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Application of ISM for the analysis of issues in Reverse Logistics for the viability of Automobile Remanufacturing in India

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Abstract
Remanufacturing is the process of converting used and discarded product into usable one subjected through a sequence of various value addition operations. The main drivers of remanufacturing world-wide are 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. Currently, remanufacturing is being practiced in numerous industrial sector globally but its main contribution comes from automotive sector only. The automotive remanufacturing business estimates around $ 85 – 100 billion worldwide as per US Automotive Parts Rebuilders Association. In this research paper, analysis has been carried out to identify the critical factors in the domain of reverse logistics and acquisition management for the feasibility of automobile remanufacturing in India. With the identified factors, ISM model is developed to know the structural relationship among them and also to know their driving and dependence power. The findings may help the Indian government to frame the policies related to product take back and thus it helps in avoiding environment contamination.
Key words: *Remanufacturing, Automobile, Interpretive Structural Modeling (ISM), India*

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I. Introduction

Environmental pollution obliged many countries to practice sustainable manufacturing in almost all the sector, in which automobile is prevalent one. Sustainable manufacturing is the process of creation of manufactured goods through economically sound processes that minimizes negative impact on environment while conserving energy and natural resources. Remanufacturing is one of the forms of sustainable manufacturing where the products are designed for multiple life usage. Remanufacturing is a value recovery process where used and discarded products/components/parts are subjected to a sequence of value addition activities, so as to convert them into reusable ones (*Lund et al., 1996*). It starts with the process of core (used product) collection from the customer and ends with the assembly of remanufactured quality product. The process of core acquisition is the most critical one among all remanufacturing activities. These can be performed by establishing cost effective reverse logistics network and collection centers (*Srivastava 2008*).

The automobile sector has a long-standing relationship with the remanufacturing industry, as vehicle parts and components are subject to significant wear and tear, thereby necessitating repairs or replacements during their operating life. Countries like USA, UK and Germany are the leaders in the automobile remanufacturing. Remanufacturing business in US worth $ 53 billion annually and employs around 480,000 people while in UK it worth £ 5 billion annually and employs around 50,000 people (*Gray et al., 2006*). 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. With remanufacturing, it is possible to substantially save raw materials and energy as well as reduce greenhouse gas emissions. Reduction down to 11% of original material and 6% of original energy consumption, and 10% of original Global Warming potential have been reported (*Steinhilper 2001, Cooper & Gutowski 2017*).

Despite many economic benefits associated with automobile remanufacturing business, India is still in nascent stage as far as implementation is concerned. This motivates us to identify the critical factors in the area of core acquisition specially and develop the strategies for its implementation in India. Interpretive structural modelling (ISM) is used to analyze and interpret the relationship between the factors. A total of fifteen factors have been identified from the literature and the expert opinion are taken to establish the relation among them.

Background Literature and identification of issues

The remanufacturing activity has gained tremendous popularity globally due to its preventive ecological concern. Remanufacturing is an industrial process where worn-out products, referred to as cores, are brought back to original specification and condition. In some cases, especially in remanufacture of OEM automotive parts, remanufactured products exceed original specifications. The reason is that the latest engineering design and specification, coupled with failure-mode countermeasures derived from failure analysis, are used instead of the original specification (*Amezquita et al., 1995*). Sequence of steps to be followed under remanufacturing operations include (i) Disassembly of the used product, (ii) Sorting and cleaning of individual parts, (iii) Inspection of the parts, (iv) Repair or replacement of worn out parts, (v) Reassembly of the parts, and (vi) Testing of the final product (*Steinhilper et al., 2001*). The main drivers of remanufacturing include economic benefits, government legislation, environmental and ethical responsibilities.

Remanufacturing is prevalent in many industrial sectors but its main contribution (about two-third) comes from automobile sector (*Steinhilper et al., 2001*). Automotive sector is one of the first industries to practice remanufacturing. Engine remanufacturing has been practicing since Second World War (*Seitz, 2007*). In USA, 95% of cars and trucks that are retired each year go to the recycler, and for each of those cars, 75% by weight is recovered for reuse (*Steinhilper et al., 2001*). In Indian automobile sector, Maruti Suzuki provides options for sell and purchase of used car under True Value car exchange (a venture of Maruti Suzuki India Ltd). True Value Category cars are refurbished in state of art workshops using Maruti Genuine Parts and by skilled technicians. These cars are then sold through Maruti True Value outlets.

In this research the main focus is towards the identification of critical factors under reverse logistics and product acquisition area which basically considered as an obstacles in viability of automobile remanufacturing business in India. Reverse logistics is a set of processes which primarily focuses on the acquisition of the used product from the customer and transporting them to the industry. More precisely, it is the process of planning, implementing, and controlling the efficient flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal.

The process of remanufacturing start with core collection from the customer. Identification and location of potential customer is very challenging as far as return is concerned. Correct database of the potential customer needs to be managed and used properly in tracing their location for return (*Krikke et al., 1999*). After customer identification, the next step is to decide how to drive the used product back to the remanufacturing facility. This could be done through optimal reverse network design to enable reverse flow of the product (*Srivastava 2008).* Few companies prefer to perform the core acquisition process by own (like, Caterpillar, Cummins) while others outsource it to third party logistics (3PLs) service provider (*Savaskan et al., 2004, Hammond et al., 1998*). In developing countries like India, customers expect some money for their return, it pose another challenge to decide about the buyback price of the used product (*Liang et al., 2009*). Further, product take-back laws are not prevalent in India due to which OEMs and customers are not interested in returning their used products. Collection centre location provides efficient structure to the reverse network design and also results in deriving cost efficiency in the reverse flow (*Jayaraman et al., 1999*). The core collected from the customer are associated with lots of uncertainties related to timing, quality and quantity. It creates imbalance between demand and supply of the used product and leads to the formation of bottleneck in the remanufacturing process (*Guide et al., 1999, Guide et al., 2003*). This problem further gets aggravated due to uneven shape and size of the return for which quality check needs to be performed (*Hammond et al., 1998*). A well-established reverse logistics network may undertake certain activities at the collection centre, which eliminates the transportation of the useless parts/components. However, this may additionally require establishing the testing facilities at every collection centre. On the other hand, if these activities are done at centralized locations, the total cost of testing would be less, but the transportation cost increases (*Fleischmann et al., 1997*). After quality inspection process the usable parts are transported to the remanufacturing facility through suitable mode of transportation to avoid the fragility of the parts. In this process, usable parts are required to be handled with specially designed tools and techniques (*Hammond et al., 1998*). At last, the application of information technology in overall reverse logistics operations could enhance the efficiency and utilization of the resources up to greater extent (*Daugherty et al., 2005*). The study of the relevant issues mentioned in this chapter offers a meaningful insight to the automobile remanufacturing operations. Table-1 shows the list of the critical factors found from the literature survey in automobile remanufacturing towards reverse logistics and product acquisition management.

Table 1. Acquisition management and Reverse logistics Issues			
Sl.No.	**Critical Factors**	**Factor Notation**	**Author**
1	Complexity in planning for return flow	F1	Srivastava., 2008
2	Reverse distribution network design	F2	Srivastava., 2008
3	Managing customer database	F3	Krikke et al., 1999
4	Problem of locating used products	F4	Krikke et al., 1999
5	Application of IT in reverse logistics	F5	Daugherty et al., 2005
6	Collection centre location	F6	Jayaraman et al., 1999
7	Mode of parts collection	F7	Savaskan et al., 2004; Hammond et al., 1998
8	Reverse logistics operating cost	F8	Fleischmann et al., 1997
9	Deciding buy back price of used products	F9	Liang et al., 2009
10	Balance between demand and supply of used products	F10	Guide et al., 1999; Guide et al., 2003
11	Uncertainties in product return	F11	Guide et al., 1999; Guide et al., 2003
12	Shape and size of product	F12	Hammond et al., 1998
13	Inspection of used products	F13	Hammond et al., 1998
14	Fragility of the used products	F14	Hammond et al., 1998
15	Special tools required for handling	F15	Hammond et al., 1998

II. Research Methodology

The primary objective of the study is to identify the pivotal factors relevant to reverse logistics and acquisition management. It is understood that there can be direct or indirect relationship among factors in any complex system. Analyzing these relationships instead of individual factors evaluated in isolation, is logical and reliable (Attri et al., 2013). Therefore, a research approach is required that can investigate several factors at a time based on a system perspective (Shen et al., 2016). ISM is such a methodology that provides insights into interrelationship with directions and ranking of factors (Tan et al., 2019). Further MICMAC in conjunction with ISM is used for classifying these factor based on driving power and dependence power.

Interpretive Structural Modeling (ISM)

Interpretive structural modelling is proposed by Warfield, 1974 for solving complex socio-econometric problems. ISM is a well-established methodology for identifying the structural relationships among the factors under study. It is an interactive learning process in which a set of different directly and indirectly related elements are structured into a comprehensive systematic model (Sage, 1977). Many researchers have successfully used ISM modeling in their research. Ravi *et al.* (2005) used this methodology to determine the key reverse logistics variables, which the top management should focus so as to improve the productivity and performance of computer hardware supply chains. Mandal and Deshmukh (1994) have analysed some important vendor selection criteria with the use of ISM that shows the inter-relationships of criteria and their different levels. Qureshi *et al.* (2007) applied this approach to model the key variables of logistics outsourcing relationship between shippers and logistics service providers (LSPs) and to study their influence on productivity and competitiveness of the shipper company. Jharkharia and Shankar (2004) used this methodology to identify the enablers affecting the IT enablement of supply chain and to understand the mutual influences among these enablers. Steps involved in ISM methodology includes the following:

1. Identification of critical factors from the literature review.
2. Establishing a contextual relationship between the factors.
3. Development of a structural self-interaction matrix (SSIM).
4. Formation of reachability matrix from SSIM.
5. Partition of reachability matrix into different levels.
6. Graphical representation of relationship developed among the factors in reachability matrix.
7. Check for conceptual inconsistencies and subsequent modification.

MICMAC analysis

The main objective of MICMAC analysis is to classify factors based on their driving and dependence power (Kannan and Haq, 2007). These classification are formed based on following criterion:

- Factors having have weak driving power and weak dependence are classified into Autonomous cluster.
- Factors having weak driving power and strong dependence are classified into dependent cluster.
- Factors having strong driving power and strong dependence are classified into linkage cluster.
- Factors having strong driving power and weak dependence are classified into independent cluster.

The detailed application of ISM coupled with MICMAC analysis for capturing the relationship and classifying relevant factor to reverse logistics and acquisition management is elaborated below:

Identification of critical factors:

A set of fifteen factors have been identified from literature review under reverse logistics and product acquisition domain. These factors are considered critical in accessing the viability of automobile remanufacturing business in India. The list of factors are provided in Table-1 of literature review section.

Structural self-interaction matrix (SSIM):

The primary input to form SSIM is expert's opinion based on brainstorming and nominal technique for developing the contextual relationships. There no criterion of minimum or maximum number of experts to be taken as input to SSIM (Liu et al., 2006 and Shen et al., 2016). After several iteration of brainstorming session with five experts from industry and academia, final consensus are obtained. The following symbols were used to capture the relationship between factors. Based on their responses, the SSIM has been developed as shown in table-2.

V: factor i will help achieves barrier j;
A: factor j will help achieve barrier i;
X: factor i and j will help achieve each other; and
O: factor i and j are unrelated.

Table 2: Structural self-interaction matrix (SSIM)

Factors	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	_	X	A	A	V	X	A	V	O	O	A	A	O	O	O
2		_	A	A	A	X	A	V	O	O	A	O	O	O	O
3			_	X	V	V	O	O	O	V	V	O	O	O	O
4				_	A	V	O	O	V	V	V	O	O	O	O
5					_	O	O	V	O	O	V	O	O	O	O
6						_	V	V	O	V	V	O	O	O	O
7							_	V	O	V	O	O	O	A	O
8								_	O	O	O	O	A	O	A
9									_	A	A	A	O	A	O
10										_	X	A	A	A	O
11											_	O	O	A	O
12												_	V	O	V
13													_	A	X
14														_	V
15															_

Reachability Matrix

The reachability matrix is a binary matrix created from the SSIM. The symbols used in SSIM matrix V, A, X and O gets replaced by 1s and 0s in reachability matrix as per the following rules:

a. If the (i,j) entry in SSIM is V, the (i,j) entry in the reachability matrix becomes 1 and the (j,i) entry becomes 0.

b. If the (i,j) entry in SSIM is A, the (i,j) entry in the reachability matrix becomes 0 and the (j,i) entry becomes 1.

c. If the (i,j) entry in SSIM is X, the (i,j) entry in the reachability matrix becomes 1 and the (j,i) entry becomes 1.

d. If the (i,j) entry in SSIM is O, the (i,j) entry in the reachability matrix becomes 0 and the (j,i) entry becomes 0.

The initial reachability matrix has been developed based on the above rules. The final reachability matrix is obtained by incorporating transitivity check. Transitivity rule states that if factor i influence factor j and factor j influence factor k, then factor i should influence factor k. By embedding transitivity rule, the final reachability matrix obtained is shown in table-3.

Table 3: Final reachability matrix

Factors	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	1	0	1	1	1	1	1	0	1	1	0	0	0	0
2	1	1	0	0	1	1	1	1	0	1	1	0	0	0	0
3	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
4	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
5	1	1	1	1	1	1	0	1	1	1	1	0	0	0	0
6	1	1	0	0	1	1	1	1	1	1	1	0	0	0	0
7	1	1	0	0	1	1	1	1	1	1	1	0	0	0	0
8	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
10	1	1	0	0	0	0	0	0	1	1	1	0	0	0	0
11	1	1	0	0	1	1	0	1	1	1	1	0	0	0	0
12	1	1	0	0	1	1	0	1	1	1	1	1	1	0	1
13	0	0	0	0	0	0	0	1	1	1	1	0	1	0	1
14	1	1	0	0	0	0	1	1	1	1	1	0	1	1	1
15	0	0	0	0	0	0	0	1	0	1	0	0	1	0	1

Level partition

The reachability set and antecedent set are generated for each factor from final reachability matrix. The reachability set consist of factor itself and other factors which influence it whereas antecedent set consist of factor itself and other factors which impact it. Then the intersection set is generated which consist of common factors of reachability set and antecedent set. The factor for which reachability set and antecedent set are same is the top level factor in ISM hierarchy. Once the top level factors are identified, it is separated out from the other factors. Then, by the same way next level factors are identified. These identified level factors are used in building final model. Table-4 below shows the reachability set, antecedent set and intersection set and level.

Table 4: Level Partition matrix

Factors	Reachability set	Antecedent sets	Intersection set	Level
1	1,2,4,5,6,7,10,11	1,2,3,4,5,6,7,10,11,12,14	1,2,4,5,6,7,10,11	II
2	1,2,5,6,7,10,11	1,2,3,4,5,6,7,10,11,12,14	1,2,5,6,7,10,11	II
3	3,4,5	3,4,5	3,4,5	V
4	3,4,5	3,4, 5	3,4,5	V
5	3,4,5	3,4,5	3,4,5	V
6	6	3,4,5,6	6	IV
7	7	3,4,6,7,14	7	III
8	8	1,2,3,4,5,6,7,8,11,12,13,14,15	8	I
9	9	3,4,5,6,7,9,10,11,12,13,14	9	I
10	1,2,10,11	1,2,3,4,5,6,7,10,11,12,13,14,15	1,2,10,11	II
11	1,2,5,6,10,11	1,2,3,4,5,6,7,10,11,12,13,14	1,2,5,6,10,11	II

12	12	12	12	IV
13	13,15	12,13,14,15	13,15	III
14	14	14	14	IV
15	13,15	12,13,14,15	13,15	III

Classification of Factors

All the critical factors are classified into four different clusters. These clusters are, Autonomous, Dependent, Linkages and Drivers. Each of these clusters are differing from one another based on driving power and dependence power. The summation of all the values from ith factor to jth factors in the final reachability matrix is called driving power. Whereas, dependence power is sum of all the values from jth factor to ith factors. The details of dependence and driving power is given table-5.

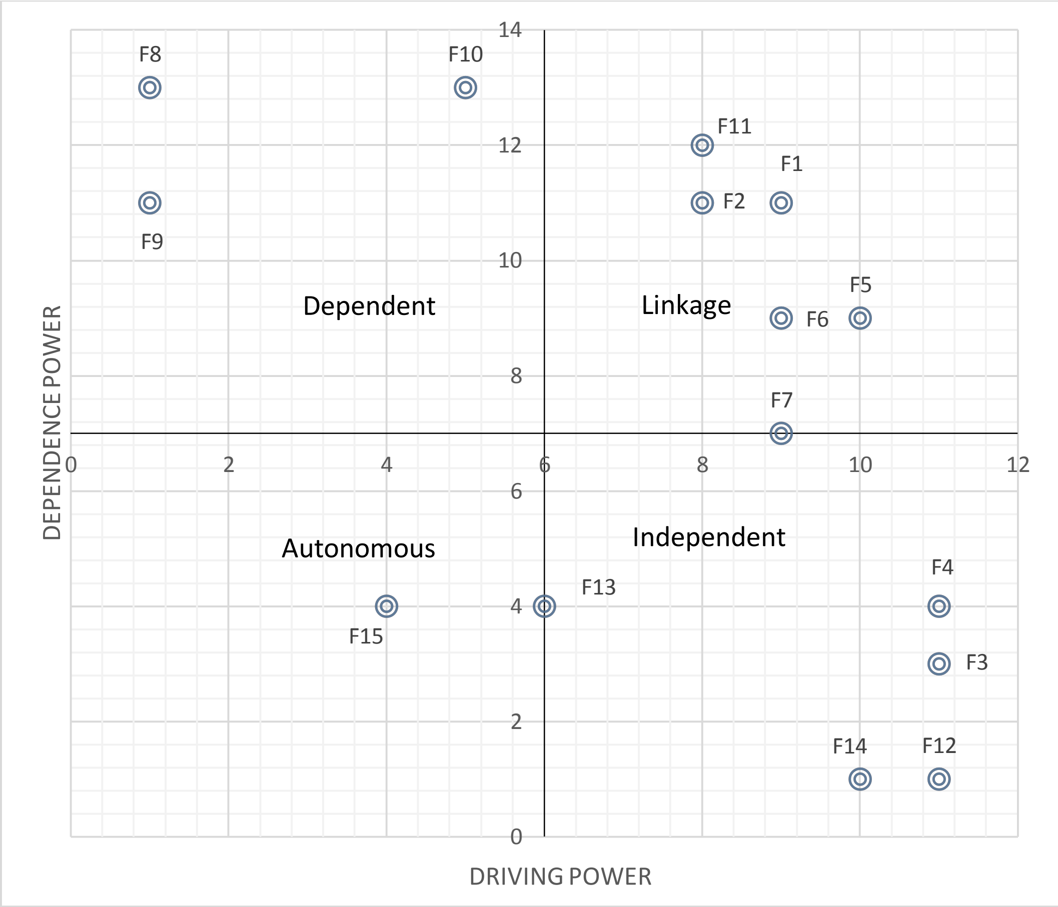
Table 5: Driving power and dependence power

Factors	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Driving Power
1	1	1	0	1	1	1	1	1	0	1	1	0	0	0	0	9
2	1	1	0	0	1	1	1	1	0	1	1	0	0	0	0	8
3	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	11
4	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	11
5	1	1	1	1	1	1	0	1	1	1	1	0	0	0	0	10
6	1	1	0	0	1	1	1	1	1	1	1	0	0	0	0	9
7	1	1	0	0	1	1	1	1	1	1	1	0	0	0	0	9
8	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
10	1	1	0	0	0	0	0	0	1	1	1	0	0	0	0	5
11	1	1	0	0	1	1	0	1	1	1	1	0	0	0	0	8
12	1	1	0	0	1	1	0	1	1	1	1	1	1	0	1	11
13	0	0	0	0	0	0	0	1	1	1	1	0	1	0	1	6
14	1	1	0	0	0	0	1	1	1	1	1	0	1	1	1	10
15	0	0	0	0	0	0	0	1	0	1	0	0	1	0	1	4
Dependence Power	11	11	3	4	9	9	7	13	11	13	12	1	4	1	4	

The "Autonomous factors" have weak driving power and weak dependence power. These factors are relatively disconnected from the system with very few linkages which are not very strong. The second cluster consist of "dependent factors" which have weak driving power but strong dependence. The third cluster constitute of "linkage factors". These factors have very strong driving power as well as dependence power. These factors are highly unstable due to the fact that any changes occurring to them will have effect on others also. The fourth cluster includes "independent factors" having strong driving power but weak dependence power.

The driving power and dependence power diagram are shown in figure-1.

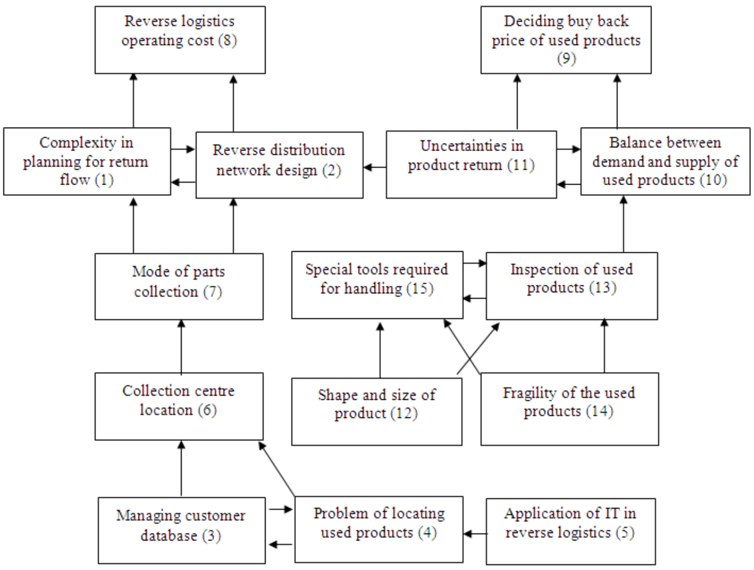
Fig-1: Driving power and Dependence power diagram



Formation of ISM

ISM model is constructed with the help of level partition matrix and final reachability matrix. This model is presented in the form of a diagraph which is the graphical representation of the factors and their interdependence in the form of vertices or nodes and lines of edges. The relationship between two factors i and j are represented by an arrow which point from node i to j. We removed transitivity i.e. indirect relationship in the diagraph. It is drawn with the help of level partition matrix. Finally the digraph is converted into ISM model by substituting the nodes of the factors with statements. The developed ISM model is shown in Fig-2.

Figure-2: ISM based Model



III. Results and Discussion

Fifteen factors are identified and analyzed through ISM modeling which are considered as critical in the area of reverse logistics and acquisition management for establishing automobile remanufacturing business in India. ISM modeling is performed to provide structural relationships among the factors and set them at different hierarchical level.

- From ISM model it is observed that the factors, reverse logistics operating cost (8) and deciding buy back price of used products (9) are at first level. These are the factors which have very high affinity to get influenced by other factors in the hierarchy. A significant portion of reverse logistics operational cost could be saved if some of the operations like, disassembly, cleaning and sorting of used parts could be performed at centralized location near the customer base. Product take-back laws are not stringent in India due to which customers are indifferent in returning their used products. In such condition offering some monetary incentive may kindle them towards selling their used products, but it creates problem of deciding the buy-back price of the used product for which the customer is willing to sale.

- Factors at second level are, complexity in planning for return flow (1), reverse distribution network design (2), uncertainties in product return (11), and balance between demand and supply of used products (10). These are the factors which mostly influence the first level factors and could be easily influenced by low level factors. Taking back the used product from customer base to the remanufacturing facility require effective complex reverse distribution network design to minimise the shortage of input materials in fulfilling the demand. Uncertainties in terms of quality, quantity and timing of the return creates imbalance between demand and supply which could be effectively handled by reverse MRP system.

- At third level these three factors are located, mode of parts collection (7), special tools required for handling (15), and inspection of used products (13). They are influencing directly to the second level factors and indirectly to the first level factors. Due to uncertainties in the quality and quantity of the return, special tools are required for handling and suitable modes of transportation should be deployed to minimize the damage of the parts. Also, proper inspection of the parts should be performed to separate the usable parts from damaged parts before moving the core to the remanufacturing facility.

- Fourth level factors include, collection centre location (6), shape and size of product (12), fragility of the used products (14). These factors have strong driving power to influence others. The cost effectiveness of the reverse logistics operations majorly depends upon the location of collection centre. If it is located near to customer base the number of facility will be more and accordingly cost will be more whereas if it is centrally located far from customer base cost will be less. The decision could be taken based on trade-off between the quantity and quality of the used product and transportation cost.

- At fifth level, the factors which are located include, managing customer database (3), problem of locating used products (4), and application of IT in reverse logistics (5). These are located at the bottom of the ISM model. They have very strong driving power due to which they can influence other top level factors. In India, where customers are unwilling to return their used product due lack of awareness, it is very difficult to locate the potential customer. In such cases, application of information technology become very important to manage the data base of the potential customer and locate them.

Driving power and dependence diagram of the critical factors for hindrance in reverse logistics and acquisition management is also plotted to categorize them into four different categories namely, Autonomous, Dependent, Linkages and Drivers.

- Only one factor, special tools required for handling (15) comes under autonomous category. This particular factor have weak driving power and weak dependence power. It has very few linkage which are not very strong that's why considered as disconnected from the system.

- There are three factors, reverse logistics operating cost (8), deciding buy back price of used products (9) and balance between demand and supply of used products (10) comes under dependent category. They have weak driving power but strong dependence power due to which they may get strongly influenced by other driving factors.

- Under linkage category, uncertainties in product return (11), complexity in planning for return flow (1), reverse distribution network design (2), collection centre location (6) and Application of IT in reverse logistics (5) are the located factors. They have very strong driving power as well as dependence power. They are considered to be highly influential and have potential to affect other factors in the system.

- There are the four factors which comes under independent category namely, shape and size of product (12), fragility of the used products (14), managing customer database (3) and problem of locating used products (4). They have strong driving power but weak dependence power due to which they are considered to be independent. They can influence others due to strong driving power and are mostly located at the bottom of ISM hierarchy.

IV. Conclusion

Despite of enormous benefits associated with remanufacturing activity especially in automotive sector, Indian companies are still struggling to take it up as a profitable business model whereas many western countries (US, UK, Germany) harnessed lots of benefits from it. In this research we have explored the factors considered critical especially in the area of reverse logistics and acquisition management for the viability of automobile remanufacturing business in India. In this study we have identified fifteen factors from the literature related to reverse logistics and acquisition management. The interpretive structural modeling (ISM) has been used to develop the structural relationship among the factors which helps in determining the driving and dependence power of the factors. It is observed that managing customer database, problem of locating used products, Application of IT in reverse logistics, collection centre location, shape and size of product and fragility of the used products are the major -drivers for achieving efficiency in reverse logistics and acquisition management. These factors helps to reverse logistics operating cost, deciding buy back price of used products, complexity in planning for return flow, reverse distribution network design, uncertainties in product return, balance between demand and supply of used products. This implies that proper management of customer database enabled with information technology (IT) is very crucial factor for improving the effectiveness of reverse logistics and acquisition management. Based on these findings, we can conclude that the Indian government should come up with stringent rules and regulations regarding product take back and direct the OEMs to manage the database of the potential customers properly to facilitate the uninterrupted flow of used product.

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