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Anil S. Dube Rupesh S. Gawande

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Anil S. Dube
Department of Mechanical Engineering, Sandip Institute of Engineering and Management, Nashik, India, and
Rupesh R. Gawande
Department of Mechanical Engineering, Bapurao Deshmukh College of Engineering, Wardha, India

Abstract

Purpose – The purpose of this paper is to identify barriers to implement green supply chain and to understand their mutual relationship. Green supply chain management (GSCM) barriers are identified using available GSCM literature and on consultations with experts from industry and academician. Interpretive structural model (ISM) was developed to identify the contextual relationship among these barriers.

Design/methodology/approach – A group of experts from industries and academics was consulted and ISM is used to develop the contextual relationship among various GSCMBs for each dimension of GSCM implementation. The results of ISM are used as an input to fuzzy matrix of cross-impact multiplications applied to classification (MICMAC) analysis, to identify the driving and dependence power of GSCMBs.

Findings – This paper has identified 14 key GSCMBs and developed an integrated model using ISM and the fuzzy MICMAC approach, which helps to identify and classify the important GSCMBs and reveal the direct and indirect effects of each GSCMB on the GSCM implementation. ISM model provides only binary relationship among GSCMBs, while fuzzy MICMAC analysis provides precise analysis related to driving and dependence power of GSCMB, to overcome this limitation, integrated approach is developed.

Research limitations/implications – ISM model development and fuzzy MICMAC analysis were obtained through the judgment of academicians and industry experts. It is the only subjective judgment and any biasing by the person who is judging the GSCMBs might influence the final result.

Originality/value – This is first kind of study to identify GSCMBs and further, to deploy ISM and fuzzy MICMAC to identify and classify the key GSCMEs that influence GSCM implementation in the organization. The results will be useful for business managers to understand the GSCMBs and overcome these GSCMBs during GSCM implementation in an organization.

Keywords Interpretive structural modelling, Fuzzy MICMAC, Green supply chain management, GSCM barriers

Paper type Research paper

1. Introduction

Worldwide the environmental protection awareness is increasing and so trend of conserving the earth's resources and protecting the environment is growing. With the overwhelming rise in carbon emission, global warming phenomena becoming more critical. Performance of the process and products can improve by adopting green supply chain management (GSCM) according to the requirements of the environmental regulations. Sustainable development can be achieved by consuming the resources which have less potential for depletion and not to utilize easily depleted resources. It also reduces environmental risks. Implementation of

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green practices in industries was increasing due to pressure from the various regulations and laws brought forward by the government. GSCM helps to achieve economical benefit and competitiveness of global market. Environmental management becomes a key strategic issue with the potential for a lasting impact on organizational performance.

According to scholars, GSCM is a modern management approach where supply chain is combination of economy and ecology. GSCM aims at reducing waste of energy and material, hence helps to conserve the energy and prevents pollution. GSCM is one of the systematic ways to maintain our resources and surrounding environments (Min and Kim, 2012). According to Zhu and Sarkis (2004) and Zhu *et al.* (2008), GSCM practices are useful for logistics management and are designed to incorporate environmental considerations into the forward and reverse logistics. GSCM practices include reverse logistics, which reduces waste. Assessment of suppliers based on environmental performance, developing products eco-friendly and reducing energy consumption (Walker *et al.*, 2008).

Barrier means hurdle which does not helps to achieve successful implementation of GSCM. GSCM implementation requires identification of GSCMBs. Various GSCMBs were discussed by different researchers. Available literature shows that some author selected few barriers like Luthra *et al.* (2011) analyzed 11 barriers using interpretive structural model (ISM), whereas Mathiyazhagan *et al.* (2012) analyzed 28 barriers. Govindan *et al.* (2014) identified 47 barriers through literature and discussion with experts. However there are many barriers to the successful implementation of GSCM, and it should be noted that not all the barriers carry an equal impact. From detailed literature survey we identified 28 barriers. Through the opinion of academia and industry experts, 14 most influential GSCMBs (see Table I) were identified, and these GSCMBs were again validated from experts. For validation purpose, eight experts (GSC managers) from the manufacturing industry and four experts from academia were consulted. These experts from industry and academia are very well conversant with issues related to GSC implementation in an organization. They were asked to comment on the sufficiency of GSCMBs and to add or delete any other GSCMB. On the basis of personal discussions, the selected GSCMBs from the literature were finalized for the analysis. Again, the opinions from the same experts were taken in the development of contextual relationship among identified GSCMBs. The facilitator is provided to coordinates the different experts so as to reduce the bias. To collect the contextual relationship among different GSCMBs, SSIM sheet without any notation was administered to each expert. The results were then discussed with the experts, and a final matrix was achieved reflecting the experts' consensus on their judgment.

But mere identifications of GSCMBs is not adequate, the successful GSCM implementation requires identification of interrelationship between various GSCMBs and find out the driving and dependence power of these GSCMBs. This can be obtained through ISM and fuzzy matrix of cross-impact multiplications applied to classification (MICMAC) analysis.

Warfield established ISM methodology for identifying relationships among specific items which define a problem or an issue. In this research, ISM and fuzzy MICMAC approach is used for analysis of various GSCMBs, which provides the interrelationships of various GSCMBs, their driving and dependence power. The opinions from experts were used in the formation and development of the ISM model.

GSCMB code	Barriers to implement GSCM	Description	Literature support
GSCMB1	Lack of government support to adopt GSCM	It means government not making industry friendly policies toward GSCM and not giving special benefits to those organizations implementing GSCM	Daine (2009), Ghobadian (2009), Wu and Hang (2009) and Srivastva (2007)
GSCMB2	Lack of top management commitment	It indicates that top management not showing interests in green practices	Singh *et al.* (2012), Luthara, Mudgal *et al.* (2010), Sarkis, Zhu *et al.* (2007)
GSCMB3	Lack of customer awareness toward GSCM	This reflects customers do not know about green products and their benefits	Sreejith (2012), Mudgal *et al.* (2009), Zhu *et al.* (2008) and Ravi and Shankar (2005)
GSCMB4	Cost implications/financial constraint	It means to the high initial cost investment required to implement various green methodologies such as green design, green manufacturing, green labeling of packing, etc.	Sreejith (2012), AlKhidir and Zailani (2009) and Hosseini (2007)
GSCMB5	Lack of understanding among supply chain stakeholders	This reflects lack of coordination between various stake holders like supplier, customer, manufacturer	Sharma *et al.* (2012), Sreejith (2012) and Daine (2009)
GSCMB6	Lack of IT implementation	Lack of IT implementation means non implementation information technology resources like computers, internet, etc. Slow, ineffective and improper communication is due to lack of IT Implementation	Wu and Hang (2009), Ravi and Shankar (2005), Mclaren *et al.* (2004) and Rogers *et al.*
GSCMB7	Resistance to adopt ion of advance technology	Resistance to technology advancement adoption is not doing advancements in machinery and equipments to improve the products	AlKhidir and Zailani (2009), Hsu (2008), Hosseini (2007) and Digawalkar and Metri (2004)
GSCMB8	Fear of failure	Fear of failure in adopting green supply chain; that firms could suffer monetary losses/product failure, lead to loss of competitive advantage	Rao and Holt (2005), Hansson *et al.* and Revell and Rutherfoord (2003)
GSCMB9	Market competition and uncertainty	In today's scenario market uncertainty is very high due to global competitiveness, and customer's requirements	Mudgal *et al.* (2010), Hosseini (2007) and Yu Lin
GSCMB10	Lack of training in GSCM	This reflects lack of training given to the employee of the organization, thus resisting enhancement of overall performance of supply chain and green practices in it	Sharma *et al.* (2012), Daine (2009), Yu and Hui, Bowen *et al.* (2001)

Table I.
Green supply chain barriers and literature support

(*continued*)

GSCMB code	Barriers to implement GSCM	Description	Literature support
GSCMB11	Lack of technical expertise to implement GSCM	Inability to find an alternative to design a pollution free product to fulfill environmental requirements	Revell and Rutherfoord (2003)
GSCMB12	Lack of mindset toward CSR	Corporate social responsibility suggests firms are willing to go beyond simple compliance. Willing to consider public consequences of organizational actions but industries fail to adopt it	Mudgal *et al.* (2010)
GSCMB13	Poor implementation of green practices	Lack of consideration of green practices like hazardous solid waste disposal, energy conservation, reusing and recycling materials, etc.	Yu Lin and Hui Ho (2008), Hsu and Hu (2008) and Ravi and Shankar (2005)
GSCMB14	Lack of EMS certification (ISO14001)	It refers to authenticity of quality of products and services as per pre-established norms	Sharma *et al.* (2012), Sreejith (2012), Yu, and Linton *et al.* (2007)

Table I.

1.1 Objectives

Implementation of green practices in conventional supply chain has been come out as an important area of research. Barriers playing a key role in implementation of GSC and GSCMBs restrict an organization to achieve better organizational performance. Hence it needs to be researched. This observation inspired the authors to do this research. The main objectives of this research are:

- to find important barriers of GSCM and rank of theses GSMBs to implement green concept;
- to establish the relationship and interaction among these identified barriers;
- to develop ISM-based structural model; and
- to classify these barriers using integrated fuzzy MICMAC analysis.

1.2 Organization of paper

Barriers for greening supply chain have been identified and with the help of literature survey and its review in Section 2. Step wise procedure of ISM formulation has been described in Section 3. Integrated Fuzzy MICMAC analysis has been carried out in Section 4. Section 5 includes findings and its discussion. Section 6 describes research implications. Section 7 is dedicated for conclusion and scope for future work.

2. Literature review

Research on GSCM usually focusses on aspects such as green purchasing, internal environmental operations management or green logistics, as against taking an integrative, whole SC approach. Many authors suggest that GSC research should move from subjective studies toward an experimental and theory grounded approach

(Beamon, 1999; Carter and Carter, 1998; Zsidisin and Siferd, 2001). Barriers to GSCM implementation in SMEs are different from those of larger enterprises in many ways including: generation of less environmental data; fewer resources, environmental performance being driven by personal views of business owners; no common access points and differences in organizational structure. Many studies confirm that adoption of GSCM in SMEs is unhurried (Mudgal *et al.*, 2010; Sarkis *et al.*, 2011; Kannan *et al.*, 2008). Carter and Rogers (2008) mention that organizations fail to adopt environmental initiatives due to internal factors including costs, improper communication structures, internal politics and institutional norms. Zhu *et al.* (2010) pointed out that lack of external cooperation and diffusion are proven obstacles to GSCM's operational performance. A GSC aims at confining the wastes within the industrial system in order to conserve energy and prevent the dissipation of dangerous materials into the environment (Torres *et al.*, 2004). It recognizes the disproportionate environmental impact of SC processes within an organization. ISM methodology was utilized 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 mostly influenced by driving barriers are identified (Ravi and Shankar, 2005).

Mudgal *et al.* (2010) investigated and ranked barriers against GSCM adoption based on an exhaustive questionnaire from more than 100 industries in different sectors by using ISM. ISM-based model for modeling the barriers of GSC practices in Indian manufacturing industries was put forward. They suggested green businesses practices are not easy to adopt and implement due to the presence of many barriers. A questionnaire based survey was conducted to analyze and rank these barriers. In total, 15 barriers were identified. ISM approach has been used to model and analyze key barriers. It is evident from literature that both academicians and practitioners are fully aware and are interested in analyzing barriers to GSCM adoption (Zhu and Sarkis, 2006; Walker *et al.*, 2008; Diabat and Govindan, 2011). Importance of GSCM and factors important to implement GSCM in Indian automobile industry was identified and described (Luthra *et al.*, 2010). In total, 11 barriers to implement GSCM in Indian automobile industry have been identified. ISM methodology has been used for finding contextual relationships among various barriers to implement GSCM in Indian automobile industry (Luthra *et al.*, 2011). Indian industries, we observed that these industries face many barriers such as the lack of governing policies, too many agencies for SMEs, inadequate data and information for development of SMEs and suppliers lacking the necessary environmental systems to adopt within their industries. Once they start implementing such practices, many barriers will still occur (Shaikha *et al.*, 2013). Lack of new technology, materials and processes and poor supplier commitment unwilling to exchange information barriers occupied the top most level. These are the barriers that are affected at the lower level and also these barriers give less impact as compared to the remaining barriers. It shows that the four industries feel that these barriers are comparatively easy to eradicate (Ahmad and Nima, 2014). Lack of government support system is most important barrier and it is at the bottom level of the ISM model. Indian industry has to take care about this bottom level barrier. Non-availability of bank loans to encourage green product, cost implication, less awareness of customer about GSCM, lack of training courses about implementing GSCM, lack of environmental awareness to the supplier, poor organizational culture in adopting GSCM and lack of top management commitment in adopting GSCM have been identified as third-level barriers (Jayant and Azhar, 2014). Lack of skilled sustainability professionals, lack of green suppliers and developers, lack of government support, lack of public awareness and demand and market uncertainty are the critical barriers to the adoption of GSCM in the

UAE construction sector. During GSCM adoption, it is not possible to eradicate all these barriers initially and so industries must identify which barrier is a major obstacle for GSCM implementation. The proposed AHP approach is used to give rank (priorities) to these 47 barriers based upon judgments of industrial experts. The green barrier index calculated can be used to find out the fitness of the company for GSCM implementation lower index values indicate fewer adverse impacts and demonstrate that a particular company may be fit for GSCM implementation. Muduli *et al.* (2012) developed model based on four selected variables using graph theoretic and matrix approach and found that factor 4, capacity constraints, has a more adverse impact on GSCM practices than the other barriers in case of large scale mining industries. Mathiyazhagan *et al.* (2012) identified 26 barriers for implementation of GSCM in Indian auto component manufacturing industries. This study found that problem in maintaining environmental awareness of supplier's barrier is acting as a key barrier for implementation of GSCM. So industry needs to give special attention and first priority to remove this barrier. Sasikumar and Haq (2010) identified the major barriers facing a battery recycling system and analyze the interaction among these barriers using ISM approach.

Gorane and Kant (2015) developed ISM-based model and analyzed 15 barriers for successful implementation of SCM in organization. They suggested that lack of top management commitment and support and unclear organizational objectives is significant supply chain management barrier. Gorane and Kant (2013) identified 24 key SCMEs and developed integrated model using ISM and fuzzy MICMAC approach. Sudarshan *et al.* identified 12 enablers for successful supplier selection process using ISM methodology and analyzed the driving and dependence power using fuzzy MICMAC analysis.

3. ISM methodology and model development

ISM is an interactive learning technique, which contains a set of different directly and indirectly related elements are structured into a comprehensive systematic model. This model portrays the structure of a complex issue or problem in a carefully designed pattern implying graphics as well as words. For any complex problem under consideration, a number of factors may be related to a problem. But the direct and indirect relationships between the factors describe the situation far more accurately than the individual factor taken into isolation. ISM develops insights into collective understandings of these relationships.

Warfield (1974) first proposed ISM, to analyze the complex socioeconomic systems. This modeling technique is suitable for analyzing the influence of one variable on other variables. Individuals or groups can develop a map of the complex relationships between the many elements involved in a complex situation using ISM technique. Basic idea is to use experts' practical experience and knowledge to convert a complicated system into several sub-systems and construct a multilevel structural model. ISM is also used to provide fundamental understanding of complex situations, as well as to put together a course of action for solving a problem. The main benefits of the ISM methodology is that it transforms unclear and poorly articulated models of systems into visible and well-defined models. However, the ISM methodology has certain drawbacks as well. There will be the subjective bias of the person who is judging the variables, as the relations among the variables always depends on that person's knowledge and familiarity with the firm, its operations and its industry; this bias will affect the final model. ISM has following broad objectives:

(1) to find interrelationships among the variables affecting GSC; and

(2) classification of these variables according to their driving and dependence power.

3.1 Significance of ISM

ISM explores the dynamic influence of different elements which brings into consideration of a system of directly and indirectly related elements. It has three dimensions by each letters. Dimension interpretive (I) is based on the judgment of a group of experts in that respective field. A group of expert decisions are collected and decides whether and how the variables are interrelated. Then, (S) is structural, since on the basis of the relationship, an overall structure is extracted from the complex set of variables. Dimension (M) the modeling which portrays the specific relationships of the variables and overall structure of the system under consideration. In other words, in ISM, I (interpretive) stand for the outcome of judgment, S (structural) stands for the extraction of outcome of a set of variables and M (model) stands for the graphical representation of the specific relationship and overall structure.

Many researchers have used ISM methodology to impose order and direction on the complexity of relationships among elements of a system (Table II).

Steps involved in the ISM methodology are as follows:

(1) Identification of variables: the elements of the system are identified which are relevant to the problem or issue and identified with a group problem-solving technique like brain storming sessions, Delphi method or opinion from industry.

(2) Contextual relationship: from the elements identified in step (1), a contextual relationship is identified among each element with respect to which pairs of elements would be examined. After resolving the elements and the contextual relationship, a structural self-interaction matrix (SSIM) is prepared based on pair-wise comparison of element of the system under consideration.

(3) 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 is related to B and B is related to C, then A is necessarily related to C.

Sr. no.	Researcher	System under consideration
1	Mudgal *et al.* (2010)	Identification and analysis of barriers to implement GSCM using ISM
2	Luthra *et al.* (2011)	Identified 11 numbers of relevant barriers to implement GSCM in automobile industry using interpretive structural modeling technique
3	Ahmad and Nima (2014)	Interpretive structural modeling (ISM) analysis was used to understand the mutual influences among the 16 barriers identified to implementation GSCM in auto component manufacturing in Iran
4	Shaikha *et al.* (2013)	Determine the relationship between the barriers and to identify the most influential barriers from the recommended barrier list with the help of interpretive structural modeling
5	Sreejith (2012)	Identified and analyzed barriers to green supply chain management in the construction sector using ISM
6	Jayant and Azhar (2014)	To determine the relationship among the barriers and to identify the most influential barriers from the recommended barrier list with the help of interpretive structural modeling
7	Ravi *et al.*	Analyze the interaction among the major barriers, which hinder or prevent the application of reverse logistics in automobile industries
8	Mandal and Deshmukh (1994)	Identifies relationships among vendor selection criteria

Table II. ISM reported in literature

(4) The reachability matrix obtained in step (3) is converted into the canonical matrix format by arranging the elements according to their levels.

(5) From the canonical matrix form of the reachability matrix a directed graph is drawn by means of vertices or nodes and lines of edges and the transitive links are removed based on the relationships given in the reachability matrix. The resultant digraph is converted into an ISM by replacing enabler nodes with statements.

3.2 SSIM

Through an extensive literature review the 14 most cited GSCMBs (see Table I) were identified and these GSCMBs were again validated from experts. For validation purpose eight experts (GSC managers) from the manufacturing industry and four experts from academia were consulted. These experts from industry and academia are very well conversant with issues related to GSC implementation in an organization. They were asked to comment on the sufficiency of GSCMBs and to add or delete any other GSCMB. On the basis of personal discussions, the selected GSCMBs from the literature were finalized for the analysis. Again the opinions from the same experts were taken in the development of contextual relationship among identified GSCMBs. The facilitator is provided to coordinates the different experts so as to reduce the bias. To collect the contextual relationship among different GSCMBs, SSIM sheet without any notation was administered to each expert. The results were then discussed with the experts and a final matrix was achieved reflecting the expert's consensus on their judgment.

For analyzing GSCMBs in developing SSIM, the following four symbols have been used to denote the direction of relationship between enablers (i and j):

(1) V – GSCMB i will lead to achieve GSCMB j.

(2) A – GSCMB j will lead to achieve GSCMB i.

(3) X – GSCMB i and j will lead to achieve each other.

(4) O – GSCMB i and j are unrelated.

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

3.3 Initial reachability matrix

The SSIM has been converted into a binary matrix, called initial reachability matrix (Table IV) by substituting V, A, X and O by 1 and 0 as per given case. The substitution of 1 and 0 are as per the following rules:

- 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;
- 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;
- 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; and
- 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.

After obtaining an initial reachability matrix, its transitivity is checked. According to expert's opinion (as discussed in Section 3.1), if there is a relationship exists between

Table III. Structural self-interaction matrix (SSIM)

Barriers	Name of GSCMBs	14	13	12	11	10	9	8	7	6	5	4	3	2
1	Lack of government support to adopt GSCM	V	V	O	V	O	O	O	O	O	V	O	V	O
2	Lack of top management commitment	V	V	V	O	V	O	V	V	V	V	V	O	
3	Lack of customer awareness towards GSCM	V	V	O	X	O	V	O	O	O	V	O		
4	Financial constraint	V	V	X	O	V	V	V	V	V	V			
5	Lack of understanding among supply chain stakeholders	A	A	A	A	A	A	A	A	A				
6	Lack of IT implementation	V	V	A	O	X	V	X	X					
7	Resistance to adopt ion of advance technology	V	V	A	O	X	V	X						
8	Fear of Failure	V	V	A	O	X	V							
9	Market competition and uncertainty	X	X	O	A	A								
10	Lack of training in GSCM	V	V	A	O									
11	Lack of technical expertise to implement GSCM	V	V	O										
12	Lack of mindset towards CSR	O	V											
13	Poor implementation of green practices	X												

Table IV. Initial reachability matrix

Barriers	Name of GSCMBs	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Lack of government support to adopt GSCM	1	0	1	0	1	0	0	0	0	0	1	0	1	1
2	Lack of top management commitment	0	1	0	1	1	1	1	1	0	1	0	1	1	1
3	Lack of customer awareness toward GSCM	0	0	1	0	1	0	0	0	1	0	1	0	1	1
4	Financial constraint	0	0	0	1	1	1	1	1	1	1	0	1	1	1
5	Lack of understanding among supply chain stakeholders	0	0	0	0	1	0	0	0	0	0	0	0	0	0
6	Lack of IT implementation	0	0	0	0	1	1	1	1	1	1	0	0	1	1
7	Resistance to adopt ion of advance technology	0	0	0	0	1	1	1	1	1	1	0	0	1	1
8	Fear of failure	0	0	0	0	1	1	1	1	1	1	0	0	1	1
9	Market competition and uncertainty	0	0	0	0	1	0	0	0	1	0	0	0	1	1
10	Lack of training in GSCM	0	0	0	0	1	1	1	1	1	1	0	0	1	1
11	Lack of technical expertise to implement GSCM	0	0	1	0	1	0	0	0	1	0	1	0	1	1
12	Lack of mindset toward CSR	0	0	0	1	1	1	1	1	0	1	0	1	1	0
13	Poor implementation of green practices	0	0	0	0	1	0	0	0	1	0	0	0	1	1
14	Lack of EMS certification (ISO14001)	0	0	0	0	1	0	0	0	1	0	0	0	1	1

element *i-j* and element *j-k* and experts think that there no relationship exists between element *i-k*, then *i-j* and *j-k* entry in the reachability matrix becomes 1 and *i-k* entry becomes 0. But according to transitivity rule as mentioned in step (4) of the ISM technique, if "I" is related to *j* and *j* related to *k* then ultimately the relationship established between *i* and *k* and *i-k* entry in the matrix converted to 1 instead of 0. By applying the transitivity rule the final reachability matrix obtained shown in Table V.

3.4 Level partitions

From the final reachability matrix, the reachability set and antecedent set for each GSCMBs are found. The reachability set includes GSCMB itself and others which it may help to achieve, similarly the antecedent set consists of GSCMB itself and the other GSCMBs which help in achieving it. Then, the intersection of these sets is derived for all GSCMB. The GSCMBs for which the reachability and intersection sets are same is the top-level GSCMBs in the ISM hierarchy. The top-level GSCMBs in the hierarchy would not help achieve any other element above its own level. Once the top-level GSCMBs are identified, it is separated

Barriers	Name of GSCMBs	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Lack of government support to adopt GSCM	1	0	1	0	1	0	0	0	1[a]	0	1	0	1	1
2	Lack of top management commitment	0	1	0	1	1	1	1	1	1[a]	1	0	1	1	1
3	Lack of customer awareness toward GSCM	0	0	1	0	1	0	0	0	1	0	1	0	1	1
4	Financial constraint	0	0	0	1	1	1	1	1	1	1	0	1	1	1
5	Lack of understanding among supply chain stakeholders	0	0	0	0	1	0	0	0	0	0	0	0	0	0
6	Lack of IT implementation	0	0	0	0	1	1	1	1	1	1	0	0	1	1
7	Resistance to adopt ion of advance technology	0	0	0	0	1	1	1	1	1	1	0	0	1	1
8	Fear of failure	0	0	0	0	1	1	1	1	1	1	0	0	1	1
9	Market competition and uncertainty	0	0	0	0	1	0	0	0	1	0	0	0	1	1
10	Lack of training in GSCM	0	0	0	0	1	1	1	1	1	1	0	0	1	1
11	Lack of technical expertise to implement GSCM	0	0	1	0	1	0	0	0	1	0	1	0	1	1
12	Lack of mindset toward CSR	0	0	0	1	1	1	1	1	1[a]	1	0	1	1	1[a]
13	Poor implementation of green practices	0	0	0	0	1	0	0	0	1	0	0	0	1	1
14	Lack of EMS certification (ISO14001)	0	0	0	0	1	0	0	0	1	0	0	0	1	1

Note: [a]Represents transitivity

Table V. Final reachability matrix

out from the other GSCMBs. Then, the same process is repeated to find out the elements in the next level. This process is continued until the level of each element is found .These levels help in building the diagraph and the final model (Table VI).

3.5 Building the ISM mode

Structural model is generated using final reachability matrix (Table V), if there is a relationship between the GSCMBs *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 transitivity the digraph is finally converted into the ISM-based model (Figure 1).

4. ISM-fuzzy MICMAC analysis

The MICMAC principle is based on multiplication properties of matrices. The objective of the MICMAC analysis is to analyze the driving power and the dependence of the variables. The previously identified variables are classified into four clusters .The first

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

Table VI. Partitioning of reachability matrix

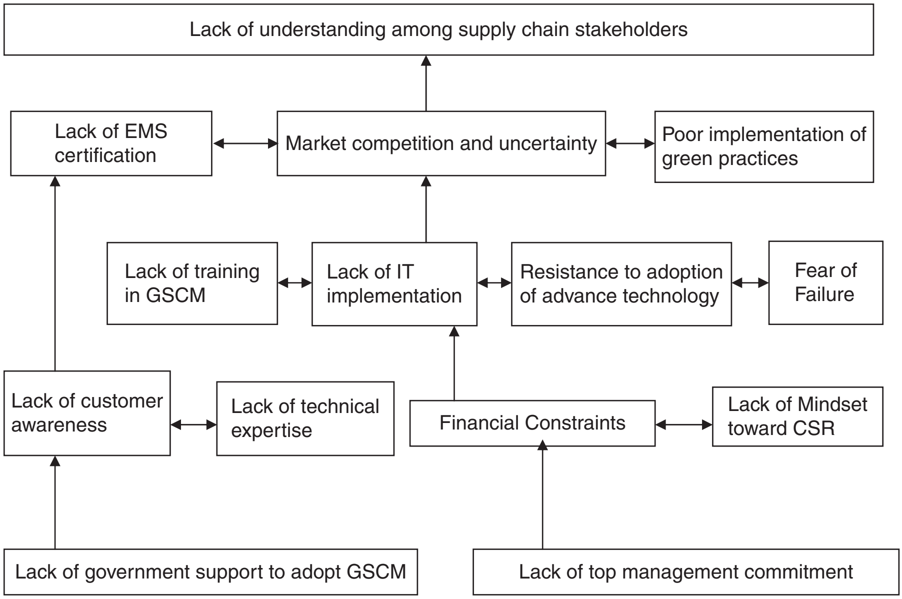
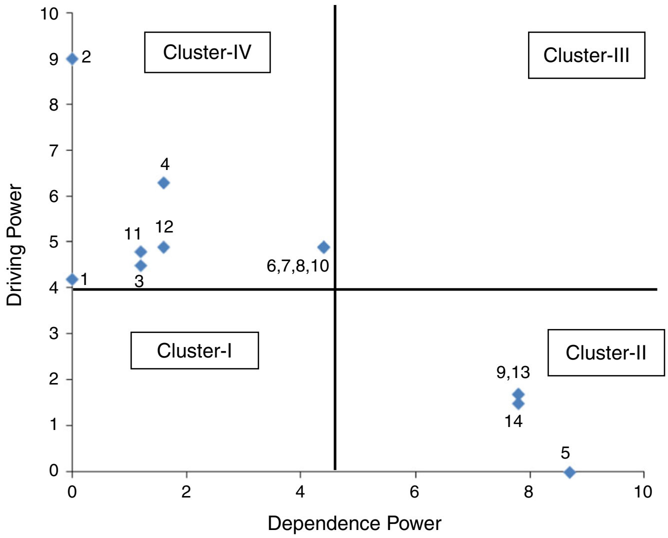


Figure 1.
ISM model for GSCMBs

cluster comprises the "autonomous barriers" that have weak driving power as well as weak dependence. These barriers are relatively disconnected from the system, with which they have only few links, which may not be strong. Second cluster consists of the "dependent barriers" that have strong dependence but weak driving power. Barriers that have strong dependence as well as strong driving power are known as "linkage barriers" and form part of the third cluster. These barriers are unstable, in the sense that any action on these barriers will have an effect on others and also a feedback on themselves. The fourth cluster consists of 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 variable falls into the category of independent or linkage barriers.

For developing the ISM model, the relation between two GSCMBs is denoted by 0 and 1. If there is no relationship between two GSCMBs then it is denoted by 0 and if there is relationship between two GSCMBs then it is denoted by 1. From Table V, the relationship between GSCMB1 and GSCMB3, GSCMB1 and GSCMB5, GSCMB 1 and GSCMB11 having equal importance and denoted by binary number 1. However, the relationship between these GSCMBs cannot be always equal. Some relations may be strong, some may be especially strong and some relations may be better. To overcome this drawback of ISM model, the fuzzy ISM is used for the MICMAC analysis. The ISM-fuzzy MICMAC analysis is carried out as per following procedure.

The dependence and the driving power of each of these barriers are shown in Table X. In this table, an entry of "1" along the rows and columns indicate the driving power and the dependence, respectively. Subsequently, the driving-dependence power diagram is constructed as shown in Figure 2. As an illustration, it is observed from Table X that barrier 1 is having a driver power of 4.2 and a dependence of 0. Therefore, in Figure 2, it is positioned at a place corresponding to a driving power of 4.2 and a dependence of 0.



Notes: Cluster-I: autonomous barriers; cluster-II: dependent barriers; cluster-III: linkage barriers; cluster-IV: driver barriers

Figure 2. Cluster of GSCMBs

4.1 Binary direct relationship matrix

A binary direct reachability matrix (BDRM) is obtained by examining the direct relationship among the GSCMB in the ISM as given in Table IV. The transitivity is ignored and the diagonal entries are converted to 0. The BDRM so derived, is shown in Table VII.

4.2 Development of fuzzy direct relationship matrix (FDRM)

Conventional MICMAC analysis considers only binary type of relationship; however, this paper uses fuzzy set theory (FST) to increase the sensitivity of MICMAC analysis. In

Barriers	Name of GSCMBs	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Lack of government support to adopt GSCM	0	0	1	0	1	0	0	0	0	0	1	0	1	1
2	Lack of top management commitment	0	0	0	1	1	1	1	1	0	1	0	1	1	1
3	Lack of customer awareness toward GSCM	0	0	0	0	1	0	0	0	1	0	1	0	1	1
4	Financial constraint	0	0	0	0	1	1	1	1	1	1	0	1	1	1
5	Lack of understanding among supply chain stakeholders	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	Lack of IT implementation	0	0	0	0	1	0	1	1	1	1	0	0	1	1
7	Resistance to adopt ion of advance technology	0	0	0	0	1	1	0	1	1	1	0	0	1	1
8	Fear of failure	0	0	0	0	1	1	1	0	1	1	0	0	1	1
9	Market competition and uncertainty	0	0	0	0	1	0	0	0	0	0	0	0	1	1
10	Lack of training in GSCM	0	0	0	0	1	1	1	1	1	0	0	0	1	1
11	Lack of technical expertise to implement GSCM	0	0	1	0	1	0	0	0	1	0	0	0	1	1
12	Lack of mindset toward CSR	0	0	0	1	1	1	1	1	0	1	0	0	1	0
13	Poor implementation of green practices	0	0	0	0	1	0	0	0	1	0	0	0	0	1
14	Lack of EMS certification (ISO14001)	0	0	0	0	1	0	0	0	1	0	0	0	1	0

Table VII. Binary direct reachability matrix (BDRM) fuzzy MICMAC, an additional input of possibility of interaction between the GSCMBs is introduced. The possibility of interaction can be defined by qualitative consideration on 0-1 scale and is given in Table VIII.

Again the opinion of same academician and industry expert as mentioned in Section 3.1 are considered to rate the relationship between two GSCMBs (Table VIII). The values for the relationship between two GSCMBs are then superimposed on the BDRM (Table VII) to obtain a FDRM. The FDRM is given in Table IX.

4.3 Fuzzy MICMAC stabilized matrix

The FDRM is taken as the base to start the process. The matrix is multiplied repeatedly until the hierarchies of the driver power and dependence stabilize. The multiplication process follows the principle of fuzzy matrix multiplication (Kandasamy, 2007). Fuzzy matrix multiplication is basically a generalization of Boolean matrix multiplication. According to FST, when two fuzzy matrices are multiplied the product matrix is also a fuzzy matrix. Multiplication follows the given rule:

$$\mathrm{C} = A,\ \mathrm{B} = \max k\left[\min\left(a_{ik},\ b_{kj}\right)\right] \text{ where } \mathrm{A} = (a_{ik}) \text{ and } \mathrm{B} = \left(b_{kj}\right)$$

Table VIII. Possibility of numerical value of reachability

Possibility of reachability	No	Very low	Low	Medium	High	Very high	Complete
Value	0	0.1	0.3	0.5	0.7	0.9	1

Table IX. Fuzzy direct reachability matrix (FDRM)

Barriers	Name of GSCMBs	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Lack of government support to adopt GSCM	0	0	0.7	0	0.5	0	0	0	0.3	0	0.5	0	0.3	0.5
2	Lack of top management commitment	0	0	0	0.9	0.7	0.5	0.3	0.5	0.3	0.5	0	0.5	0.5	0.5
3	Lack of customer awareness toward GSCM	0	0	0	0	0.5	0	0	0	0.3	0	0.9	0	0.3	0.5
4	Financial constraint	0	0	0	0	0.5	0.7	0.5	0.7	0.5	0.5	0	0.7	0.5	0.7
5	Lack of understanding among supply chain stakeholders	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	Lack of IT implementation	0	0	0	0	0.3	0	0.7	0.7	0.3	0.7	0	0	0.5	0.5
7	Resistance to adopt ion of advance technology	0	0	0	0	0.5	0.7	0	0.5	0.3	0.3	0	0	0.3	0.3
8	Fear of Failure	0	0	0	0	0.3	0.7	0.5	0	0.3	0.5	0	0	0.3	0.3
9	Market competition and uncertainty	0	0	0	0	0.7	0	0	0	0	0	0	0	0.5	0.5
10	Lack of training in GSCM	0	0	0	0	0.5	0.7	0.3	0.5	0.3	0	0	0	0.5	0.5
11	Lack of technical expertise to implement GSCM	0	0	0.9	0	0.3	0	0	0	0.3	0	0	0	0.3	0.5
12	Lack of mindset toward CSR	0	0	0	0.7	0.3	0.5	0.7	0.5	0.5	0.5	0	0	0.5	0.3
13	Poor implementation of green practices	0	0	0	0	0.7	0	0	0	0.3	0	0	0	0	0.5
14	Lack of EMS certification (ISO14001)	0	0	0	0	0.3	0	0	0	0.5	0	0	0	0.5	0

A stabilized matrix is shown in Table X. The driving power of the GSCMB in fuzzy MICMAC is derived by summing the entries of possibilities of interactions in the rows, and the dependence of the GSCMB is determined by summing the entries of possibilities of interactions in the columns.

5. Findings and discussions

GSC is an important subject for researchers and practitioners. Implementing GSCM in an organization is challenging and difficult or costly to implement. A range of GSCMBs can make it hard to achieve successful GSCM implementation. It is necessary to investigate the impact of these barriers and to find the relationship between these barriers during the implementation of GSCM. Another useful approach would be to find the dominant barriers in the adoption of GSCM. Generally, the eradication of barriers is not easy and it needs further analysis. It is not possible to eradicate all kinds of barriers simultaneously. Hence, industries need to determine the most influential barrier.

The main objective of this research work is to identify and find out the interdependencies among all selected GSCMBs and further to analyze the driving and dependencies of GSCMBs for successful GSCM implementation in the organization. To achieve these objectives, the ISM-based model and fuzzy MICMAC analysis have been deployed in order to understand the interactions among different GSCMBs completely so that the

Barriers	Name of GSCMBs	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Driving power
1	Lack of government support to adopt GSCM	0	0	0.7	0	0.7	0	0	0	0.7	0	0.7	0	0.7	0.7	4.2
2	Lack of top management commitment	0	0	0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0	0.9	0.9	0.9	9.0
3	Lack of customer awareness toward GSCM	0	0	0	0	0.9	0	0	0	0.9	0	0.9	0	0.9	0.9	4.5
4	Financial constraint	0	0	0	0	0.7	0.7	0.7	0.7	0.7	0.7	0	0.7	0.7	0.7	6.3
5	Lack of understanding among supply chain stakeholders	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	Lack of IT implementation	0	0	0	0	0.7	0	0.7	0.7	0.7	0.7	0	0	0.7	0.7	4.9
7	Resistance to adopt ion of advance technology	0	0	0	0	0.7	0.7	0	0.7	0.7	0.7	0	0	0.7	0.7	4.9
8	Fear of failure	0	0	0	0	0.7	0.7	0.7	0	0.7	0.7	0	0	0.7	0.7	4.9
9	Market competition and uncertainty	0	0	0	0	0.7	0	0	0	0	0	0	0	0.5	0.5	1.7
10	Lack of training in GSCM	0	0	0	0	0.7	0.7	0.7	0.7	0.7	0	0	0	0.7	0.7	4.9
11	Lack of technical expertise to implement GSCM	0	0	0.9	0	0.7	0	0	0	0.7	0	0	0	0.7	0.7	3.7
12	Lack of mindset toward CSR	0	0	0	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0	0	0.7	0.7	4.9
13	Poor implementation of green practices	0	0	0	0	0.7	0	0	0	0.5	0	0	0	0	0.5	1.7
14	Lack of EMS certification (ISO14001)	0	0	0	0	0.5	0	0	0	0.5	0	0	0	0.5	0	1.5
Dependence power		0	0	1.2	1.6	8.7	4.4	4.4	4.4	7.8	4.4	1.2	1.6	7.8	7.8	

Table X. Fuzzy MICMAC stabilized matrix management may lay stress on overcoming those barriers which are more effective for GSCM implementation. This will help to improve environmental and economical performance of the organization and thus will help in improving customer satisfaction.

The ISM is used by various researchers for modeling the GSCM variables for improving the GSC performance. The ISM technique has been applied to many areas of GSCM like vendor selection, IT enabled GSCM. However, a major contribution of this research lies in the development of linkages among various GSCMBs for entire GSC through ISM and fuzzy MICMAC analysis. In this research, the ISM-fuzzy MICMAC approach is used since the ISM provides only binary relationship between identified variables, while the fuzzy MICMAC approach provides sensitive analysis related to driving and dependent behavior of GSCMBs.

From the ISM Model (Figure 1), it has been observed that lack of top management commitment and lack of government support are at the first level of the ISM model. These two GSCMBs are at the bottom of the model. An uncommitted management cannot set proper goals and, if government does not support to adopt GSCM, it is difficult to implement GSCM in industry. A lack of top management support and lack of government support lead to lack of mindset for CSR, financial constraints, lack of customer awareness and lack technical expertise are the barriers at level 2. Level 3 constitutes lack of IT implementation, resistance to adoption of advance technology, fear of failure, lack of training in GSCM. All these GSCMBs support each other. Poor implementation of green practices, market competition and uncertainty forms level 4 of the ISM model. Finally, lack of understanding among supply chain stakeholders (level 5) is at top level of ISM model.

The second objective of this paper was to analyze the driving and the dependence power of GSCMBs that influence the GSCM implementation in an organization through fuzzy MICMAC analysis. In the fuzzy MICMAC analysis, variables are classified into four clusters (Figure 2). The first cluster consists of the autonomous criteria that have weak driver and weak dependence. These criteria are relatively disconnected from the system, with which they have only a few links, which may be strong. A second cluster consists of the dependent criteria that have weak driver power but strong dependence. The third cluster has the linkage criteria that have strong driving power and also strong dependence. These criteria are unstable and any action on these criteria will have an effect on others and also a feedback on themselves. The fourth cluster includes the independent criteria, having strong driving power but weak dependence. Some of the observations from the fuzzy MICMAC analysis, which provides important managerial implications, are discussed in Figure 2.

The driving-dependence power diagram (Figure 2 – cluster I) indicates that there are no autonomous GSCMBs in the process of GSCM implementation. Autonomous GSCMBs are weak drivers and also weak dependent. The autonomous GSCMBs are relative disconnected from the system, with which they have only a few links, which may not be strong. Hence, they do not have much influence on the system. Therefore, among the 14 selected GSCMBs, all the GSCMBs have much influence in the GSCM implementation. Hence top management cannot take lightly any of these GSCMBs, if they are very serious about making the GSCM successful.

Lack of understanding among supply chain stakeholders, market competition and uncertainty, lack of EMS certification (ISO14001) and poor implementation of green practices are weak drivers but are strongly dependent on the others (Figure 2 – cluster II). They are seen at the top of the ISM hierarchy (Figure 1), therefore considered as important GSCMBs. Their strong dependence indicates that they require all the other

GSCMB (Figure 2 – cluster IV) to minimize the effect of these GSCMBs in GSCM. The management should therefore accord high priority in tackling these GSCMBs. Besides tackling these GSCMBs, the management should also understand the dependence of these GSCMBs on the lower level of the ISM.

There are no GSCMBs in the linkage category that has a strong driving power and also a strong dependence (Figure 2 – cluster III GSCMBs). Any change occurring to these GSCMBs will have an effect on others and also a feedback on themselves. Hence, these GSCMBs are unstable in nature which may affect the successful GSCM implementation in the organizations. The absence of any linkage GSCMBs in this study indicates that no GSCMBs are unstable among all the 14 GSCMBs chosen in this study.

The driving-dependence diagram (Figure 2 – cluster IV) indicates independent GSCMBs such as 1ack of top management commitment, lack of mindset toward CSR, financial constraint, lack of IT implementation, resistance to adoption of advance technology, fear of failure, lack of training in GSCM, lack of technical expertise to implement GSCM and lack of customer awareness toward GSCM. Thus management needs to address these GSCMBs (Figure 2 – cluster IV GSCMBs) more cautiously and may be treated as the root cause of all the GSCMBs. It has been observed that these GSCMBs help to achieve the GSCMBs which appear at the top of the ISM hierarchy. Therefore, it can be anecdotal that management should work out strategies to overcome these independent GSCMBs for successful GSCM implementation in an organization. Those GSCMBs possessing higher driving power in the ISM need to be considered on a priority basis, because there are few other dependent GSCMBs being affected by them. The joint meetings of all the entities of GSC at regular interval may prove to be useful in this regard

6. Implications of research

The implications for practitioners and researchers are as follows:

- In the present research paper, an attempt has been made to identify the major GSCMBs to GSCM implementation in the organizations and is brought to one platform. Though a few research papers are available on different GSCMBs, no study available on the categorization of barriers according to the fuzzy MICMAC analysis. The present ISM-based model will help GSCM managers and practitioners to understand the relationship framework. Hence, this research assumes importance in this context.
- A key finding of this research is that the lack of top management commitment is significant GSCMBs. This GSCMB is at the uppermost right corner of the MICMAC analysis and imply the highest driving power. Therefore, management should focus on developing commitment and leadership within the organization and a development co-ordinal environment for a healthy relationship between different departments with a view to creating a healthy culture and awareness about the benefits of the GSCM program.
- The ISM-based model proposed in this paper can provide practitioners and academician more realistic representation of the problem in the course of GSCM implementation. During GSCM implementation, management cannot randomly peek up any GSCMB and try to overcome the same. Before overcoming any

GSCMB, the manager should thoroughly understand the hierarchy of actions (ISM model shown in Figure 1) to be taken and understand their relative importance and interdependence. The fuzzy MICMAC analysis (Figure 2) indicates the category of the GSCMBs which needs attention by practitioners according to their driving and dependence power. Practitioners should concentrate on those GSCMBs which have higher driving power (cluster IV GSCMBs shown in Figure 2), because these GSCMBs are the biggest hurdle for effective and successful GSCM implementation. These higher driving GSCMBs are the root cause for the other GSCMBs (cluster II GSCMBs shown in Figure 2) which have higher depending. Once these higher driving power GSCMBs are identified, the top management could formulate a strategy for overcoming their effects during GSCM implementation.

7. Conclusion and scope for future research

The environmental consciousness of customers and the increase of environmental image in the market day by day have forced industry to think about cleaner production by means of getting acquainted to GSCM practices. Due to the complexity of GSCM practices, increase in cost of product and regulation uncertainty, implementing GSCM is considered as a tough task that increases overall product cost.

In this present research work the ISM-based model has been developed for successful GSCM implementation in the organization for better environmental and financial performance. This ISM-based model has been upgraded to fuzzy ISM-based model so that the structural model can be interpreted with higher sensitivity rather than just binary relationship among the barriers. The present paper also makes an attempt to identify GSCMBs. Although a large amount of literature is available on GSCMBs, no study has been carried out to understand the interactions among these GSCMBs using ISM and fuzzy MICMAC analysis. The major contribution of this research work lies in the development of contextual relationships among identified GSCMBs through a systematic framework. The present research work provides an ISM-fuzzy MICMAC-based model to understand the relationships among identified variables. Hence, this research assumes importance. A major finding of this research work is that the lack of top management commitment and support, lack of mindset toward CSR, financial constraint, lack of IT implementation, resistance to adoption of advance technology, fear of failure, lack of training in GSCM, lack of technical expertise to implement GSCM and lack of customer awareness toward GSCM, are significant barriers for successful GSCM implementation in an organization. These GSCMBs have the strongest driving power and the weak dependence power and these GSCMBs are at the bottom of ISM model and seem to be the root cause for all other GSCMBs. Thus management needs to address these GSCMBs more cautiously. These GSCMBs possessing higher driving power in the ISM model can be considered on a priority basis, because there are other dependent GSCMBs (cluster II GSCMBs shown in Figure 1) in the hierarchy of ISM model being affected by them. To tackle these GSCMBs, management requires long term strategic planning and concentrates these barriers only after resolving the barriers appear at the bottom of the ISM model (cluster IV GSCMBs shown in Figure 1).

The findings are very crucial for the management, policy makers and consultants for GSCM implementation. Thus, the proposed model provides a more realistic approach to the problems during the course of GSCM implementation. The fuzzy MICMAC analysis developed in this paper acts as a tool for the top management to understand the GSCMBs which having higher driving and dependent power. Further, this model improves the sensitivity of MICMAC analysis compared with conventional model. The result of the research guides to the top management to lay stress on selected GSCMBs in order to implement the GSCM program effectively and efficiently, which will help to improve organizational performance.

ISM model development and fuzzy MICMAC analysis were obtained through the judgment of academicians and industry experts. It is the only subjective judgment and any biasing by the person who is judging the GSCMBs might influence the final result. A questionnaire survey can be conducted to catch the insight of these GSCMBs for more organizations. Further, structural equation modeling can be used for the statistical validation of the developed hypothetical model.

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About the authors

Anil S. Dube completed his ME in Mechanical Engineering from SVNIT Surat and is a Research Scholar at the Department of Mechanical Engineering, Bapurao Deshmukh College of Engineering, Wardha. Currently, he is working as an Associate Professor at Department of Mechanical Engineering, Sandip Institute of Engineering and Management, Nashik. He is doing his PhD in the area of green supply chain management. He has about two years of industry experience and 16 years of teaching and research experience. Anil S. Dube is the corresponding author and can be contacted at: anildube100@gmail.com

Rupesh R. Gawande is currently working as an Associate Professor at Department of Mechanical Engineering, Bapurao Deshmukh College of Engineering, Wardha. He obtained his PhD in the area of supply chain management. His area ofresearch interest includes, supply chain management, green supply chain and operation management. He has about 14 years of experience in industry, teaching and research. He has published more than 40 papers in international journals and conferences.