ANALYSIS OF BARRIERS TO ENVIRONMENTAL SUPPLY CHAIN MANAGEMENT

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Abstract.

Environment friendly supply chain is now the need of hour. However, some barriers adversely impact the process of Environmental Supply Chain Management. Many authors have contributed to the identification of these barriers. Some of these barriers are independent of each other but some other barriers influence each other also in a varying manner. The aim of this paper is to understand the interrelationship of these barriers so that those barriers which are more powerful and influence other barriers too are given adequate attention by the management. It will help in making the supply chains more environments friendly. On the basis of literature review relevant barriers have been identified. Interpretive Structural Modeling (ISM) is a methodology in social science research to investigate the relationship among various causes of a problem. This methodology has been used to evolve the mutual relationships among these barriers. Some barriers are found to be more influential with a very high driving power. These barriers need greater attention from the management. The study concludes with more discussion on this issue, managerial implications, and scope of future research.

Keywords: *Environmental Supply Chain, Green Supply Chain, Barriers, Interpretive structural modelling*

INTRODUCTION

Environmental supply chain management (also commonly known as green supply chain management) is receiving significant attention in industries in the past two-three decades. Many companies have taken initiatives to implement green supply chain management. The governments are also laying great emphasis on the need of green or environment friendly supply chain. However, there are certain barriers across the sectors / nations to the environmental supply chain management. Therefore, the efforts towards green supply chain management have given varied results across the industry sectors and the countries. It is also observed that the barriers to environmental supply chain are not equally impacting the process of making the supply chain environment friendly. Some of the barriers have greater impact on the objective of making the supply chain environment friendly however, some other have less level of impact. It is therefore important to identify those barriers which significantly influence the success of environmental supply chain management compared to other barriers. A research on these barriers may give some valuable findings which may help the managers to achieve a higher success rate in making the supply chain environment friendly. Accordingly, many researches have been carried out in past few decades to identify and analyze these barriers. On the other hand some researchers have instead of finding barriers have focused on the drivers of green supply chain management. In any case these barriers or drivers not only affect the process of making the supply chain environment friendly they may also influence each other. It is therefore important to understand their mutual relationships so that those barriers which are at the root of some more barriers (hereinafter called driving barriers) and those which are most influenced by the others (hereinafter called driven barriers) are identified. Thereafter, it is prudent for the management to accord appropriate attention to these barriers which may result in environment friendly supply chains.

Interpretive Structural Modeling (ISM) is a well-established methodology for identifying relationships among specific items, which define a problem or an issue (Sage, 1977). Therefore, in this research, the barriers have been analyzed using the ISM approach, which shows the interrelationships of the factors, their driving power, and dependencies.

In this study, nine barriers have been identified from the literature and subjected to analysis for interrelationships. In accordance with the standard ISM methodology, experts' opinion was sought in developing the relationship matrix, which is later used in the development of ISM model. Three experts from industry who were part of the supply chain functions in their respective organizations were consulted in developing the interrelationship matrix.

The main objectives of this paper are:

(i) to identify the main barriers in green supply chain management,
(ii) to establish relationships among the identified barriers using ISM, and
(iii) to discuss the managerial implications of this research and suggest directions for future research.

The remainder of this paper has been organized as follows. The next section discusses the identification of barriers. This is followed by the use of ISM methodology. The results of this research are followed by the discussion and conclusion.

BARRIERS IN ENVIRONMENTAL SUPPLY CHAINS

Several authors (Walker et al., 2008 etc.) have attempted to identify the drivers and barriers to environmental supply chain management. Walker et al. (2008) have grouped the barriers in two categories: internal and external barriers. They put costs of environmental supply chain and lack of legitimacy lie in the category of major internal barriers. They reported that many a times companies do not change practices for green supply chain but merely advertise that they do, this is known as lack of legitimacy. Among the external barriers they included: poor supplier commitments, industry specific barriers, and regulations. Zhu and Sarkis (2006) have highlighted the industry specific barriers. These barriers apply to certain industries and vary from industry to industry. For example lack of raw materials in one industry may be referred to as one industry specific barrier. Sarkis (2009) has identified the importance of top management support and commitment in green supply chains.

AlKhidir and Zailani (2009) have stressed on the need of technology in sustainable supply chains. Lack of knowledge and training (Bowen et al/, 2001) and lack of experience (Yu and Hui, 2008) are also the important barriers in environmental supply chains. The desire of customers for low price (Orsato, 2006) and the magnitude of demand (Sarkar and Mohapatra, 2006) are also the important factors in green SCM. Prior to the work reported in this paper Balasubramanian (2012) and Luthra et al. (2011) have analyzed the barriers to green supply chain management in construction and auto sector respectively. On the basis of literature and opinion of three experts from the industry nine most relevant barriers were identified and used in this study. These barriers are given in Table 1.

Table 1
Identified barriers for this study

S. No.	Barriers to Environmental Supply Chain Management
1.	Costs (Additional cost due to green SCM)
2.	Lack of legitimacy
3.	Regulations
4.	Poor supplier commitment
5.	Industry specific barriers e.g. lack of resources
6.	Lack of corporate leadership and support
7.	Lack of knowledge and experience
8.	Resistance to technology adoption
9.	Lack of demand and public awareness

ISM METHODOLOGY AND MODEL DEVELOPMENT

ISM has been used to achieve the research objectives of this paper. ISM methodology helps to impose order and direction on the complexity of relationships among elements of a system (Sage, 1977). For complex problems, like the one under consideration, a number of barriers may be affecting the environmental supply chain management. However, the direct and indirect relationships among these barriers describe the situation far more accurately than the individual barrier taken into isolation. Therefore, ISM develops insights into collective understandings of these relationships. The various steps involved in the ISM technique are explained by Jharkharia and Shankar (2005). These steps are:

(i) Identification of elements, which are relevant to the problem or issues; this could be done by survey or any group problem solving technique,
(ii) Establishing a contextual relationship between elements with respect to which pairs of elements would be examined,
(iii) Developing a structural self-interaction matrix (SSIM) of elements, which indicates pair-wise relationship between elements of the system,
(iv) Developing a reachability matrix from the SSIM, and checking the matrix for

transitivity. Transitivity of the contextual relation is a basic assumption in ISM which states that if element A is related to B and B is related to C, then A is necessarily related to C,

(v) Partitioning of the reachability matrix into different levels,

(vi) Based on the relationships given above in the reachability matrix draw a directed graph (DIGRAPH), and remove the transitive links,

(vii) Convert the resultant digraph into an ISM-based model, by replacing element nodes with the statements,

(viii) Review the model to check for the conceptual inconsistency, and make the necessary modifications.

The above steps, which lead to the development of ISM model, are illustrated as under. The application of ISM methodology in this paper is in line with that used by Jharkharia and Shankar (2005).

Formation of structural self-interaction matrix (SSIM)

ISM methodology suggests the use of expert opinions (based on management techniques such as brain storming, nominal group technique etc) in developing the contextual relationship. Three experts from different organizations, who were part of the supply chain functions in their respective organizations, were separately consulted in identifying the nature of contextual relationships among the identified barriers listed in Table I. The author acted as a moderator in finalizing the relationship among these factors. For analyzing the factors in developing SSIM, the following four symbols have been used to denote the direction of relationship between factors (i and j):

V- Factor i will help achieve factor j;
A- Factor j will be achieved by factor i;
X- Factors i and j will help achieve each other; and
O- Factors i and j are unrelated.

The following statements explain the use of symbols V, A, X and O in SSIM.

(i) Barriers 1 and 7 are unrelated (O)

(ii) Barrier 4 helps achieve barrier 8 (V)

(iii) Barrier 2 will be achieved by barrier 6 (A)

Based on these contextual relationships the SSIM is developed (Table II)

Table 2

Structural self-interaction matrix (SSIM)

Critical Failure Factors	9	8	7	6	5	4	3	2
1. Costs	A	X	O	A	A	A	A	V
2. Lack of legitimacy	A	X	A	A	A	A	A	
3. Regulations	A	A	A	A	A	A		
4. Poor supplier commitment	A	V	O	A	X			
5. Industry specific barriers e.g. lack of resources	A	O	O	O				
6. Lack of corporate leadership and support	A	V	X					
7. Lack of knowledge and experience	A	V						
8. Resistance to technology adoption	A							

Reachability Matrix

The SSIM has been converted into a binary matrix, called the initial reachability matrix (Table III) by substituting V, A, X and O by 1 and 0 as per the following rules:

(i) if the (i, j) entry in the SSIM is V, the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry becomes 0,
(ii) if the (i, j) entry in the SSIM is A, the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry becomes 1,
(iii) if the (i, j) entry in the SSIM is X, the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry also becomes 1,
(iv) if the (i, j) entry in the SSIM is 0, the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry also becomes 0.

Table 3
Initial reachability matrix

Factors	1	2	3	4	5	6	7	8	9

1. Costs	1	1	0	0	0	0	0	1	0
2. Lack of legitimacy	0	1	0	0	0	0	0	1	0
3. Regulations	1	1	1	0	0	0	0	0	0
4. Poor supplier commitment	1	1	1	1	1	0	0	1	0
5. Industry specific barriers e.g. lack of resources	1	1	1	1	1	0	0	0	0
6. Lack of corporate leadership and support	1	1	1	1	0	1	1	1	0
7. Lack of knowledge and experience	0	1	1	0	0	1	1	1	0
8. Resistance to technology adoption	1	1	1	0	0	0	0	1	0
9. Lack of demand and public awareness	1	1	1	1	1	1	1	1	1

After incorporating the transitivities as described in step (iv) of the ISM methodology, the final reachability matrix is shown in Table 4. In Table IV, the driving power and the dependence of each factor are also shown. Driving power for each factor is the total number of factors (including itself), which it may help achieve. On the other hand dependence is the total number of factors (including itself), which may help achieving it. These driving power and dependencies would be used in the classification of factors into the four groups of autonomous, dependent, linkage, and driver factors.

Table 4

Final reachability matrix after incorporating transitivities

Factors	1	2	3	4	5	6	7	8	9
1. Costs	1	1	0	0	0	0	0	1	0
2. Lack of legitimacy	1	1	1	0	0	0	0	1	0
3. Regulations	1	1	1	0	0	0	0	1	0
4. Poor supplier commitment	1	1	1	1	1	0	0	1	0
5. Industry specific barriers e.g. lack of resources	1	1	1	1	1	0	0	1	0
6. Lack of corporate leadership and support	1	1	1	1	1	1	1	1	0
7. Lack of knowledge and experience	1	1	1	1	0	1	1	1	0
8. Resistance to technology adoption	1	1	1	0	0	0	0	1	0
9. Lack of demand and public awareness	1	1	1	1	1	1	1	1	1

Level partitions

From the final reachability matrix, the reachability and antecedent set (Warfield, 1974) for each factor are found. The reachability set consists of the element itself and the other elements, which it may help achieve, whereas the antecedent set consists of the element itself and the other elements, which may help achieving it. Thereafter, the intersection of these sets is derived for all the factors. The factors for which the reachability and the intersection sets are the same occupy the top level in the ISM hierarchy. The top-level element in the hierarchy would not help achieve any other element above its own level. Once the top-level element is identified, it is separated out from the other elements. Then, the same process is repeated to find out the elements in the next level. This process is continued till the levels of each element are found (Refer Tables 5 to 8). These identified levels help in building the digraph and final model.

Table 5
Partition of reachability matrix- first iteration

Barrier No.	Reachability set	Antecedent set	Intersection set	Level
1	1,2,8	1,2,3,4,5,6,7,8,9	1,2,8	I
2	1,2,3,8	1,2,3,4,5,6,7,8,9	1,2,3,8	I
3	1,2,3,8	2,3,4,5,6,7,8,9	2,3,8	
4	1,2,3,4,5,8	4,5,6,7,9	4,5	
5	1,2,3,4,5,8	4,5,6,9	4,5	
6	1,2,3,4,5,6,7,8	6,7	6,7	
7	1,2,3,4,6,7,8	6,7	6,7	
8	1,2,3,8	1,2,3,4,5,6,7,8,9	1,2,3,8	I
9	1,2,3,4,5,6,7,8,9	9	9	

Table 6
Second Iteration

Barrier No.	Reachability set	Antecedent set	Intersection set	Level
3	3	3,4,5,6,7,9	3	II
4	3,4,5	4,5,6,7,9	4,5	
5	3,4,5	4,5,6,9	4,5	
6	3,4,5,6,7	6,7	6,7	
7	3,4,6,7	6,7	6,7	
9	3,4,5,6,7,9	9	9	

Table 7
Third Iteration

Barrier No.	Reachability set	Antecedent set	Intersection set	Level
4	4,5	4,5,6,7,9	4,5	III
5	4,5	4,5,6,9	4,5	III
6	4,5,6,7	6,7	6,7	
7	4,6,7	6,7	6,7	
9	4,5,6,7,9	9	9	

Table 8
Fourth Iteration

Barrier No.	Reachability set	Antecedent set	Intersection set	Level
6	6,7	6,7	6,7	IV
7	6,7	6,7	6,7	IV
9	6,7,9	9	9	V

FORMATION OF ISM MODEL

As a result of iterations the levels of various factors are known. Making use of Table IV these factors can now be graphically portrayed in the form of a diagram. If there is a relationship between the factors *i* and *j*, this is shown by an arrow which points from *i* to *j*. This graph is called a directed graph or digraph. After removing the transitivities (refer step iv of the ISM methodology), the digraph is finally converted into ISM-based model (Figure 1).

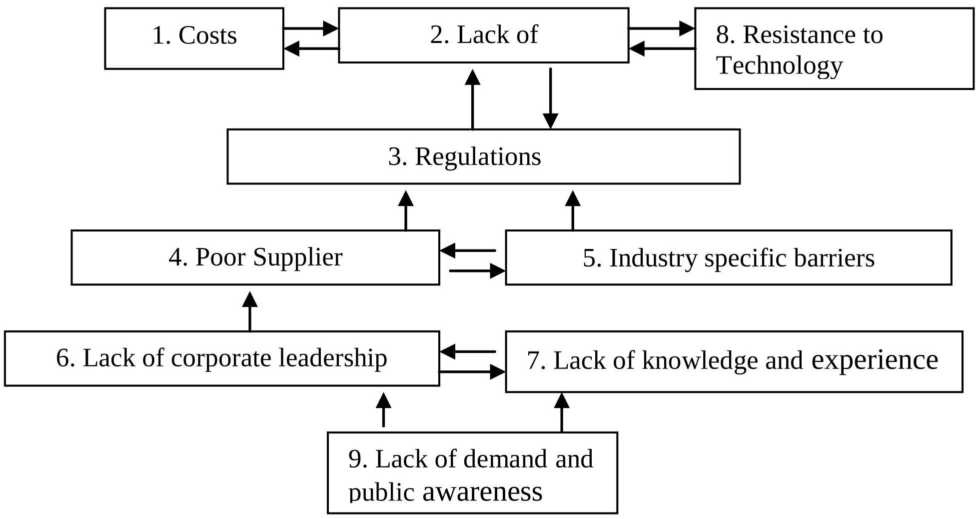

Figure 1: ISM-based model for Relationship of Barriers in Environmental SCM Implementation

DISCUSSION

The ISM model suggests that "Costs (of environmental supply chain management), Lack of legitimacy, and Resistance to technology adoption" are the three barriers at the top of the model. Accordingly, these barriers are most influenced by some other barriers which are the root cause of these three barriers. The root cause barriers lie at the bottom of the ISM model. It is revealed from the model that lack of demand and public awareness is the most influential barrier among the nine under study. It is having a very high driving power and hence attention must be paid to create awareness among the public about green supply chain. This will lead to an increase in the demand for the products supported by green supply chain. Two more barriers at the lower level namely "Lack of corporate leadership" and "Lack of knowledge and experience" are also having a high driving power and therefore need attention. However, these barriers may be addressed to a large extent if there is an increase in demand and public awareness for green supply chain. An increase in demand and public awareness will have manifold effect. Because of the increase in volume of production scale of economy in production may be observed in the cost of products. The other three barriers in addition to those already discussed have moderate driving power and dependency. This study has implications for practicing managers. The barriers, analyzed in this study, need to be overcome by the management of the companies planning to go for greening of their supply chains.

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