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Enhancing Remanufacturability of Automotive Product Design through Driver Prioritization Using Interpretive Structural Modelling

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Abstract - **With the automobile sector pacing the tracks among their competitors to lead the market and adopting eco-friendly technologies, a much economic and vital field of making use of the manufactured product beyond its useful life span i.e. when its integrated utilisation is finished, has been widely neglected or has not come to spotlight across the globe for various reasons. A product/part/component designed with a scope of easy disassembilibility paves many benefits including running time service as well as for the very crucial remanufacturing after its useful running time before being completely put out of the context of usage. This paper throws light on the necessity for implementing and highlights the various reasons for which these guidelines have not come to the attention of the responsible organizations including law making agencies, automobile manufacturers and as well the consumers. An interpretive structural modelling analysis is made to point out ten driving factors in consultation with various experts from the relevant fields and the results provide guidance to how far the idea of design for remanufacturing has sought the world for the sustainability of the automobile manufacturers in the industry, for the days to come.**

Keywords – Barrier analysis, Design for remanufacturing, End of life vehicles, ISM.

INTRODUCTION

Being one of the prime contributors to the economy, the automobile sector is probably the largest industrial sector in many nations (Seval Ene et. al). The amount of vehicles reaching their lives end will also hike as there is rise in the production and sales of the automobile sector (Tian and Chen, 2014). Automobiles are one of the most critical products causing considerable environmental pollution issues during the phase of usage and disposal. An ELV cites to End-of-Life vehicles i.e. a vehicle reaching the final stage of its useful life. ELVs can be categorised into two - Natural ELV, those that have neared their end of useful life cycle due to the natural wear and tear and Premature ELVs, those that have neared their end of useful life cycle for unnatural/unpredicted factors such as floods, fire, accidents etc.

The reprocessing procedure of waste recycling has come to be viewed as pivotal course of action to concurrently tackle the resource exhaustion, energy depletion, environmental effects, climate change etc. (Fuli Zhou et. al. 2019). The environmental standards are deemed to rise with increasing incomes, and people are going to get more concerned and sensitive about the issues/factors related to deterioration of environment (Dowell et. al., 2000). Policies, techniques and influential factors are examined, learned and experimented to enhance the progress of eco-friendly automotive sector (Su et. al., 2018). Moreover, the practices of the automobile sector pertaining to sustainable supply chain also help to bring out this objective by way of green production, material design for sustainability & assembling practices, and different activities relating to sustainable SC (Johnsen et al., 2017; Kirwan and Wood, 2012; Luthra et al., 2017.).

LITERATURE REVIEW

Economic and effective recycle of ELVs is regarded as a hotspot in sustainable development because the earth is overlooking a situation of depleting resources and prevailing tendency of circular economy. This will be beneficial to ameliorate the liveability of the automotive sector. The conceptual and industrial scenario of ELV reprocessing is elaborated in this section. To explore into the drivers of ELV recycling sector and figure out the reasons for the infancy in market of recycling, the existing state of ELV treatment operations and the hinted factors which will lead to the success is summed up from the industrial point of view.

There exists no universally accepted definition for Remanufacturing (Bras and McIntosh, 1999). For instance, as per the definition cited by Adrian Chapman, et. al., (2010), the principle of remanufacturing is "the industrial processes of bringing back a used product to a minimum of its original performance, and should be equivalent to or better than that of the newly manufactured product". However, William Hauser and Robert Lund (2008) affirm the fact: "Remanufacturing is the process of transforming durable products that are worn, defective, or discarded to a 'better or like new' condition through a batch-production process of disassembly, cleaning, refurbishment and replacement of parts, reassembly, and testing". As a continuation to this explanation, Winifred Ijomah (2009) in addition proposes: "the performance specification of a remanufactured item should be returned to the original level from the customers' perspective and warranty should be given as equivalent to new products". Fundamentally, these statements necessarily convey the similar concept i.e. reclamation of utilized or items at their lives end, turning modules/parts into a new- like state and maintaining this order in a manufacturing habitat. Anyhow, the performance level and predicted condition of a remanufactured part/component when contrasted with a newly manufactured product paves way to the debatable problems relating to the definitions pertaining to remanufacturing.

Despite the distinctions in definitions, it is important to note that remanufacturing isn't same as reconditioning, repairing and recycling. The meaning of reconditioning and repairing might limit to just the restoration of deteriorated products/components back to 'functioning capacity', with the fixed or renovated item by large seen as subservient one to the original product. Adversely, recycling mainly involves the reclamation and reuse of items from products which neared the peak of their satisfactory life cycles. But in the instance of remanufacturing, the recovered item functions as primal raw resource in the production of products with characteristics and functionalities possibly separate from that of the original one. Put another way, recycling signifies part/component recovery unaccompanied by conservation of the structure of product, like for instance, the metal parts recycled out of scrap automobiles.

DATA COLLECTION

There are mainly three types of members, namely individual consumers, government and industrial organizations who are constantly involved throughout the ELV recovery and recycling processes (Chen et. al., 2015). To be specific, these participants mainly constitute of ELV owners, used-car consumers, auto-factories and auto-part manufacturers, renewable resource firms, OEMs, remanufacturing organizations, public law-making organizations etc. In order to disclose the aspects which may influence the growth and development of DfD and remanufacturing techniques, an enlistment and filtration of the ingredient factors by way of a comprehensive literary assessment from government agencies, recycling enterprises and individual viewpoint was performed as demonstrated in table 1.

TABLE 1
LIST OF BARRIERS FOR ADOPTING EFFICIENT REMANUFACTURING TECHNOLOGIES

SI NO:	Barriers	Reference
1	Non existing ELV direc- Tives	Webster. S and Mitra. S, (2007), Wang. Y et. al., (2014), Chakraborty, (2019)
2	Low volume of ELVs	Abdul Rahman et. al., (2014)
3	Lack of research	Chaowanapong, (2018), Parkinson, (2003)
4	Lack of implementation of green practices	Kaliyan. M et. al., (2018), Y. C. Wong et. al., (2018), Liu et. al., (2017)
5	Unaware customers	Guide V.D.R and Li. J, (2010); Wu, (2013)
6	Political factors	Bellmannn. K. et. al., (1999)
7	Economical imbalance	Bouzon. M. et. al., (2016), Soo, (2017), Ijomah, (1998)
8	Lack of coordination of technology transfer	Carrell. J. et. al., (2009), Vermeulen. I. et. al., (2011)
9	Low market for refurbished spare parts	Kurilova-Palisaitiene et. al., (2018)
10	Unawareness about refurbishing benefits among cus Tomers	Bhatia and Srivastava, (2018); Khou and Hazen, (2017), Dowlatshahi, (2005)

ANALYTICS

1. Interpretive Structural Modelling (ISM)

ISM is a computer-supported interactive learning set-up that facilitates groups or individuals to establish a network of the complicated connections betwixt the numerous constituents engaged in a complex circumstance. The primary notion behind usage of ISM is to utilize the practical expertise and intelligence of experts to break down a complex structure into various sub-systems (members) and build a multi- layered illustrative structure depicting the relationship between the adjacent elements.

To be specific, ISM is regarded to be a sort of learning procedure wherein a group of distinct and directly related constituents are organized in the form of a comprehensive systematized hierarchy and is interactive in nature. The formulated model depicts the understandable framework of a complicated subject, a system or an area of study, in cautiously configured pattern incorporating words as well as graphics. (Warfield, 1974; Sage, 1977).

Stated below are the different activities involved in application of the ISM methodology:

I. Firstly, the parameters (criterion) deemed for the domain under review are shortlisted.
II. A context-sensitive correlation is settled between the parameters identified in step I so as to determine which sets of parameters are to be studied.
III. A structural self-interaction matrix (SSIM) depicting the twin set interlink amidst the parameters comprising the system under review is established for the given variables.
IV. Next, a reachability matrix (Initial RM) is devised from the SSIM, following which transitivity verification is done for the matrix. In ISM, the transitivity posed on the connection made on behalf of the context is a simple and fundamental conjecture made. It says that if a variable A is linked to B and B is linked to C, then A is certainly linked to C.
V. Next, the reachability matrix is split to form various levels.
VI. On the basis of relationships (Level split-up) attained in the reachability matrix, a directional graphical network is sketched further to which the transitivity ties are withdrawn.
VII. The resulting digraph is reformed and changed over to an Interpretive Structural Model, by substituting the barriers parameters at nodal points with verbal assertions.
VIII. The developed ISM model is examined thoroughly for any theoretical discrepancies followed by creating required alterations. The methods dis- cussed above are depicted in figure. 1.

2. Questionnaire Survey

Earlier researches suggest that the ISM methodology recommends the use of collective opinions from the experts in preparing the contextual connections in between the shortlisted reasons. These collective opinions are based on several administration methods like brain storming, rapid ideation, nominal technique, etc. To examine and study the barriers for the affectation of remanufacturing techniques in industry, a survey was deemed. Out of the literature survey ten barriers were considered following which an exchange of views and conversations with industrial experts of automotive sector was carried out to check the authentication of the enablers.

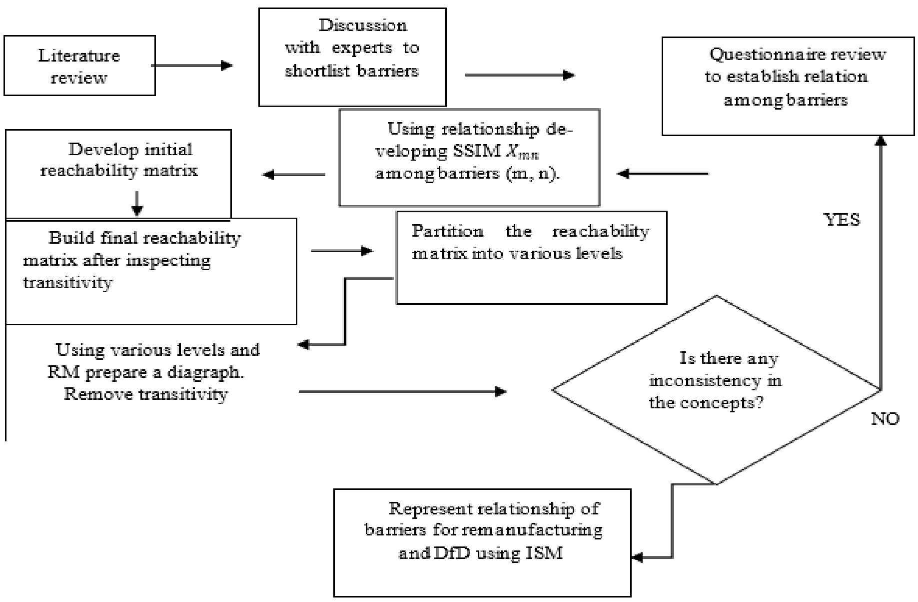

FIGURE 1
FLOWCHART OF THE ISM METHODOLOGY

3. Self Structural Interaction Matrix (SSIM)

With the contextual understanding and relationship for each barrier churned from the previous stage, an attempt is made to identify the link and its associated direction- al effect in between any two barriers (m and n). This is made by using four symbols denoting the direction of linkage between the two barriers (m and n) as:

- V means factor m will assist to achieve factor n.
- A means factor n will assist to achieve factor m.
- X means factor m and n will assist in achieving one another.
- O means factors m and n have no relation.

The SSIM for the barriers in the implementation of remanufacturing and DfD is elaborated in table 2.

TABLE 2
SSIM (SELF STRUCTURAL INTERACTION MATRIX)

Barriers n m	10	9	8	7	6	5	4	3	2
1	V	V	V	X	A	V	V	O	V
2	O	O	V	O	A	A	V	V	
3	A	A	A	A	A	A	V		
4	O	A	X	V	O	V			
5	X	O	O	X	V				
6	X	V	V	V					
7	X	V	O						
8	V	A							
9	V								

The explanation for use of sign characters V, A, X, and O in the SSIM is provided as follows.

- Non existing ELV directives barrier will assist to attain unaware customers' barrier. Therefore, relationship for barriers m1 and n5 are designated by 'V'.
- Low volume of ELVs barrier is stimulated by political factors barrier (m2 and n6). So, the connection in between them is designated by 'A'.
- Lack of implementation of green practices barrier and lack of coordination of technology transfer barrier instigate each other (m4 and n8) and therefore the link among these factors is designated by 'X'.
- There is no relationship connecting the factors lack of implementation of green practices and unawareness about refurbishing benefits among customers' (m4 and n10) and so the relation between these two barriers is depicted by 'O'.

4. Reachability Matrices

Here, reachability matrices are formulated in a two-stage process in which the SSIM format is at first changed over to a matrix configuration after assigning a binary value (zeros and ones) to the data in every cell of SSIM giving rise to an Initial Reachability Matrix (IRM). This conversion is carried out along the given guidelines:

For the listing in the cell (m, n) in SSIM denoted by V, the entry in IRM in cell (m,n) is assigned by 1 and in the cell (n, m) by 0.

For the listing in the cell (m, n) in SSIM denoted by A, the entry in IRM in cell (m,n) is assigned by 0 and in the cell (n, m) by 1.

For the listing in the cell (m, n) in SSIM denoted by X, the entries in IRM in cells (m, n) and cell (n, m) are both assigned 1.

For the listing in the cell (m, n) in SSIM denoted by O, the entries in IRM in cells (m, n) and cell (n, m) are both assigned 0.

Adhering to these guidelines, the completed Initial Reachability Matrix is stated in Table 3.

TABLE 3

INITIAL REACHABILITY MATRIX

Barriers	2	3	4	5	6	7	8	9	10
1	1	0	1	1	0	1	1	1	1
2	1	1	1	0	0	0	1	0	0
3	0	1	1	0	0	0	0	0	0
4	0	0	1	1	0	1	1	0	0
5	1	1	0	1	1	1	0	0	1
6	1	1	0	0	1	1	1	1	1
7	0	1	0	1	0	1	0	1	1
8	0	1	1	0	0	0	1	0	1
9	0	1	1	0	0	0	1	1	1
10	0	1	0	1	1	1	0	0	1

TABLE 4

FINAL REACHABILITY MATRIX

Barriers	1	2	3	4	5	6	7	8	9	10	Dr. P
1	1	1	1	1*	1	1*	1	1	1	1	10
2	1	1*	1	1	0	0	1*	1	0	0	6
3	0	0	1	1	0	0	0	0	0	0	2
4	0	1*	1	1*	1	0	1	1	1*	0	7
5	1	1*	1	1*	1	1	1	0	0	1	8
6	1	1	1	0	1*	1	1	1	1	1	9
7	1	0	1	0	1	0	1	0	1	1	6
8	0	1*	1	1	0	0	0	1	0	1	5
9	0	0	1	1	0	0	1*	1	1	1	6
10	1*	0	1	0	1	1	1	0	0	1	6
De. P	6	6	10	7	6	4	8	6	5	7	

Secondly, with respect to the description of the ISM methodology mentioned in Step IV, the Final Reachability Matrix acquired by integrating the transitivities is given in Table 4. The Final Reachability Matrix will, at that point, comprise of certain listings based on pair-wise correlations and a few deduced listings. * denotes the transitivities made, “Dr. P” denotes driving power and “De. P” denotes the dependence power of each barrier.

5. Partitioning the Levels

In this step, a reachability set and an antecedent set for every factor (Warfield, 1974) was traced from the Final Reachability Matrix as given in Table 5. For a select- ed barrier the reachability set comprises of itself and the other barriers that assist in accomplishing it, given by the denotation 1 horizontally in the FRM. The antecedent set encompasses the hindrances themselves and other obstructions which that work to reach it, given by the denotation 1 vertically in the FRM. In addition to this, for all barriers, an intersection set of both these sets was also determined. According to Kan- nan and Haq, (2007), a barrier is examined to be in level I and is given the highest priority in the ISM hierarchy if its reachability set and the intersection set is equivalent. Progressing with this partitioning procedure, the first iteration is finished (allude table 5). After completion of first iteration, the factors framing level I are disposed of and with the rest of the barriers, the above described technique is proceeded for the second iteration. These iteration processes are resumed till the level of every barrier has been obtained. In this way the partitioning of Final Reachability Matrix, acquired from past stage, into various levels was cried out. Table 6 portrays the level of each barrier after the iterations.

TABLE 5

Barriers	Reachability set	Antecedent set	Intersection set	Level
B1	1,2,3,4,5,6,7,8,9,10	1,2,5,6,7,10	1,2,5,6,7,10	
B2	1,2,3,4,7,8	1,2,4,5,6,8	1,2,4,8	
B3	3,4	1,2,3,4,5,6,7,8,9,10	3,4	I
B4	2,3,4,5,7,8,9	1,2,3,4,5,8,9	2,3,4,5,8	
B5	1,2,3,4,5,6,7,10	1,4,5,6,7,10	1,4,5,6,7,10	
B6	1,2,3,5,6,7,8,9,10	1,5,6,10	1,5,6,10	
B7	1,3,5,7,9,10	1,2,4,5,6,7,9,10	1,5,7,9,10	
B8	2,3,4,8,10	1,2,4,6,8, 9	2,4,8	
B9	3,4,7,8,9,10	1,4,6,7,9	4,7,9	
B10	1,3,5,6,7,10	1,5,6,7,8,9,10	1,5,6,7,10	

Five iterations were performed to determine the Levels of these barriers. The barrier, Lack of research (3) is placed in the *Ist* level and secures the top degree in ISM hierarchy. Economical imbalance (7) and Unawareness about refurbishing techniques among customers (10) are placed at level II; Low volume of ELVs (2), Lack of implementation of green practices (4), Lack of coordination of technology transfer (8) are positioned at level III; Unaware customers (5) and Low market for refurbished spare parts (9) are placed at level IV; Non existing ELV directives (1) and political factors (6) secure the last level of ISM hierarchy. The digraph is developed with the help of these determined levels and this caters to frame the final model of ISM.

TABLE 6

FINAL LEVEL OF EACH BARRIER

Iteration	Level#	Barriers to remanufacturing Design
1^{st}	I	3.Lack of research
2^{nd}	II	7. Economical imbalance 10.Unawareness about refurbishing techniques among customers
3^{rd}	III	2.Low volume of ELVs 4.Lack of implementation of green practices 8.Lack of coordination of technology transfer
4^{th}	IV	5.Unaware customers 9.Low market for refurbished spare parts
5^{th}	V	1.Non existing ELV directives 6. Political factors

6. Formation of Diagraph and ISM Hierarchical Model

A basic model depicting the directional relation among barriers derived from the Final Reachability Matrix is depicted in Figure 2. A line with an arrow mark gives the connection between any 2 barriers n and m directing from one to other. The subsequent diagram is known as a digraph. Finally, the ISM model is extracted from the digraph after evacuating the transitivities as per the guidelines of ISM technique. The last phase of the ISM procedure is the model diagram depicted in Figure 3. This mod- el speaks to the factors by outwardly depicting the connections among them. Each individual barrier is situated corresponding to its driving and dependence/reliance capacities. These levels of barriers are related to the four quadrants that appear in the MICMAC graph in Figure 4. There is no severe decision about which level speaks to which quadrant; it is rather a dynamic representation that mulls over the specific score of the barriers based on its driving and reliance capacity. The top level of the digraph identifies just the one variable in 'Lack of research (3). The logic behind its position at highest point of the model is pertinent in the reality that it possesses extreme possibilities of dependency and insignificant driving force. Subsequently, the variable re- lies intensely upon the lower level factors so as to accomplish any importance with respect to the impacts it might have on remanufacturing design.

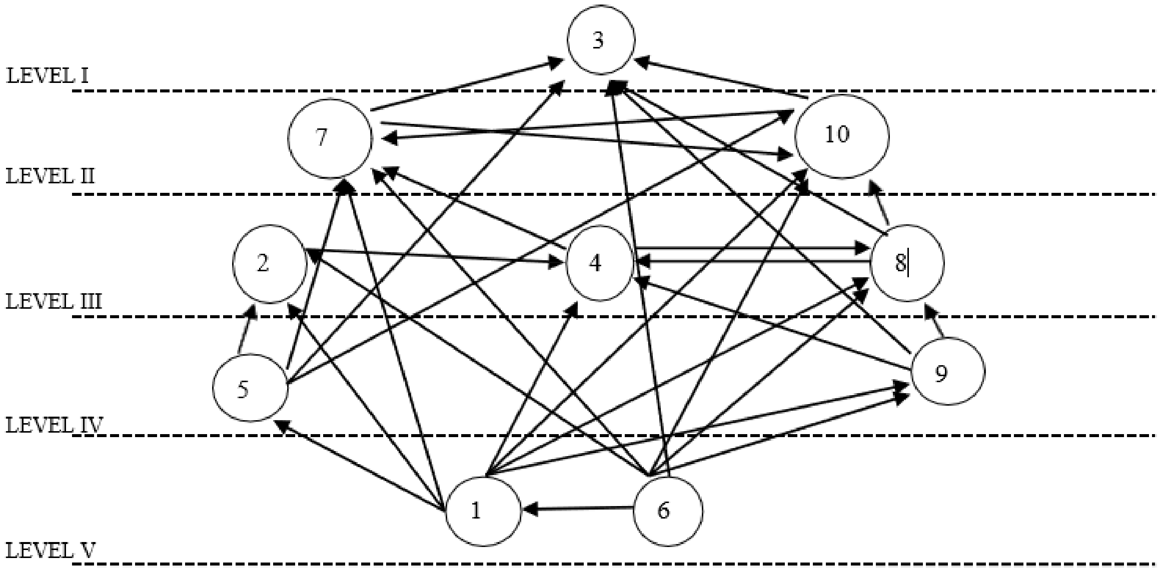

FIGURE 2

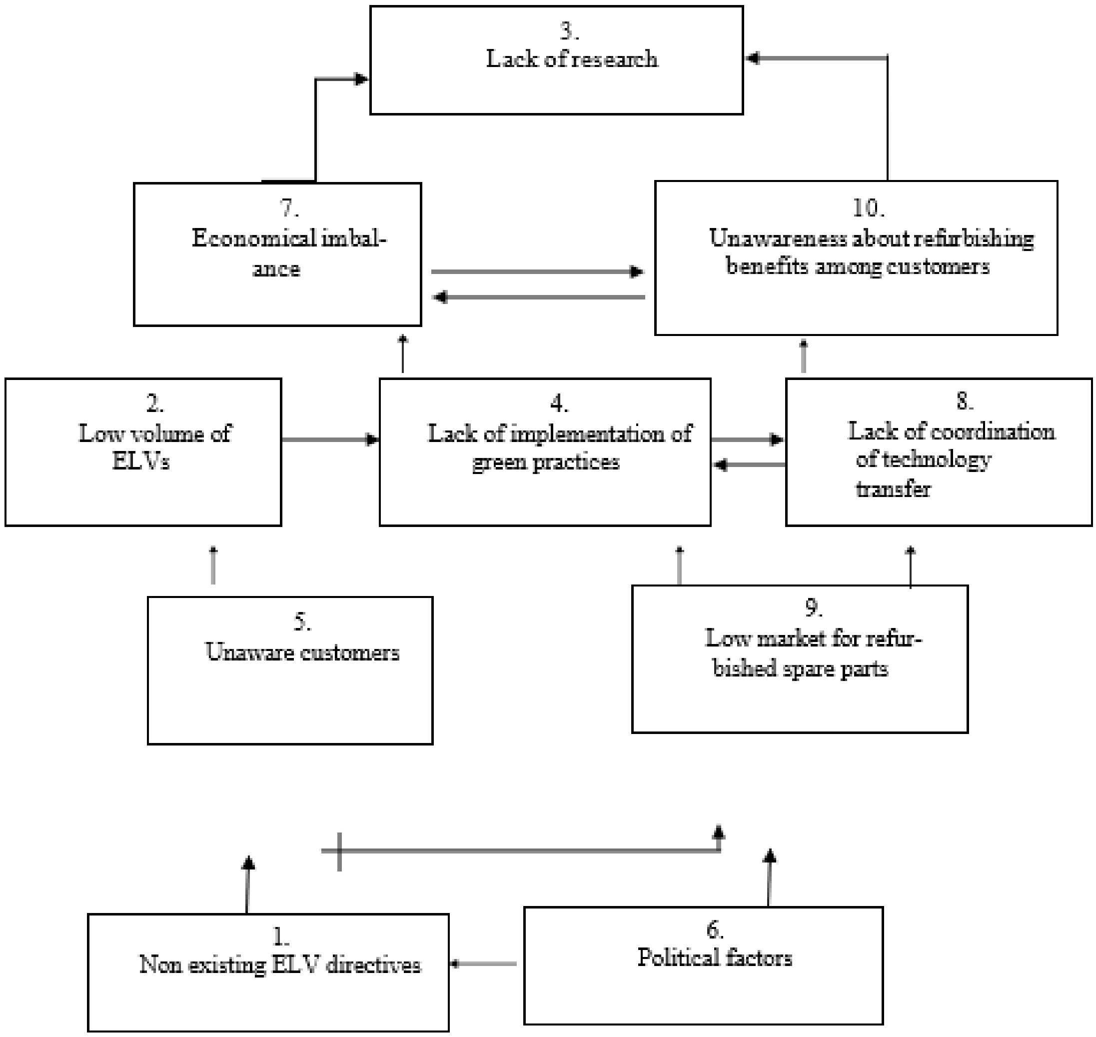

FIGURE 3
FINAL ISM MODEL FOR DFD AND REMANUFACTURING BARRIERS

The level below is also constituted by just two variables in the form of 'Unaware- ness about refurbishing benefits' (10) and 'Economic imbalance' (7). The nature of variables '7' and '10' are very similar to that of '2′, '4' and '8'; anyhow, the driving and reliance counts aren't as outrageous and in this way it performs what's needed to propel the higher layer while sufficiently reliant and subordinate enough to interface with three different factors in the adjacent level underneath. The factors with powerful connections among themselves and different levels are accommodated in the third level. 'Lack of implementation of green practices' (4), 'Lack of coordination of technology transfer' (8) and 'Low volume of ELVs' (2) acquire the Linkage and dependence region in the MICMAC graph, having nearly similar reliance and driving capacities, thereby implying a sense of direct impact on the factors with which they are associated. In the fourth level, i.e. the factors in the penultimate ground section holds 'Unaware customers' (5) and 'Low market for refurbished spare parts' (9). In spite of the fact that their driving and reliance power scores shift somewhat and they dwell in various quadrants, it is the nature wherein the two of them depend and affect other factors that assembles them jointly. The last layer (fifth) is comparable in character, having 2 factors. But because the reliance counts of these two are most reduced, they are pushed down to the levels. These are, 'Non existing ELV directives' (1) and 'Political factors' (6) with a very high driving force and least reliance power that resides isolated on the MICMAC graph. Thus, it is highlighted in the base level as it comes up short on the associations with different factors that makes it subordinate yet has enough driving capacity to impact the levels above.

7. MICMAC Analysis

The fundamental reason for the MICMAC examination is to comprehend the driving and reliance intensity of every factor inside the ISM and to distinguish key empowering agents inside the progressive system of re-manufacturing hindrances (Rana et. Al., 2019). Positioning the driving and reliance controls inside the MICMAC graph is completed by summing up the figures through each column and row of all factors listed in Table 4. Eventually, coordinates for positioning the barriers on the chart is obtained from the aggregate resulting from each row and column considered for every factor (Fig. 4).

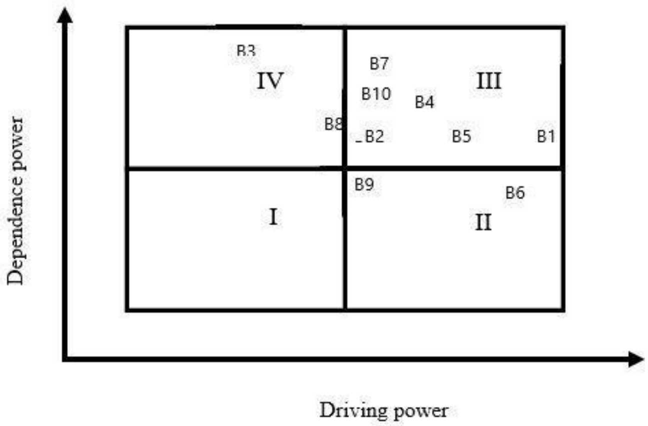

FIGURE 4
MICMAC DIAGRAM SHOWING DRIVING AND DEPENDENCE POWER

The four quadrants constituting the MICMAC graph indicate the impact of driving and reliance features involved with various connections among the factors. As a matter of fact, the quadrant in which the barrier is placed shows the degree of its capacity and reliance in comparison with other factors and how it suits in the ISM hierarchy. The four quadrants are described below, Autonomous, quadrant I – characterizes factors with feeble driving force and reliance power. They have insignificant impact or affect and keep up scarcely any connections with other factors.

Independent, quadrant II – characterizes factors having a frail reliance capacity yet strong driving force and are frequently observed as main components.

Linkage, quadrant III – characterizes factors possessing both strong driving and reliance forces. Subsequently these are considered unstable as any move made along with these factors would probably seed an equivalent response, influencing itself and other factors.

Dependent, quadrant IV – characterizes factors that have a powerful reliance capability yet feeble driving force. They are normally factors that are vigorously impacted by others.

Most of factors in the MICMAC graph lie in the top half of the diagram, specifically inside the Linkage quadrants providing an indication that a greater number of variables possess average to powerful driving force accompanied by strong reliance tendencies. The nesting around the central region shows that there are cardinal sums of factors that steer a lesser amount of more reliant factors and thereby placed in the central region of the ISM hierarchical model. All things considered, these factors, particularly those inside the Linkage quadrant pose an unstable nature. Also, any move made involving the linkage factors would result in an equivalent impact on further connecting factors. A primary trait in this sort of factors lies in their character depending on a large scale of interrelations. They will pose a chain reaction consequence and momentum to collapse related factors if at all any shortcomings between them is made. The Dependent quadrant comprises of factors which are vigorously influenced as a result of the operations made on the factors arranged in Linkage quad- rant. Since they don't possess a driving force enough to impact different factors, they are therefore arranged towards the top layer of the diagram. The Autonomous quad- rant hosts no barriers suggesting that there aren't any factors that don't have any inter- relations with other factors in the MICMAC graph. Subsequently it is reasonable to assume that all factors are associated somehow or another because of the degrees of driving and reliance capabilities that they have.

RESULTS AND DISCUSSIONS

It can be seen that drawing out a pattern for the barriers obtained from the analysis can be a confusing task which is explained further. Throughout this research, a number of expert opinions and thoughts were gathered and brainstormed at each section of development to analyse the criticality and effect of each understanding how they organize the hindrances of appropriation and on the off chance that they recognize the levels and interconnections among them. These factors were extracted from the literature and are an assortment of irrelevant hindrances from past research that didn't concentrate explicitly on their placement and interconnections. With the guide of industry explicit specialists and a top to bottom investigation of the ebb and flow literature, an endeavour to fill this exploration breach has been made with the goal of teaching and supporting automotive industries.

This investigation has various commitments to hypothesis. Firstly, this examination has incorporated every single significant investigation based on remanufacturing and Dfd backdrop, evaluated and orchestrated the literature to separate their reasons for hindrances. Secondly, this is the initial research of its sort that has investigated the obstructions of appropriation of Dfd and remanufacturing methods of automotive industry in a worldwide context and inferred its structure utilizing ISM for the factors in the unique domain. Thirdly, the MICMAC graph likewise gives the idea of factors that unmistakably distinguishes their driving and reliance powers. This will aid analysts, all the more obviously, to comprehend the idea of factors as far as them being progressively similar to an autonomous, interceding or subordinate variable. Lastly, the framework created employing ISM could help research scholars in getting to the chosen factors for exactly assessing the presented research prototype.

A good amount of factors pertaining to this concept have elevated level of driving capacity and are placed in the 'linkage quadrant' of the MICMAC graph. As an out- come, within the model, they are described by their reliance on one another and their capacity to impact different factors. The lack of research barrier poses the lowest driving power and scores the topmost grade of dependence power. So it is placed in the dependence quadrant and this suggests that it relies heavily on other factors. This is the reason why it acquires the highest position in the ISM hierarchical model diagram. This is a direct indication of the fact that much research is needed in this do- main to prove and convince the automotive counterparts across the world to rely on these principles of remanufacturing and DfD for their betterment as well as for the consumers. Without promising research, manufacturers and customers will become redundant of the various profit abilities in this context and the current scenario will continue as such leading to more serious issues in the economy and environment. It will be difficult to probe into this scenario without adequate knowledge. The outcome of these studies point out how a deficiency in proper research and studies is a leading blockade in the adoption of remanufacturing and DfD principles in the automotive industry and for what reason it is positioned at the summit of ISM hierarchical model. The second levels of barriers are the economic imbalance and consumers being una- ware of the refurbishing benefits. These two barriers have a considerable power of dependence but are the key factors which drive to lack of research. Anyway it is their lower driving force that makes the feeling of powerlessness as they depend on every other variable beneath them. Therefore these find their position in the linkage quad- rant but on a lower scale. This implies these components are unequivocally stimulated by various connected barriers inside the ISM model.

At level III and IV, lower dependent variables are placed for which the MICMAC examination recognizes elevated levels of driving force associated with nether levels of reliance power. The lack of coordination of technology transfer and lack of green practices are identified to have a significant relationship. Their inter connections as a pilot point in the ISM diagram have significant level of effect and are barriers that drive a large group of factors prompting a scope of responses because of the power they have through built up interconnections. It can be clearly seen how unaware customers are prompted to dispose of their ELVs. This leads to a sensible fact of why there is significant lack of green practices and overflow in the scrap yards. The barri- ers in these two levels are seen to have almost nearer value of dependence and driving power. So, these factors are a sort of cyclic interconnection which are bound to be constant and this is evident in most of the research literatures.

Directly linked to 'Unaware consumers' (5) and 'Low market for refurbished spare parts' (9) are 'Non existing ELV directives' (1) and 'Political factors' (6) in the V^{th} Level. The two barriers portray an elevated rate of driving and decreased dependence power that place them at a bottom region in the model diagram. These are the base factors that trigger the initial pitch or leap for a potential enterprise into adoption of DfD and remanufacturing principles. This crucial result in the ISM hierarchical model is significant as an intrinsic entity in terms of the impact it has on other related barriers. It will be difficult to convince the automotive manufacturers in this regard as they are the key drivers in manipulating the ELV directives across an area of their control. This fact when applied globally makes sense in why there are stringent ELV directives in some parts of the earth and why there are not in some economic zones. They are also responsible for the economy dependent on ELV recycling as they directly influence it with their current status of progressive production and marketing which is devoid of integrating recollected and used parts thereby declining a possible and probing market for the refurbished parts/components. This drives away the attention and awareness among consumers and they become reluctant to purchase of new parts/components. It is important and necessary to give an example by usage relating to the fact "the world leads by examples". Unless, the automobile industry probes into the remanufacturing and DfD technologies, this whole concept will remain under-mined or of lower importance.

CONCLUSION

This research indulges into the various factors affecting the adoption of design for remanufacturing principles in the automotive industry. By applying Interpretive structural modelling, a flowchart that classifies and speaks for the inter relation among each barrier has been made to aid further research on this behalf and become familiar with the factors that hinder their adoption. Based on a literature survey, certain factors were shortlisted and in consultation with experts and industrial personnel these were critically analysed to form a frame of guide. The results thus project the sensitive character of factors based on their effect and aftermath on one another, their association and their self. Rather than observing the factors of hindrance in an isolated viewport, it demonstrates the significance of scrutinizing information as a cumulative unit. The MICMAC diagram in figure 4 has been employed in graphically displaying the dependence and driving capacity of each factor after their positioning on the diagram to a particular quadrant. The arrangement of the barriers in the outcome indicates that a significant value of driving capacity is associated with most of the enablers which in turn is associated to substantial amounts of impact upon connected barriers. The barriers with the strongest range of dependency ability populate the peak levels in the ISM hierarchical diagram (Figure 3) indicating that these will be affected if, by any chance, the connected factors constituting the base levels are allowed to be manipulated stringently. This is a denotation of how top degree dependent barriers should cautiously be looked upon and manipulated if a crisis arises with high driving power barriers. Specifically, low market for the refurbished items and political factors are the primal issues which trigger the issues relating to Dfd and remanufacturing. Their inter dependency and relation is seen to be quite impacting as they truly pose high driving power as seen in the MICMAC diagram. Equally supporting is the issue of non-existence of ELV management directives which can be inferred as the outcome of political benefits on this concept. All these factors can be brought to limelight and awareness can be made by way of proper breakthrough into this alarming subject which can be only made possible through efficient research, which in turn is displayed to be the topmost positioning barrier in this ISM based research. This is a clear indication of how this barrier, of 'Lack of research', has been affected by the underlying factors to have been deteriorated pertaining to this subject. A key indication of how this process of commencing true research can be initialized is depicted in the ISM model i.e., the lack of green practices and lack of proper techno- logical applications based on treatment of ELVs. These form the central portion of the ISM hierarchy which if enkindled will have systematic and connected impact on other related barriers as this cloud up the central portion in the MICMAC analysis.

This research is only limited to a certain number of factors. Of course, there are lot of other factors and reasons necessary to study this concept as suggested by the end result of this research i.e., the need of significant research. This article can be reference to further researches in the field of re manufacturability enhancement. Also, if this article can come into the reach of some organization powerful enough to amalgamate and manipulate the directives or rules pertaining to the seriousness of ELV recycling in a particular country/state, then this would pave as a pathfinder to revolution of a new recycling technology in the automotive sector.

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