacturing and Product Design, Designing for the 7th Generation, SEEDA", *The Centre for Sustainable Design University College for the Creative Arts, Farnham.*

[10]. Guide,Jr.V.D.R.(1996),"Scheduling using drum-buffer-rope in a remanufacturing environment", *International Journal of Production Research*, 34, 1081-91.

[11]. Guide, V., Jayaraman, V., and Srivastava, R. (1999),"The effect of lead time variation on the performance of disassembly release mechanism",*Computers and Industrial Engineering*, 36, 759- 79.

[12]. Guide, V.D.R. (2000),"Production planning and control for remanufacturing: Industry practice and research needs", *Journal of Operations Management*, 18, 467–83.

[13]. Guide, V., Teunter, R., and Van Wassenhove, L. (2003),"Matching demand and supply to maximize profits from remanufacturing", *Manufacturingand Service Operations Management*, 5(4), 303-16.

[14]. Gungor, A., and Gupta, S.M. (1999),"Issues in environmentally conscious manufacturing and product recovery-a survey", *Computers and Industrial Engineering*, 36, 811- 53.

[15]. Gungor, A. (2006),"Evaluation of connection types in design for disassembly (DFD) using analytic network process", *Computers& Industrial Engineering*, 50, 35–54.

[16]. Huang, Z., Nie, J., and Tsai, S.B. (2017),"Dynamic collection strategy and coordination of a remanufacturing closed-loop supply chain under uncertainty", *Sustainability*, 9(5).

[17]. Hammond, R., Amezuita, T., and Bras, B. (1998),"Issues in the automotive parts remanufacturing industry: a discussion of results from surveys performed among remanufacturers",*Engg Design Automation*, 4(1), 27-46.

[18]. Hauser, W.M., Lund, R.T. (2008),"The remanufacturing industry: Anatomy of a Giant: a view of remanufacturing in America based on a comprehensive survey across the industry",*Dept of Manufacturing Engineering. Boston University, Boston.*www. bu.edu/reman (accessed 10.07.12).

[19]. Inderfurth, K. (2004),"Optimal policies in hybrid manufacturing /remanufacturing systems with product substitution", *International. Journal of Production Economics*, 90(3), 325-43.

[20]. Ishii, K., Lee, B.H., and Eubanks, C.F. (1995),"Design for product retirement and modularity based on technology life-cycle. IN", *Manufacturing Science and Engineering*, 921-33.

[21]. Kiesmuller, G.P.(2003),"A new approach for controlling a hybrid stochastic manufacturing/remanufacturing system with inventories and different lead times", *European Journal of Operational Research*, 147, 62–71.

[22]. Khor, K.S., and Hazen, B.T.(2017),"Remanufactured products purchase intentions and behaviour: Evidence from Malaysia", *International Journal of Production Research*, 55(8), 2149–62.

[23]. Lambert, A. (2002),"Determining optimum disassembly sequences in electronic equipment", *Computers and Industrial Engineering*, 43, 553–575.

[24]. Lund, R. (1998),"Remanufacturing: An American resource In: Proc. Fifth int. Congress on Environmentally Concious design and manufacturing", *Rochester NY: Rochester Institute of Technology.*

[25]. Majumder, P., Groenevelt, H. (2001),"Procurement competition in remanufacturing", *Submitted to Management Science, Duke University,*October, 1.

[26]. Meade, L., and Sarkis, J. (2002),"A conceptual model for selecting and evaluating third-party reverse logistics providers", *Supply Chain Management: An International Journal*, 7(5), 283-295.

[27]. Minner, S. (2001),"Strategic safety stocks in reverse logistics supply chains", *International. Journal of Production Economics*, 71, 417-428.

[28]. Savaskan, R. C., Bhattacharya, S., and Van Wassenhove, L. N. (2004),"Closed-loop supply chain models with product remanufacturing", *Management Science*, 50 (2), 239–252.

[29]. Sharma, V., Garg, S.K., and Sharma, P.B.(2016),"Identification of major drivers and roadblocks for remanufacturing in India", *Journal of Cleaner Production*, 112, 1882–92.

[30]. Steinhilper, R. (2001),"Recent trend and benefits of remanufacturing: from closed loop businesses to synergetic networks",*IEEE*, 0-7965-1266-6/01.
[31]. Steinhilper, R. (2006),"Interviewed by Gray C", 22 Nov, 2006.
[32]. Sundin, E. (2004),"Product and Process Design for Successful Remanufacturing", *Department of Mechanical Engineering, LinköpingsUniversitet, SE-581 83 Linköping, Sweden, Dissertation*, No. 906.
[33]. Thierry, M., Salomon, M., Van Nunen, J., and Van Wassenhove, L. (1995),"Strategic issues in product recovery management", *California Management Review*, 37(2), 114–35.
[34]. Wei, S., Tang, O., and Liu, W. (2015),"Refund policies for cores with quality variation in OEM remanufacturing", *International Journal of Production Economics*, 170 (B), 629–640.
[35]. Xiong, Y., Li, G., Zhou, Y., Fernandes, K., Harrison, R., and Xiong, Z. (2014),"Dynamic pricing models for used products in remanufacturing with lost-sales", *International. Journal of Production Economics*, 147 (C), 678–688.
[36]. Xiong, Y., Zhou, Y., Li, G., Chan, H.-K., Xiong, Z. (2013),"Don't forget your supplier when remanufacturing", *European Journal of Operational Research*, 230 (1), 15–25.
[37]. Yang, C.H., Bao, X.Y., Song, C., and Liu, H.B.(2016),"Optimal acquisition policy in remanufacturing systems with quantity discount and carbon tax scheme", Technical Gazette, 23(4), 1073–81.
[38]. Yang, S.S., Ong, S. K., and Nee, A.Y.C. (2013),"Design for Remanufacturing-A Fuzzy QFD Approach",*Re-engineering Manufacturing for Sustainability*, 655-661.

Ajay Kumar Sinha. " Analytical approach to evaluate potential automobile remanufacturers in India." IOSR Journal of Business and Management (IOSR-JBM), Vol. 21, No. 11, 2019, pp. -.85-94