Analysis of interactions among the barriers of reverse logistics

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Abstract

The aim of this article is to analyze the interaction among the major barriers, which hinder or prevent the application of reverse logistics in automobile industries. A key task of top management is to diagnose those barriers of reverse logistics that could be crucial to the survival of the organization in the future. Existing models have focused on diagnosing these barriers independently. As a result, we lack a holistic view in understanding the barriers that hinder reverse logistics. This paper utilizes the Interpretive Structural Modeling (ISM) methodology to understand the mutual influences among the barriers so that those driving barriers, which can aggravate few more barriers and those independent barriers, which are most influenced by driving barriers are identified. By analyzing the barriers using this model, we may extract crucial barriers that hinder the reverse logistics activities. It can be observed that there are some barriers, which have both high driving power and dependency, thus needing more attention. An actual example of a small case automobile company provides some managerial insights into the methodology. Finally, the implications for practice and future research are discussed.

Keywords: Reverse logistics; Barriers; Interpretive Structural Modeling (ISM)

1. Introduction

Supply chains are undergoing radical transformations due to the mega-competition taking place on a global scale. Technological changes are becoming a primary driver in the domain of businesses.
Companies are finding that they must deal with a high level of uncertainty, which is not only technical in nature. It is being observed by companies that there is an increase in the flow of returns of the product due to product recalls, warranty returns, service returns, end-of-use returns, end-of-life returns, and so on. Reverse logistics stands for all the operations related to the reuse of used products, excess inventory of products and materials including collection, disassembly and processing of used products, product parts, and/or materials [1]. Economic, environmental or legislative reasons have also increased the relevance of reverse logistics in the present-day scenario. Many industries have adopted reverse logistics practices. Fleischmann et al. [2] review the case studies on logistics network design in different industries. Some industries have also engaged third parties for providing reverse logistics services. Krumwiede and Sheu [3] have dealt with a model for reverse logistics entry by third-party providers. Martino and Lenz [4] identify the major barriers that hinder the application of policy-relevant information, derived from analytical techniques, to practical decisions by actual decision makers. Ettlie [5] report a study of barriers, facilitators, and incentives to innovation among suppliers to the U.S. automotive industry. Veloso and Fixson [6] provide a new framework to analyze the decision of the automakers of whether to develop a new component in-house or to subcontract it to a supplier.

The concept of reverse logistics has received growing attention in the last decades, due to a number of factors. Competition and marketing motives, direct economic motives and concerns with the environment are some of the important of them. With the legislative measures tightening up, there are not many options left with the companies, but to go for reverse logistics practices. The implementation of these may be a risky endeavor for the top management as it involves financial and operational aspects, which determine the performance of the company in the long run. A critical analysis of the barriers hindering reverse logistics and their interaction with the various aspects in integrative planning can be a valuable source of information to decision makers.

The Indian automobile industry is flooded with automobile manufacturers like General Motors, Hyundai, Fiat, Honda, etc., setting up manufacturing bases in India. These industries invest a great deal of resources in terms of capital, labor, energy, and raw materials in delivering goods and services to customer. When the products complete their life cycle, an important question that remains to be answered is what would be the ultimate fate of these products. Thus, the reverse distribution of the process of bringing products from the retailer level through the distributor back to the supplier or manufacturer is an important factor, which needs consideration. The reverse logistics assumes tremendous importance in this context. Reverse logistics is extensively used in the automobile industry [7] and many other industries are following suit. However, the deployment of reverse logistics is not free from barriers. Some of these barriers are lack of systems, management inattention, financial resources, personnel resources, lesser importance of reverse logistics relative to other issues, and company policies [8]. The above-mentioned barriers not only affect the operations of reverse logistics but also influence one another. Thus, it is very essential to understand the mutual relationship among the barriers. The identification of the barriers that are at the root of some more barriers (called driving barriers) and those which are most influenced by the others (called driven barriers) would be helpful for the top management implementing the reverse logistics programs. This can be a guide for taking appropriate action to tackle barriers in reverse logistics.

Interpretive Structural Modeling (ISM) can be used for identifying and summarizing relationships among specific variables, which define a problem or an issue [9,10]. It provides us a means by which order can be imposed on the complexity of such variables [11,12]. Therefore, in this paper, the barriers of
the reverse logistics in automobile industries have been analyzed using the ISM methodology, which shows the interrelationships of the barriers and their levels. These barriers are also categorized depending on their driving power and dependence.

After review of literature on reverse logistics and the opinion of experts, both from automobile industry and the academia, 11 important barriers of reverse logistics have been identified. The literature review, together with the experts' opinion, was used in developing the relationship matrix, which is later used in the development of an ISM model.

The main objectives of this paper are:

(i) to identify and rank the barriers of reverse logistics in automobile supply chains,
(ii) to find out the interaction among identified barriers using ISM, and
(iii) to discuss the managerial implications of this research.

This paper is further organized as follows. The next section discusses the identification of barriers of reverse logistics in Indian automobile industries, which is followed by the discussion of ISM methodology. MICMAC analysis of developed ISM model is carried out subsequently. The model is subsequently applied to a decision that is being faced by a small automobile company. Finally, the results of this research are presented, which is followed by discussion and conclusion.

2. Barriers of reverse logistics

Despite the fact that practices related to reverse logistics have helped the cause of environment protection, practicing the much-needed approaches is not free from barriers. In this paper, 11 variables for barriers to the reverse logistics have been selected from the literature primarily from Ref. [8] and also from discussions with experts in the automobile industry, keeping the Indian automotive industry in focus (Table 1). These barriers are explained as follows.

2.1. Lack of information and technological systems

A very serious problem faced by the firms in the implementation of reverse logistics is the dearth of good information systems [8]. An efficient information and technological system is very necessary for supporting the reverse logistics during various stages of the product life cycle. During the product development phase, the important variables to be considered are the material content and the product structure. The type of the materials and the technology used for manufacturing determine the extent of the product recovery that is possible after the end-of-use/end-of-life of the product. Excellent information and technological systems can be very useful for the product development programs encompassing the design for the environment, recovery, reuse, and so on generally called as the Design for X (DfX). Efficient information systems are needed for individually tracking and tracing the returns of the product, linking with the previous sales. Relating the product return with a past sale can support forecasting of product returns, thus helping in the inventory management [13]. It can be very useful for the planning and control of the product recovery activities. Information support is necessary for developing linkages to achieve efficient reverse logistics operations [14]. Landers et al. [15] describe a concept of virtual warehousing where real-time information feeds expeditious algorithms to support
Table 1
Structural Self-Interaction Matrix (SSIM)

<table>
<thead>
<tr>
<th></th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
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<tbody>
<tr>
<td>1. Lack of efficient information and technological systems</td>
<td>V</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>V</td>
<td>X</td>
<td>A</td>
<td>O</td>
</tr>
<tr>
<td>2. Problems with product quality</td>
<td>V</td>
<td>A</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>V</td>
<td>V</td>
<td>V</td>
<td>V</td>
<td>V</td>
</tr>
<tr>
<td>3. Company policies</td>
<td>V</td>
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<td>A</td>
<td>0</td>
<td>A</td>
<td>V</td>
<td>V</td>
<td>V</td>
<td>V</td>
<td>V</td>
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<tr>
<td>4. Resistance to change for activities related to reverse logistics</td>
<td>V</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>X</td>
<td>V</td>
<td>V</td>
<td>V</td>
<td>V</td>
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<tr>
<td>5. Lack of appropriate performance metrics</td>
<td>A</td>
<td>O</td>
<td>A</td>
<td>A</td>
<td>O</td>
<td>O</td>
<td>O</td>
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<td>O</td>
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<tr>
<td>6. Lack of training related to reverse logistics</td>
<td>V</td>
<td>A</td>
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<td>7. Financial Constraints</td>
<td>V</td>
<td>A</td>
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<td>8. Lack of commitment by top management</td>
<td>V</td>
<td>V</td>
<td>V</td>
<td>V</td>
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<td>V</td>
<td>V</td>
<td>V</td>
<td>V</td>
<td>V</td>
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<tr>
<td>9. Lack of awareness about reverse logistics</td>
<td>V</td>
<td>V</td>
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<tr>
<td>10. Lack of strategic planning</td>
<td>V</td>
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<td>V</td>
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<td>V</td>
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<tr>
<td>11. Reluctance of the support of dealers, distributors and retailers.</td>
<td>V</td>
<td>V</td>
<td>V</td>
<td>V</td>
<td>V</td>
<td>V</td>
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<td>V</td>
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</table>

decisions for tracking component's order in the case of a closed-loop business telephones supply chain. Maslennikova and Foley [16] describe the case of Xerox where bar code labels were used to track packaging material with the aim of achieving resources preservation. Mok et al. [17] describe the use of information and new technologies to improve processes in the reverse chain for the situation where products and equipment need to be disassembled. Very few Indian firms have successfully automated the information surrounding the returns process. There is a dearth of good reverse logistics information management systems commercially available [8]. Thus, this is a very significant barrier affecting good reverse logistics.

2.2. Problems with product quality

Another important barrier affecting reverse logistics is the condition of the quality of the end-of-use/end-of-life returned products. The product quality is not uniform in reverse logistics compared to the forward logistics where the product quality is uniform [18]. Thierry et al. [7] opine that the overall quality targets for remanufactured/recycled products must be, at the least, equivalent to the virgin products. Customers usually expect the same level of quality of product from the manufacturer regardless of the nature of the returned product. Rudi et al. [19] describe the product recovery at the Norwegian national insurance administration where the Technical Aid Centers (TACs) had the task of distributing and servicing the wheelchairs, hearing aids, and speech synthesizers where depending upon the product quality, the TACs reused some units, repaired others, and refurbished still others. When the returned products arrive at the distribution center, a decision must be made for its disposition. Gatekeeping, which is a process of screening of the defective and unwarranted returned products at the
entry point into the reverse logistics, is a very critical factor in realizing the entire reverse flow manageable and profitable. The returned product quality could be in any range; like that it could be faulty, damaged, or simply unwanted by the customer. Thus, there could be variations in the pricing of the products. The prices of the products in the forward channel could vary due to a lot of the factors like the quantity of the products purchased. The quality of the returned products is inspected by gatekeeping and a decision is then made to the disposition of the product. Thus, in the case of the returned product, the pricing can be more difficult compared to the forward logistics.

2.3. Company policies

Restrictive company policies are an important barrier to the reverse logistics [8]. The lack of the importance of the reverse logistics and the management inattention are related to the policies followed by the companies. Companies want to create a brand image to the customers. They do not want to compromise on the end-product quality by using the returned products. Thus, the policies developed by companies of producing only virgin products also have a major effect of not handling the returned products and to recover the hidden secondary value from the returns. Due to the advent of extended producer responsibility [20], many companies have started to integrate the recovery options for the products into their supply chain. There seems to be a paradigm shift by the companies to change their rigid policies to incorporate the returns of the product to recover value economically that could give them edge over their competitors.

2.4. Resistance to change to reverse logistics

A chief barrier seen in the implementation of the reverse logistics is the resistance to change, human nature being a fundamental barrier. People avoid change when possible, and the reverse logistics require a radical change in the mindset and practice. Resistance to change can also be caused especially in the case for small business with limited purchasing power to influence contracts with suppliers [21]. The company policies and organizational structures get in the way rather than facilitate change. The absence of a clear reverse logistics vision further accelerates the problem. With increased competition in the market and shrinked profit margin, companies are increasingly interested in savings with the recovery of the used products. Most importantly, the adoption of the reverse logistics practices results in direct benefits to the environment. The lack of awareness of the benefits of the reverse logistics both from economic and environment angles could be a major factor for the resistance to change to reverse logistics. Reverse logistics systems initially involve high economic investment. Financial constraints could also lead to resistance to change to reverse logistics.

2.5. Lack of appropriate performance metrics

Lack of performance metrics is a major barrier to the reverse logistics programs. One of the barriers for supply chain alignment is lack of appropriate performance metrics [22]. Performance metrics form the basis of integrated work management systems. Simply stated, “Work not measured cannot be managed.” The performance measurement of any system is a key element in enabling the process of performance management, performance improvement, performance documentation, etc. If the firms take action linking their performance measurement system to their reverse logistics practices, they will be in a
better position to succeed in their endeavor. Successful reverse logistics programs will effectively coordinate all the processes, focus on recapturing value or proper disposal of products, create environmental friendly products, and create performance measurement systems that provide data as to whether the designed reverse logistics is performing up to the expectations.

2.6. Lack of training and education

A significant barrier to good reverse logistics is lack of personnel resources [8]. Lack of training and education is a major challenge to commercial cycling [23]. Education and training are prime requirements for achieving success in any organization. The need for training on reverse logistics extends throughout the company and reaches up and downstream. New or revamped technology necessitates change and the personnel should be given adequate training in the new technology and processes that will be implemented. The training should be provided in critical business functions like product development, customer account management, etc., so as which gives rise to new development opportunities to improve integration of environmental issues.

2.7. Financial constraints

Financial constraints are a key barrier to good reverse logistics programs [8]. Cost considerations are a prime challenge in commercial recycling [23]. Finance is essential to support the infrastructure and manpower requirements of the reverse logistics. Companies require allocation of funds and other resources for the implementation of reverse logistics. Efficient information and technological systems are significant enabler for reverse logistics. Information and technological systems require more funds because without these, the returns product tracking and tracing and product recovery by various process like reuse, remanufacturing, recycling, etc. is not possible in the present environment. The training of personnel related to the reverse logistics is also very important for efficiently managing and eventually making the reverse logistics profitable. However, all these require financial support.

2.8. Lack of commitment by top management

Lack of commitment by top management is a chief barrier for successful reverse logistics [8]. Mintzberg [24] states that top management commitment is the dominant driver of corporate endeavors. A major challenge seen in commercial recycling is the lack of commitment by top management [23]. Efficient leadership is needed to provide clear vision and value to reverse logistics programs. The top management should demonstrate commitment to the reverse logistics activities on par with other organizational goals by integrating all the members of the supply chain. They should provide continuous support for reverse logistics in the strategic plans, action plans for successfully implementing them.

2.9. Lack of awareness about reverse logistics

A chief barrier of reverse logistics seen in Indian automobile supply chain is lack of awareness about the benefits of reverse logistics. Even if companies knew about it, giving relative unimportance to reverse logistics was seen as the largest barrier to reverse logistics [8]. Firms are finding in a
position irrespective of whatever industry they are, whether automobile, food processing, or paper industry, there is an increasing case of product recalls. Today, many consumer products have a shorter life cycle. While the customers have the benefits of greater product variety, it has resulted in an increase in unsold products, rate of returns, packing materials, and also the waste [25]. This has given rise to increase in the volume of product returns in the form of reverse logistics. Therefore, the management of parts or product coming back into the supply chain network from its outbound side is a matter of concern for many industries [26]. The reverse logistics can lead to economic benefits by the recovery of the returned products for reuse, remanufacturing, recycling, or a combination of these options for adding value to the product. The implementation of the reverse logistics leads to direct benefits to the environment, too. Thus, the lack of the awareness of these benefits is a major barrier to reverse logistics.

2.10. Lack of strategic planning

More than ever before, the economy and e-commerce are demanding that companies make reverse logistics part of their strategic planning arsenal [27]. Reverse logistics can be used as a strategic weapon in the present industrial environment [8]. Strategic planning is the identification of reverse logistics goals and the specification of long-term plans for managing them. It involves the attempt on the part of the manager on the course of action that has to be adopted for the realization of reverse logistics. In the present scenario, due to the rapid changes in technology and also due to changes in the behaviors of competitors, consumers, suppliers, etc., a sound strategic planning is necessitated for the reverse logistics programs. For implementation of reverse logistics in any organization, the role of strategic planning is very important to achieve the goals for the survival of the organization in the global market.

2.11. Reluctance of the support of dealers, distributors, and retailers

Another important barrier to the reverse logistics is the reluctance of the support of the dealers, distributors, and retailers towards the reverse logistics activities. A generous return policy leads to improved risk sharing between sellers and consumers. The liberal returns policy can lead to the consumers returning the product in any form to the retailers. The liberal returns policy occasionally turns into Return abuse policies [8].

3. ISM methodology and model development

The methodology of ISM is an interactive learning process. In this a set of different and directly related variables affecting the system under consideration is structured into a comprehensive systemic model. The beauty of the ISM model is that it portrays the structure of a complex issue of the problem under study, in a carefully designed pattern employing graphics as well as words. The methodology of ISM can act as a tool for imposing order and direction on the complexity of relationships among elements of a system [10,28]. Saxena et al. [29] applied the ISM methodology to the case of Energy Conservation in Indian Cement Industry and identified the key variables using direct as well as indirect interrelationships amongst the variables. Sharma et al. [30] have employed ISM methodology to develop
a hierarchy of actions required to achieve the future objective of waste management in India. Mandal and Deshmukh [11] used the ISM methodology to analyze some of the important vendor selection criteria and have shown the inter-relationships of criteria and their levels. These criteria have also been categorized depending on their driver power and dependence. A number of barriers exist in the practice of reverse logistics in automobile industry. An examination of the direct and indirect relationships between the barriers of the reverse logistics can give a clearer picture of the situation than considering individual factors alone in isolation. The ISM can be judiciously employed for getting better insights into the system under consideration.

The ISM methodology is interpretive from the fact that as the judgment of the group decides whether and how the variables are related. It is structural too, as on the basis of relationship; an overall structure is extracted from the complex set of variables. It is a modeling technique in which the specific relationships of the variables and the overall structure of the system under consideration are portrayed in a digraph model. ISM is primarily intended as a group learning process, but it can also be used individually. The various steps involved in the ISM methodology are as follows:

**Step 1:** Variables affecting the system under consideration are listed, which can be Objectives, Actions, and Individuals etc.

**Step 2:** From the variables identified in step 1, a contextual relationship is established among variables with respect to which pairs of variables would be examined.

**Step 3:** A Structural Self-Interaction Matrix (SSIM) is developed for variables, which indicates pairwise relationships among variables of the system under consideration.

**Step 4:** Reachability matrix is developed from the SSIM and the matrix is checked for transitivity. The transitivity of the contextual relation is a basic assumption made in ISM. It states that if a variable A is related to B and B is related to C, then A is necessarily related to C.

**Step 5:** The reachability matrix obtained in Step 4 is partitioned into different levels.

**Step 6:** Based on the relationships given above in the reachability matrix, a directed graph is drawn and the transitive links are removed.

**Step 7:** The resultant digraph is converted into an ISM, by replacing variable nodes with statements.

**Step 8:** The ISM model developed in Step 7 is reviewed to check for conceptual inconsistency and necessary modifications are made.

These steps of ISM modeling are illustrated in Fig. 1.

### 3.1. Structural Self-Interaction Matrix

ISM methodology suggests the use of the expert opinions based on various management techniques such as brain storming, nominal technique, etc., in developing the contextual relationship among the variables. Thus, in this research for identifying the contextual relationship among the barriers of the reverse logistics, two experts, one each from the automobile industry and the academia, were consulted for the same. These experts from the industry and academia were well conversant with reverse logistics practices in the automobile industry having an experience of over 10 years. For analyzing the barriers of the reverse logistics variables, a contextual relationship of “leads to” type is chosen. This means that one variable leads to another variable. Based on this, contextual relationship between the variables is developed.
Keeping in mind the contextual relationship for each variable, the existence of a relation between any two barriers (i and j) and the associated direction of the relation is questioned. Four symbols are used to denote the direction of relationship between the barriers (i and j):

- **V**: Barrier *i* will help alleviate Barrier *j*;
- **A**: Barrier *j* will be alleviated by Barrier *i*;
X: Barriers $i$ and $j$ will help achieve each other; and
O: Barriers $i$ and $j$ are unrelated.

The following would explain the use of the symbols V, A, X, and O in SSIM (Table 1).

(i) Barrier 8 helps alleviate Barrier 10. This means that as efforts are made to plug the gap in the top management commitment towards the reverse logistics practices, effectiveness of strategic planning improves. Thus, the relationship between Barriers 8 and 10 is denoted by $V$ in the SSIM (Table 1).

(ii) Barrier 8 can be alleviated by Barrier 9, i.e. removal of Barrier 9, namely, lack of awareness about reverse logistics would help alleviate Barrier 8 (i.e. lack of commitment by top management). Awareness about the various benefits of reverse logistics would promote the top management commitment for implementing reverse logistics programs. Thus, the relationship between these barriers is denoted by $A^T$ in the SSIM (Table 1).

(iii) Barriers 4 and 6 help achieve each other. Barrier 4, namely, resistance to change for activities related to reverse logistics, and Barrier 6, namely, lack of training related to reverse logistics help achieve each other. Thus, the relationship between these barriers is denoted by $X^T$ in the SSIM (Table 1).

(iv) No relationship exists between lack of appropriate performance metrics (Barrier 5) and financial constraints (Barrier 7) and hence the relationship between these barriers is denoted by $O^T$ in the SSIM (Table 1).

| Table 2
Initial reachability matrix |
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Barriers</strong></td>
</tr>
<tr>
<td>1. Lack of efficient information and technological systems</td>
</tr>
<tr>
<td>2. Problems with product quality</td>
</tr>
<tr>
<td>3. Company policies</td>
</tr>
<tr>
<td>4. Resistance to change for activities related to reverse logistics</td>
</tr>
<tr>
<td>5. Lack of appropriate performance metrics</td>
</tr>
<tr>
<td>6. Lack of training related to reverse logistics</td>
</tr>
<tr>
<td>7. Financial Constraints</td>
</tr>
<tr>
<td>8. Lack of commitment by top management</td>
</tr>
<tr>
<td>9. Lack of awareness about reverse logistics</td>
</tr>
<tr>
<td>10. Lack of strategic planning</td>
</tr>
<tr>
<td>11. Reluctance of the support of dealers, distributors and retailers.</td>
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</tbody>
</table>
Based on similar contextual relationships, the SSIM is developed for all the 11 barriers identified for the reverse logistics (Table 1).

3.2. Reachability matrix

The SSIM is transformed into a binary matrix, called the initial reachability matrix by substituting V, A, X, O by 1 and 0 as per the case. The rules for the substitution of 1's and 0's are the following:

1. If the \((i,j)\) entry in the SSIM is V, then the \((i,j)\) entry in the reachability matrix becomes 1 and the \((j,i)\) entry becomes 0.
2. If the \((i,j)\) entry in the SSIM is A, then the \((i,j)\) entry in the reachability matrix becomes 0 and the \((j,i)\) entry becomes 1.
3. If the \((i,j)\) entry in the SSIM is X, then the \((i,j)\) entry in the reachability matrix becomes 1 and the \((j,i)\) entry also becomes 1.
4. If the \((i,j)\) entry in the SSIM is O, then the \((i,j)\) entry in the reachability matrix becomes 0 and the \((j,i)\) entry also becomes 0.

Following these rules, initial reachability matrix for the barriers is shown in Table 2.

<table>
<thead>
<tr>
<th></th>
<th>Barriers</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
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<th>11</th>
<th>Driver</th>
<th>Power</th>
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<td>0</td>
<td>0</td>
<td>1</td>
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<td>1</td>
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<td>0</td>
<td>0</td>
<td>1</td>
<td>5</td>
<td></td>
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<tr>
<td>2</td>
<td>Problems with product quality</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<td>Company policies</td>
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<tr>
<td>4</td>
<td>Resistance to change for activities related to reverse logistics</td>
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<td>0</td>
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<tr>
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<td>Lack of training related to reverse logistics</td>
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<td>7</td>
<td>Financial Constraints</td>
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<td>0</td>
<td>1</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Lack of commitment by top management</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Lack of awareness about reverse logistics</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Lack of strategic planning</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Reluctance of the support of dealers, distributors and retailers.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

**Table 3**

Final reachability matrix
The final reachability matrix is obtained by incorporating the transistivities as enumerated in Step 4 of the ISM methodology. This is shown in Table 3. In this table, the driving power and dependence of each barrier are also shown. The driving power of a particular barrier is the total number of barriers (including itself) which it may help achieve. The dependence is the total number of barriers which may help achieving it. These driving power and dependencies will be used in the MICMAC analysis, where the barriers will be classified into four groups of autonomous, dependent, linkage, and independent (driver) barriers.

### 3.3. Level partitions

The reachability and antecedent set [9] for each barrier is found out from final reachability matrix. The reachability set for a particular variable consists of the variable itself and the other variables, which it may help achieve. The antecedent set consists of the variable itself and the other variables, which may help in achieving them. Subsequently, the intersection of these sets is derived for all variables. The variable for which the reachability and the intersection sets are the same is given the top-level variable in the ISM hierarchy, which would not help achieve any other variable above their own level. After the identification of the top-level element, it is discarded from the other remaining
Table 6
Iteration 3

<table>
<thead>
<tr>
<th>Barrier</th>
<th>Reachability set</th>
<th>Antecedent set</th>
<th>Intersection set</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3, 4, 6</td>
<td>1, 2, 3, 4, 6, 7, 8, 9, 10</td>
<td>1, 4, 6</td>
<td>III</td>
</tr>
<tr>
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<td>1, 2, 3, 4, 6</td>
<td>2, 3, 7, 8, 9, 10</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1, 3, 4, 6</td>
<td>1, 2, 3, 4, 6, 7, 8, 9, 10</td>
<td>1, 4, 6</td>
<td>III</td>
</tr>
<tr>
<td>4</td>
<td>3, 4, 6</td>
<td>1, 2, 3, 4, 6, 7, 8, 9, 10</td>
<td>1, 4, 6</td>
<td>III</td>
</tr>
<tr>
<td>5</td>
<td>3, 4, 6</td>
<td>1, 2, 3, 4, 6, 7, 8, 9, 10</td>
<td>1, 4, 6</td>
<td>III</td>
</tr>
<tr>
<td>6</td>
<td>1, 3, 4, 6, 7</td>
<td>7, 8, 9, 10</td>
<td>7</td>
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</tr>
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<td>1, 2, 3, 4, 6, 7, 8, 9, 10</td>
<td>9</td>
<td>9</td>
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</tr>
<tr>
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<td>1, 2, 3, 4, 6, 7, 8, 9, 10</td>
<td>8, 9, 10</td>
<td>10</td>
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</tr>
</tbody>
</table>

variables. From Table 4, it is seen that lack of performance metrics (Barrier 5) is found at Level I. Thus, it would be positioned at the top of the ISM model. This iteration is continued till the levels of each variable are found out. The identified levels aids in building the digraph and the final model of ISM. The barriers, along with their reachability set, antecedent set, intersection set and the levels, are shown in Tables 4-10.

3.4. Formation of ISM-based model

From the final reachability matrix, the structural model is generated. If the relationship exists between the Barriers \( j \) and \( i \), an arrow pointing from \( i \) to \( j \) shows this. This resulting graph is called a digraph. Removing the transitivities as described in the ISM methodology, the digraph is finally converted into the ISM model as shown in Fig. 3.

It is observed from Fig. 3 that lack of awareness of reverse logistics (Barrier 9) is a very significant barrier for the reverse logistics in the Indian automobile industries as it comes as the base of the ISM hierarchy. Lack of appropriate performance metrics (Barrier 5) is the reverse logistics barrier on which the effectiveness of the reverse logistics depends. This barrier has appeared at the top of the hierarchy.

The lack of awareness about reverse logistics (Barrier 9) leads to the lack of commitment by the top management towards the reverse logistics activities (Barrier 8), which results in lack of strategic planning pertaining to reverse logistics activities (Barrier 10). A good strategic planning should be in place before allocating finance related to reverse logistics (Barrier 7) as otherwise it may lead to problems with product quality (Barrier 2) which would be counter to the objectives of green supply

Table 7
Iteration 4

<table>
<thead>
<tr>
<th>Barrier</th>
<th>Reachability set</th>
<th>Antecedent set</th>
<th>Intersection set</th>
<th>Level</th>
</tr>
</thead>
<tbody>
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<td>2, 3</td>
<td>2, 8, 9, 10</td>
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</tr>
<tr>
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<td>9</td>
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<td>2, 3, 7, 10</td>
<td>8, 9, 10, 10</td>
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</tr>
</tbody>
</table>
chain. Financial constraints (Barrier 7) force restrictive company policies as the reverse logistics systems involve high investment, which small firms cannot afford. Problems with product quality (Barrier 2) would lead to rigid company policies (Barrier 3) as the companies, in order to keep up their brand image in the market, would be producing new products for attaining customer satisfaction. This could result into resistance to change in the practices of reverse logistics (Barrier 4). Thus, awareness about reverse logistics must be created at the grass roots level and should be disseminated to all the partners of the supply chain such that effective reverse logistics practices can be implemented.

Lack of information and technological systems (Barrier 1) and resistance to change to reverse logistics (Barrier 4) are interrelated. Good information and technological systems are very essential for successful reverse logistics programs. Lack of these would cause a resistance to change by people, as the required technologies are not available. The resistance to change related to reverse logistics would further result in lack of procurement of information and technological systems for reverse logistics. Resistance to change during implementation of reverse logistics activities (Barrier 4) would have a negative impact on the outcomes of training and education on these issues (Barrier 6). This would also result in reluctance to gain support from the dealers, distributors, and retailers (Barrier 11). Without this support, it would be difficult to evolve and implement performance metrics related to reverse logistics (Barrier 5).

4. MICMAC analysis

The objective of the MICMAC analysis is to analyze the driver power and the dependence power of the variables [11]. The variables are classified into four clusters (Fig. 2). The first cluster consists of the autonomous barriers that have weak driver power and weak dependence. These barriers are relatively disconnected from the system, with which they have only few links, which may be strong. Second cluster consists of the dependent barriers that have weak driver power but strong dependence. Third cluster has the linkage barriers that have strong driving power and also strong dependence. These barriers are unstable in the fact that any action on these barriers will have an effect on others and also a
feedback on themselves. Fourth cluster includes the independent barriers having strong driving power but weak dependence. It is observed that a variable with a very strong driving power called the key variables, falls into the category of independent or linkage barriers. The driving power and the dependence of each of these barriers are shown in Table 3. In this table, an entry of 1' along the columns and rows indicates the dependence and driving power, respectively. Subsequently, the driver power-dependence diagram is constructed which is shown in Fig. 2. As an illustration, it is observed from Table 3 that Barrier 7 is having a driver power of 7 and a dependence of 4. Therefore, in this figure, it is positioned at a place corresponding to a driver power of 7 and a dependency of 4.

5. A small company example

The ISM model presented here has been evaluated in an actual automobile company that was interested in implementing reverse logistics. Due to limited budget, the company wanted a systematic
Lack of appropriate performance metrics

Reluctance of dealers, distributors, and retailers

Lack of information and technological systems

Resistance to change to reverse logistics

Lack of training and education

Company policies

Problems with product quality

Financial constraints

Lack of strategic planning

Lack of commitment by top management

Lack of awareness about reverse logistics

Fig. 3. ISM-based model for the barriers of reverse logistics.

way of analyzing the interaction of barriers that hinder implementation of reverse logistics. This case experience allows us to see the benefits of the model in a practical setting.

6. Discussion and conclusion

The barriers hindering the reverse logistics programs pose considerable challenges both for managers and policymakers in industries. Some of the major barriers have been highlighted here and put into an ISM model, to analyze the interaction between the barriers. These barriers need to be overcome for the success in reverse logistics programs. The driver-dependence diagram gives some valuable insights about the relative importance and the interdependencies among the barriers. This can give better insights
to the top management so that they can proactively deal with these barriers. Some of the observations from the ISM model, which give important managerial implications, are discussed below.

Lack of the awareness of reverse logistics practices is a very significant barrier. From the ISM model, it is observed that strategic management issues like lack of awareness of reverse logistics and lack of commitment by top management are at the bottom level of the hierarchy implying higher driving power. Therefore, top management should focus on developing strategies to create awareness about the use of reverse logistics so that the benefits of it can be reaped.

There are no autonomous barriers seen in the driver-dependence diagram (Fig. 2). The absence of these barriers brings light to the fact that all the considered barriers influence the reverse logistics in the automobile supply chain. It is also observed that lack of performance metrics, reluctance of support by supply chain partners, lack of information and technological systems, resistance to change during deployment of reverse logistics practices, lack of training, and unconcerned company policies are weak drivers but strongly dependent on other barriers such as lack of awareness, lack of commitment, lack of strategic planning, quality problems, and financial constraints. The management should place a high priority in tackling the barriers, which have a high driving power and thus possessing the capability to influence other barriers, which are shown at the upper level of the ISM (Fig. 3). No barrier is found under the linkage element category possessing a strong driving power along with strong dependence. Therefore, among all the 11 selected barriers of reverse logistics, no barrier is unstable.

It is also observed from the ISM model that five barriers, namely, lack of awareness of reverse logistics, lack of commitment by the top management, problems with product quality, lack of strategic planning, and financial constraints have strong driver power and therefore, these are less dependent on the other barriers. Thus, it can be inferred that these are strong drivers and may be treated as the root cause of remaining barriers. To manage these barriers, a comprehensive strategic plan for reverse logistics should be initiated to achieve success. The decision maker, in this small company example, could potentially target the barriers hindering reverse logistics so that the desired objectives could be met.

Despite the fact that the ISM model developed in this research is for the barriers prominently seen in the automobile companies, some generalization of results are still possible. The corporate environment is fast moving towards an environment-conscious supply chain and reverse logistics is an obvious candidate for being managed better. Thus, the identification of the barriers affecting the implementation of reverse logistics in any supply chain assumes great importance. This can aid the top management in deciding the priority so that it can proactively take steps in combating these barriers. The barriers identified in the ISM model are quite generic and, with marginal adjustments, can be used for many other supply chains.

Thus, the ISM-based model proposed in this paper for identification of barriers of reverse logistics can provide the decision maker a more realistic representation of the problem in the course of conducting reverse logistics. A major contribution of this research lies in the development of linkages among various barriers of a reverse logistics through a single systemic framework. The utility of the proposed ISM methodology in imposing order and direction on the complexity of relationships among elements of a system assumes tremendous value to the decision makers.

At the end, we examine the scope of further research. In this research, using the ISM methodology, a relationship model among the barriers of reverse logistics in Indian automobile industries has been developed. But this model has not been statistically validated. Structural equation modeling (SEM), also referred to as linear structural relationship approach, has the capability of testing the validity of such hypothetical models. Thus, this approach can be applied in the future research to test the validity of this
model. It is worth mentioning here that while comparing ISM and SEM, although SEM has the capability of statistically testing an already developed theoretical model, it cannot develop an initial model for testing. ISM, on the other hand, has the capability to develop an initial model through managerial techniques such as brainstorming, nominal group techniques, etc. In this sense, ISM is a supportive analytic tool for the discussed situation.

References


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