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A STUDY OF GREEN SUPPLY CHAIN MANAGEMENT BARRIERS FOR MANUFACTURING INDUSTRIES

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Abstract: Present research work is based on the study of green supply chain management barriers for manufacturing industries in Madhya Pradesh. For this purpose, first of all with the help of expert opinion and literature review, a list of barriers were created and assembled with the help of principal components analysis (PCA), followed by investigations on the interrelationships among the principal components with the help of interpretive structural modelling (ISM). After that, ranking of different criteria was carried out the with the help of analytical hierarchy process (AHP).

Keywords: Green supply chain management (GSCM), Barriers, Pprincipal components analysis (PCA), Interpretive structural modelling (ISM), Aanalytical hierarchy process (AHP).

1. Introduction

According to Shetty & Bhat (2022) the effect of globalization has been the spread of manufacturing across the globe driving the competition to increase the profitability of business organizations. The economic prosperity resulting from globalization increased the consumer demand and this, in turn, created a demand for goods and services. According to Delipinar & Durdağ (2021), increase in population and development in industry and technology have a great impact on consumption. Increase in the consumption leads to environmental pollution and global warming eventually. Shetty & Bhat (2022) also adds that the majority of the organizations had aimed for increasing profits which resulted in severe damage to the environment due to the process and the end of the useful life of the products. According to Geng et al. (2017), in recent years, the rapid industrial modernization has led to negative environmental impacts including greenhouse gas emissions, toxic pollutions, and chemical spills. Due to rapid change in climate and irresponsible consumption behaviors of human has led to natural resources scarcity and frequent natural disasters. Considering these facts, the present research work is based on the investigations on GSCM barriers. During the research, investigations on a compact list of barriers and their interrelationships has been made with the help of principal component analysis (PCA) and interpretive structural modelling (ISM), respectively, and ranking of different industrial areas in Madhya Pradesh on the anvil of GSCM barriers, with the help of analytical hierarchy process (AHP).

Following points represent the objectives of the research work:

a) Identification of a comprehensive set of green supply chain barriers;

b) Identification of a compatible set of green supply chain barriers and their interdependencies;

c) Investigation on ranking of barriers for different industrial sectors.

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2. Literature Review

Present section tells about the scenario of research in the field of green supply chain management, definitions of GSCM, contributions of researchers, and concludes with the gaps in the research.

2.1 Scenario of research in the field of GSCM

GSCM has been a topic of great interest among the researchers in last few years, and still the interest is continuing. Figure 2.1 shows the radar graph drawn on the basis of research publication in last five years, which explains the interest of researchers in GSCM.

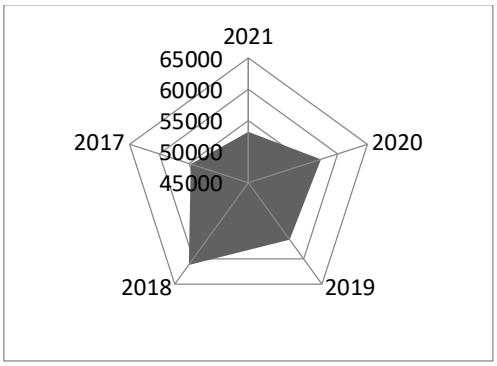

Figure 2.1: Radar Graph for last five years research publications
(www.scholar.google.com)

Figure 2.2 shows the Google trends data in India for the word green supply chain management.

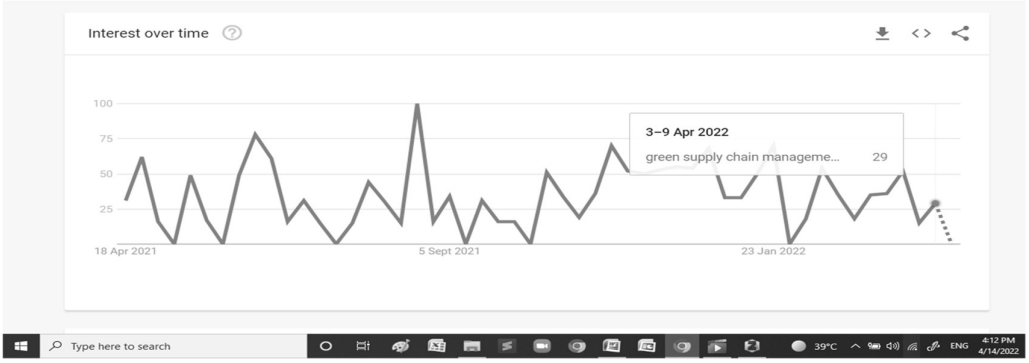

Figure 2.2: Google trend data in India for the word green supply chain management
(www.trends.google.com)

From Figure 2.1 and Figure 2.2 one can understand the importance of GSCM research in present context.

2.2 Contributions of Researchers in the field of GSCM

Present section tells about the contributions of researchers in the field of GSCM, as follows:

- **Panpatil & Kant (2022)**

This study identified twenty green chain practices conducted in consultation with a panel of industry and academic professionals. Explanatory structural modeling (used to

develop relationships between green supply chain practices, showing the direct and indirect impact of each green supply chain practice.

- **Fasan et al. (2021)**

Supply chain management has played an important role during the COVID-19 crisis, as the pandemic outbreak has disrupted much of all global supply chains. This article examines whether companies implementing green supply chain management (GSCM) practices have benefited from the buffering effect in the context of COVID-19.

- **J. Li & Sarkis (2021)**

This article comprehensively and systematically investigates and critiques the practice of environmental product design in environmental supply chain management research.

- **Huang et al. (2021)**

The of the research work shows that stakeholders in all countries simultaneously play three roles in ecodesign, similar to environmental regulations in China.

- **Elbaz & Iddik (2020)**

This article attempts to identify, summarize, and interpret the existing literature linking green supply chain management (GSCM) with culture.

- **Tseng et al. (2019)**

This study presents a comprehensive yet simple conceptual model for green supply chain management. The study results and directions for future research open new opportunities for further study and contributions to this discipline.

- **Yildiz Çankaya & Sezen (2018)**

The purpose of this article is to explore the impact of the eight dimensions of Green Supply Chain Management (GSCM), which are the three dimensions of business sustainability, on economic, environmental, and social performance

- **Kang & Hwang (2017)**

In this article, various inter-organizational measures for environmental supply chain management are classified according to different cooperation models and their structural relationships are analyzed using explanatory structural models.

- **Jabbour & de Sousa Jabbour (2016)**

The purpose of this study is to propose a synergistic and integrated framework for the GHRM-GSCM relationship and to propose a research agenda for this integration.

- **Singh and Trivedi (2016)**

This article aims to provide an updated and structured review of the literature on sustainable environmental supply chain management that has been published over the last decade.

- **Dube and Gawande (2016)**

The purpose of this article is to identify the barriers to green supply chain adoption and understand the relationship.

2.3 Gaps in the Research and Objectives of the Proposed Research

Following points represent gaps in the research:

a) A limited research is available on the investigations of effective number of green supply chainbarriers; and
b) There is a strong need of understanding investigations on the interdependencies among the barriers as well as ranking of different industrial areas on these barriers.

3. Solution Methodology

Present section portrays the details of solution methodology and techniques used for solving the research problem, the details of which are presented in upcoming sub-sections.

3.1 Steps in solution of Research Problem

Figure 3.1 shows the solution methodology used for solving the research problem.

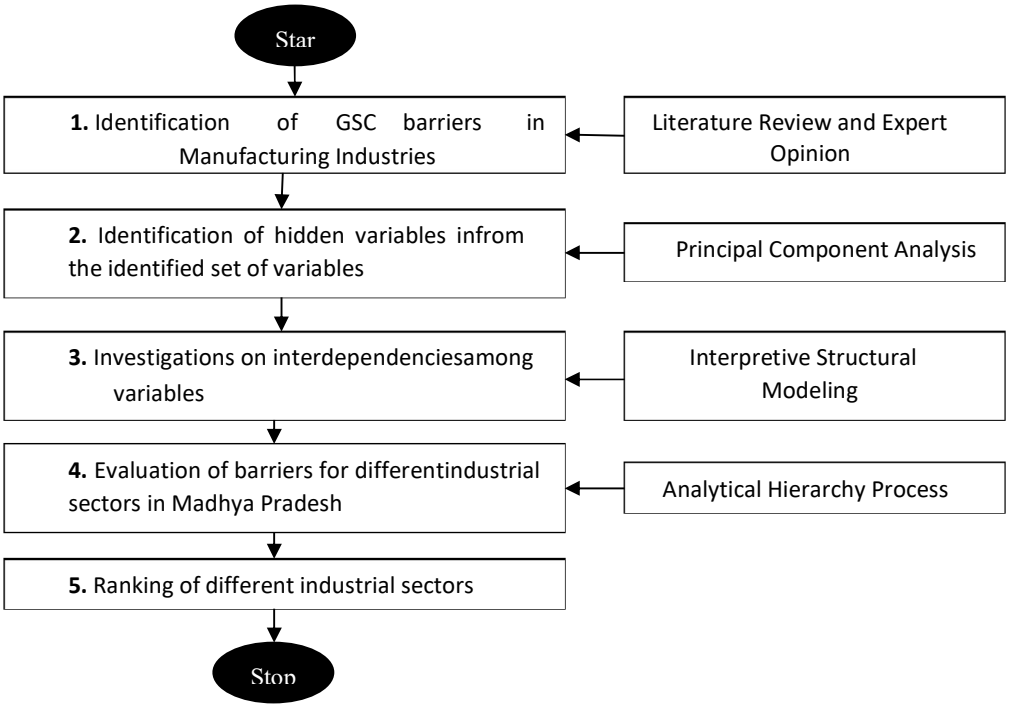

Figure 3.1: Solution methodology used for solving the research problem

Following points represent the procedure used for solving the research problem:

a) In the first step, a detailed list of barriers affecting the performance of green supply chain was prepared with the help of academia and industry personnel;
b) In next step, hidden barriers from the list of barriers were investigated with the help of a data reduction technique called principal components analysis;
c) In next step, interdependencies among the barriers were investigated using interpretive structural modeling;
d) In next step, evaluation of barriers was performed for different industrial sectors using analytical network process; and
e) In the last step of research ranking of different industrial sectors was performed.

Details of techniques used in solution methodology are presented in upcoming sub-sections.

3.1.1 Principal Components Analysis (PCA)

According to Illin and Raiko (2010), principal components analysis (PCA) is a classical data analysis technique that finds linear transformations of data that preserve the maximum variation. The goal of PCA is to explain the variance of the observed variables as best as possible using some confounding variables (commonly called components). Kothari (2004, p. 330) argues that the main components of factor analysis try to maximize the sum of the squared weights of each factor, which in turn is obtained. The aim of PCA is the construction out of a given set of variables Xj's (j = 1, 2… k) of new variables (pi), called principal components which are linear combinations of the Xs. Thus,

$$\begin{aligned} p_1 &= a_{11}X_1 + a_{12}X_2 + \cdots + a_{1k}X_K \\ p_2 &= a_{21}X_1 + a_{22}X_2 + \cdots + a_{2k}X_K \\ &\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ &\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ p_K &= a_{k1}X_1 + a_{k2}X_2 + \cdots + a_{kk}X_K \end{aligned} \tag{3.1}$$

The method is being applied mostly by using the following equation:

$$z_j = \left(X_j - \bar{X}_j\right)^2 / \sigma_j \tag{3.2}$$

Standardized variables, i.e.,

$$y_1 p_1 + y_2 p_2 \ldots + y_m p_m \ (m < k) \tag{3.3}$$

The term a_{ij} called loading.

Following steps are usually involved in principal components analysis:

a) Estimates of aij's are obtained with which X's are transformed into orthogonal variables i.e., the principal components;
b) Next step is the regression of Y on these principal components;
c) From the a_{ij} and y_{ij} ,one can find b_{ij} of the original model, transferring back from p_s into the standardized X_s.

3.1.2 Interpretive Structural Modeling (ISM)

The Explanatory Structural Modeling (ISM) proposed by Warfield (1974) is used to transform a complex system into a visual hierarchical structure. This systematic application of the fundamentals of graph theory uses theoretical, conceptual, and computational levers to construct a direct graph or network representation of complex models of contextual relationships between a set of elements. ISM theory is based on discrete mathematics, graph theory, social science, group decision making, and computational support. The steps suggested by Singh and Kant (2008) to implement the ISM method are as follows:

Step 1: List the variables that affect the system in question, which can be goals, objectives, people, etc.

Phase 2: Based on the variables defined in Phase 1, a contextual relationship is established between the variables with respect to the pairs of variables to be examined.

Step 3: A self-talk structural matrix (SSIM) is developed for the variables, indicating the pairwise relationships between the variables in the system under consideration.

Step 4: SSIM develops an accessibility matrix and the transitivity of the matrix is verified. The transitivity of the reference relation is the basic concept of ISM. It states that if the variable A is associated with B and B is associated with C, then A is necessarily associated with C.

Step 5: The range capability matrix obtained in step 4 is divided into several levels.

Step 6: Based on the previous relations in the availability matrix, an oriented diagram is constructed and the transitive relations are eliminated. Element i reaches another element j, so the entry in cell (i, j) of the accessibility matrix is 1, and if element i does not reach j, the entry in cell (i, j) of accessibility matrix is 0 The transitivity property of accessibility estimates also allows some cell arrays to be filled. The accessibility matrix has some pairwise comparison input and some derived input. The ISM process becomes more efficient as the number of required relational queries is reduced by 50-80% (Sohani and Sohani, 2012) through the use of transitive inference.

Step 7: The resulting digraph is converted to ISM, replacing the variable nodes with instructions.

Step 8: The ISM model developed in step 7 is checked for conceptual inconsistencies and any necessary changes are made.

3.1.3 Analytical Hierarchy Process (AHP)

The Analytical Hierarchy Process (AHP) allows you to break down the problem into a hierarchy of subtasks that are easier to understand and subjectively evaluate. Subjective scores are converted to numerical values and processed to rank each option on a numerical scale. The AHP methodology can be explained by the following steps:

Step 1: The problem is divided into a hierarchy of objectives, criteria, sub-criteria (if any), and alternatives. Structuring the decision problem into a hierarchy is fundamental to the AHP process. The hierarchy shows the relationship between items at one level and items at the next lower level. This connection permeates the lower levels of the hierarchy, and thus each element is at least indirectly related to the other. In Figure 3.2 shows an example of a hierarchical structure.

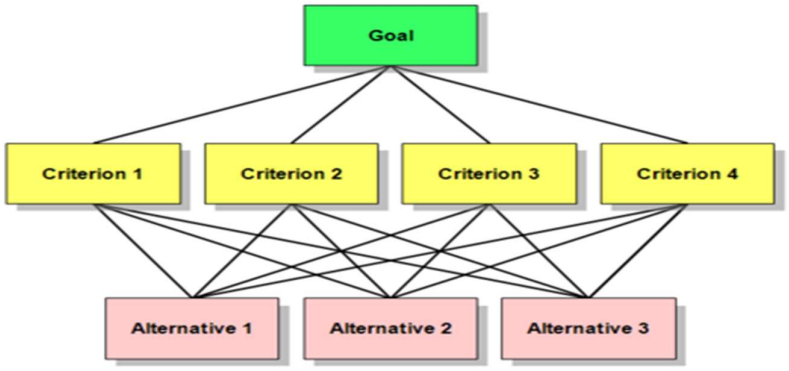

Figure 3.2: A Hierarchy for Analytical Hierarchy Process (Saaty, 1980)

Step 2: Data is collected from experts or decision makers according to a hierarchical structure to compare options in pairs according to a qualitative scale as shown in Table 3.1 below.

Table 3.1: Pair wise comparison scale for Analytical Hierarchy Process (Saaty, 1980)

Intensity of Importance	Definition	Explanation
1	Equal importance	Two elements contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor element over another
5	Strong importance	Experience and judgment strongly favor element over another
7	Very strong importance	One elements is favored very strongly over another; its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one element over another is of the highest possible order of affirmation
Intensities of 2, 4, 6 and 8 can be used to express intermediate values. Intensities 1.1, 1.2, 1.3, etc. can be used for elements that are very close in importance.		

Step 3: The pair wise comparisons of various criteria generated at step 2 are organized into a square matrix. The diagonal elements of the matrix are 1. The criterion in the ith row is better than criterion in the jth column if the value of element (i, j) is more than 1; otherwise the criterion in the jth column is better than that in the ith row. The (j, i) element of the matrix is the reciprocal of the (i, j) element.

Step 4: The principal eigenvalue and the corresponding normalized right eigenvector of the comparison matrix give the relative importance of the various criteria being compared.

Step 5: The consistency of the matrix of order n is evaluated. Comparisons made by this method are subjective and the AHP tolerates inconsistency through the amount of redundancy in the approach. If this consistency index fails to reach a required level then answers to comparisons may be re-examined. The consistency index, CI, is calculated as

$$CI = (\lambda_{max} - n)/(n - 1) \quad (3.4)$$

Where, λ_{max} is the maximum Eigen value of the judgment matrix. This CI can be compared with random consistency index (RI). The ratio derived, CI/RI, is termed the consistency ratio, CR. Value of CR should be less than 0.1. With the help of Table 3.2 value of RI may be identified.

Table 3.2: Values of Random Consistency Index (RI) (Saaty, 1980)

Size of Matrix	1	2	3	4	5	6	7	8	9	10
Random Consistency Index (R.I.)	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

With the help of AHP, decision on best alternative design may be easily made. For this purpose, local weights of alternatives are multiplied by the weights of the criteria and aggregated to get global ratings.

4. Case Study

Present research work investigates on the barriers in the field of implementation of GSCM in different manufacturing industries in Madhya Pradesh.

4.1 Targeted Industrial Areas

Targeted industries for the implementation of research work were from different industrial sectors belonging to Pithampur & Indore, Dewas, Ujjain, Mandasur and Ratlam, on the account of following reasons:

1. Sufficient number of manufacturing units; and
2. Enough manpower.

4.2 Problem Formulation

The research problem was the investigations on GSCM barriers, under which focus has been made on the creation of list of easily computable barriers, finding interdependencies among the barriers, and ranking of industrial areas on the basis of barriers.

4.3 Solution of the Problem

Following are the main stages of methodology used for solution of the model:

a) Criteria collection;
b) Criteria finalization using principal component analysis;
c) Investigations on the relationships between the criteria with the help of Interpretive structural modeling; and
d) Evaluation of alternatives using AHP.

Details of above mentioned stages are given as follows:

a) Criteria Collection

In this stage, a list of criteria was prepared by the candidate with the help of detailed survey of available literature, and expert opinion. With the help of an expert, that list was sorted to *twenty six* criteria and classified into *three* classes, *cost factors, lacking factors and other factors,* as follows:

Table 4.1: Distribution of criteria

S. No	Main Barriers	Component Barriers	Abbreviations
1.	Cost Factors	High_cost of Systems	HCS
2.		Cost_reduction_at_the_cost_of_environment	CRCE
3.		Cost_of_eco-friendly_packaging	CEP
4.		No_/low_return_from_investment	NRI
5.		Pressure_for_lower_price_with_competitors	PLPC
6.		Pressure_for_lower_prices	PLP
7.	Lacking Factors	Lack_of_technology_infrastructure	LTI
8.		Lack_of_skilled_human_resources_in_implementation_of_GSCM	LSHRIGSCM
9.		Lack_of_government_support	LGS
10.		Lack_of_information_technology	LIT
11.		Lack_of_ethical_standards_and_corporate_social_responsibility	LESCSR

12.		Lack_of_demand_and_public_awarenes s	LDPA
13.		Lack_of_awareness_in_the_society	LAS
14.		Lack_of_knowledge_and_experience_a mong_suppliers	LKES
15.		*Lack_of_understanding_among_supply _chain_stakeholders*	LUASCS
16.		Lack_of_understanding_to_incorporate _green_buying	LUIGM
17.		Lack_of_management_commitment	LMC
18.		Lack_of_adaptation_of_advancement_i n_technology/manuacturers_reluctatnce _to_change	AAAT
19.		Lack_of_training	LTRNG
20.	Other Factors	Too_complex_to_implement	TCI
21.		Inappropriate_organizational_structure	IOS
22.		Poor_supplier_commitment	PSC
23.		Not_willing_to_change_trade_informati on	NWCTI
24.		Inhibits_innovation_	II
25.		Competition_and_uncertainity	CU
26.		Reluctant_to_change_towards_GSCM	RCTGSCM

b) Criteria Finalization

The next stage in solution methodology is *criteria finalization*. From the review of available literature, it was realized that in spite of having list of criteria, it was quite impracticable to use. So, therefore, decided to obtain the hidden variables (principal components), lying within sets of criteria. For this purpose, one of the very renowned multivariate techniques *principal component analyses* was used. Following are the sub-stages of the procedure:

[1] First of all, a *criteria survey sheet* was prepared and sent to various industries in the country as well as abroad, to know the degree of importance of GSCM evaluation criteria in their organization. Following are the details of responses:

Table 4.2: Details of responses collected for criteria finalization

S.No	Item	Output
1.	Total number of questionnaire sent	300
2.	Type of scale used	Likert Scale
3.	Number of industries covered	300
4.	Type of industries covered	Manufacturing
5.	Number of responses obtained	223
6.	Number of complete responses obtained	223
7.	Response ratio	74%
8.	Regions covered	Different industrial sectors of the Country

[2] As next sub-stage, *principal component analysis* was applied to the responses obtained. During the obtainment of principal components, *seven* out of *twenty six* criteria were eliminated due to their less factor loadings,. As a result, *nine* principal components consisting of *nineteen* GSCM barriers were obtained. Following are the results obtained:

Table 4.3: Identification of Principal Components

S. No	Identified Categories	Principal Components	Component Variables	Abbreviation	Factor loadings	α
1.	Cost Factors	Costs associated with firms	Cost_of_eco-friendly_packaging	CEP	.782	0.602
2.			High_cost of Systems	HC	.655	
3.			No_/low_return_from_investment	NRI	.626	
4.		Pressures for cost reduction	Pressure_for_lower_price_with_competitors	PLPC	.837	
5.			Pressure_for_lower_prices	PLP	.797	
6.	Lacki ng	Lack of supplier and	Lack_of_knowledge_and_experience_among_suppliers	LKES	.842	0.728

7.		management commitment	Lack_of_management_commitment	LMC	.834	
8.		Lack of demand and training	Lack_of_training	LTRNG	.702	
9.			Lack_of_demand_and_public_awareness	LDPA	.669	
10.		Lack of technical and human resources	Lack_of_technology_infrastructure	LTI	.852	
11.			Lack_of_skilled_human_resources_in_implementation_of_GSCM	LSHRIGSCM	.677	
12.		Lack of social and technical awareness	Lack_of_awareness_in_the_society	LAS	.846	
13.			Lack_of_adaptation_of_advancement_in_technology/manuacturers_reluctatnce_to_change	LAAAT	.604	
14.		Lack of Information technology	Lack_of_information_technology	LIT	.900	
15.	**Other Factors**	Non readiness of different organizational factors	Competition_and_uncertainity	CU	.751	0.638
16.			Too_complex_to_implement	TCI	.749	
17.			Not_willing_to_change_trade_information	NWCTI	.726	
18.			Reluctant_to_change_towards_GSCM	RCTGSCM	.582	
19.		Inappropriate organizational structures	Inappropriate_organizational_structure	IOS	.807	

c) Investigations on Interdependencies among the Criteria

In order to investigate the interdependencies among the criteria, a well known technique, ***interpretive structural modeling (ISM),*** was used. For this purpose a systematically designed questionnaire was sent to a group of experts, which yield the following responses:

Table 4.4: Responses in the form of Matrix

	C9	C8	C7	C6	C5	C4	C3	C2	C1
C1	A	A	A	A	A	A	A	A	

C2	V	V	V	0	V	A	0		
C3	V	V	V	V	V	A			
C4	V	V	X	X	V				
C5	X	V	V	X					
C6	V	V	V						
C7	V	V							
C8	X								
C9									

On following the above matrix, initial reachability matrix was obtained, as follows:

Table 4.5: Initial Reachability Matrix

From/To	C1	C2	C3	C4	C5	C6	C7	C8	C9	Driving power
C_1	1	0	0	0	0	0	0	0	0	1
C_2	1	1	0	0	1	0	1	1	1	6
C_3	1	0	1	0	1	1	1	1	1	7
C_4	1	1	1	1	1	1	1	1	1	9
C_5	1	0	0	0	1	1	1	1	1	6
C_6	1	0	0	1	1	1	1	1	1	7
C_7	1	0	0	1	0	0	1	1	1	5
C_8	1	0	0	0	0	0	0	1	1	3
C_9	1	0	0	0	1	0	0	1	1	4
Dependence Power	9	2	2	3	6	4	6	8	8	

From initial reachability matrix, different levels for criteria were obtained, as shown below.

Table 4.6: Iteration for Level 1

Criteria	Rechability Set (Criteria No.)	Antecedent Set (Criteria No.)	Intersection (Criteria No.)	Level
C_1	1	1, 2, 3, 4, 5, 6, 7, 8, 9	1	1
C_2	1, 2, 5,7, 8, 9	2, 4	2	
C_3	1, 3, 5, 6, 7, 8, 9	3, 4	3	
C_4	1, 2, 3, 4, 5, 6, 7, 8, 9	4, 6, 7	4, 6, 7	
C_5	1, 5, 6, 7, 8, 9	2, 3, 4, 5, 6, 9	5, 6, 9	

C6	1, 4, 5, 6, 7, 8, 9	3, 4, 5, 6	4, 5, 6	
C7	1, 4, 7, 8, 9	2, 3, 4, 5, 6, 7	4, 7	
C8	1, 8, 9	2, 3, 4, 5, 6, 7, 8, 9	8, 9	
C9	1, 5, 8, 9	2, 3, 4, 5, 6, 7, 8, 9	5, 8, 9	

Table 4.7: Iteration for Level 2

Criteria	Rechability Set (Criteria No.)	Antecedent Set (Criteria No.)	Intersection (Criteria No.)	Level
C2	2, 5,7, 8, 9	2, 4	2	
C3	3, 5, 6, 7, 8, 9	3, 4	3	
C4	2, 3, 4, 5, 6, 7, 8, 9	4, 6, 7	4, 6, 7	
C5	5, 6, 7, 8, 9	2, 3, 4, 5, 6, 9	5, 6, 9	
C6	4, 5, 6, 7, 8, 9	3, 4, 5, 6	4, 5, 6	
C7	4, 7, 8, 9	2, 3, 4, 5, 6, 7	4, 7	
C8	8, 9	2, 3, 4, 5, 6, 7, 8, 9	8, 9	2
C9	5, 8, 9	2, 3, 4, 5, 6, 7, 8, 9	5, 8, 9	2

Table 4.8: Iteration for Level 3

Criteria	Rechability Set (Criteria No.)	Antecedent Set (Criteria No.)	Intersection (Criteria No.)	Level
C2	2, 5,7	2, 4	2	
C3	3, 5, 6, 7	3, 4	3	
C4	2, 3, 4, 5, 6, 7	4, 6, 7	4, 6, 7	
C5	5, 6, 7	2, 3, 4, 5, 6,	5, 6	
C6	4, 5, 6, 7	3, 4, 5, 6	4, 5, 6	
C7	4, 7	2, 3, 4, 5, 6, 7	4, 7	3

Table 4.9: Iteration for Level 4

Criteria	Rechability Set (Criteria No.)	Antecedent Set (Criteria No.)	Intersection (Criteria No.)	Level
C_2	2, 5	2, 4	2	
C_3	3, 5, 6	3, 4	3	
C_4	2, 3, 4, 5, 6	4, 6	4, 6	
C_5	5, 6	2, 3, 4, 5, 6,	5, 6	4
C_6	4, 5, 6	3, 4, 5, 6	4, 5, 6	4

Table 4.10: Iteration for Level 5

Criteria	Rechability Set (Criteria No.)	Antecedent Set (Criteria No.)	Intersection (Criteria No.)	Level
C_2	2	2, 4	2	5
C_3	3	3, 4	3	5
C_4	2, 3, 4	4	4	

Table 4.11: Iteration for Level 6

Criteria	Rechability Set (Criteria No.)	Antecedent Set (Criteria No.)	Intersection (Criteria No.)	Level
C_4	4	4	4	6

In next step, all the levels were assembled as follows.

Table 4.12: Levels of Criteria

Criteria	**Rechability Set (Criteria No.)**	**Antecedent Set (Criteria No.)**	**Intersection**	**Level**
C_1	1	1, 2, 3, 4, 5, 6, 7, 8, 9	1	1
C_8	8, 9	2, 3, 4, 5, 6, 7, 8, 9	8, 9	2
C_9	5, 8, 9	2, 3, 4, 5, 6, 7, 8, 9	5, 8, 9	2
C_7	4, 7	2, 3, 4, 5, 6, 7	4, 7	3
C_5	5, 6	2, 3, 4, 5, 6,	5, 6	4
C_6	4, 5, 6	3, 4, 5, 6	4, 5, 6	4
C_2	2	2, 4	2	5

C_3	3	3, 4	3	5
C_4	4	4	4	6

From above table, cluster wise distribution of criteria was accomplished, as follows.

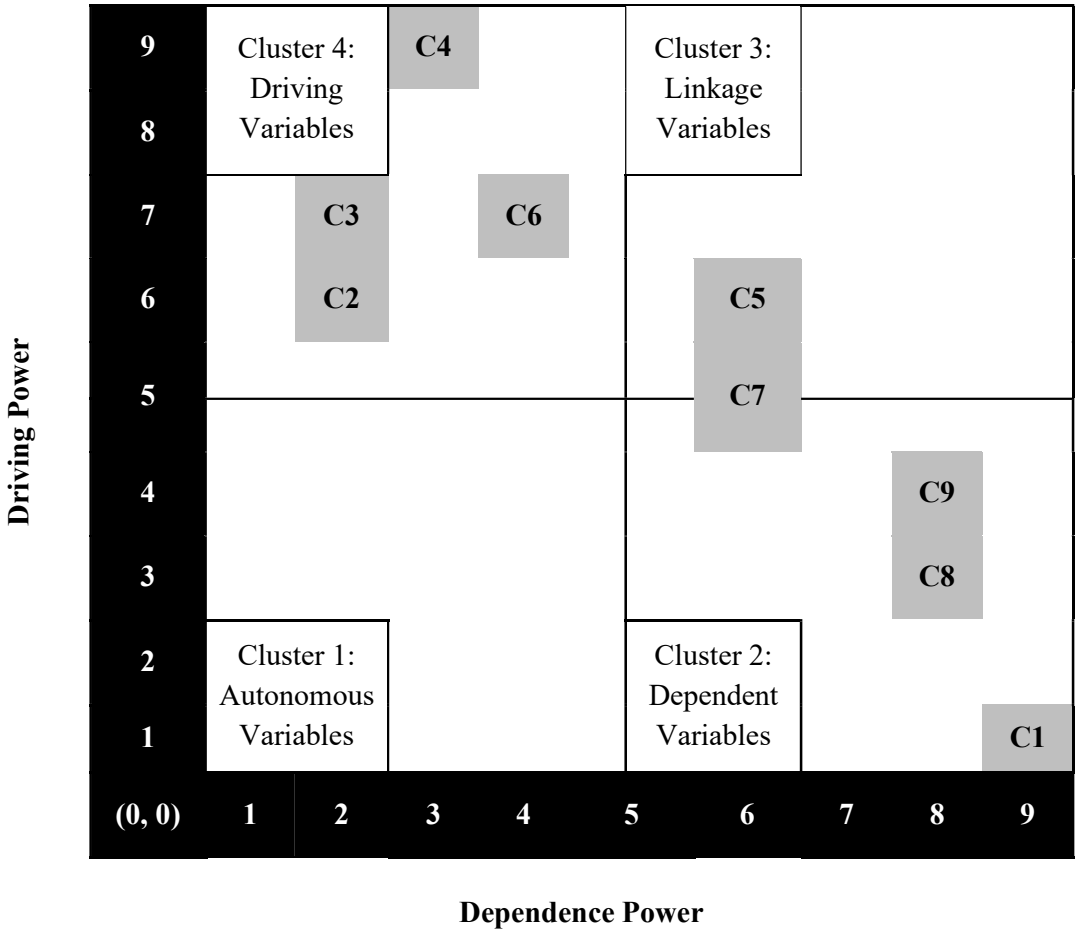

Figure 4.1: Cluster-wise Distribution of Criteria

From cluster wise distribution, diagraph showing relationships among the criteria was obtained as follows.

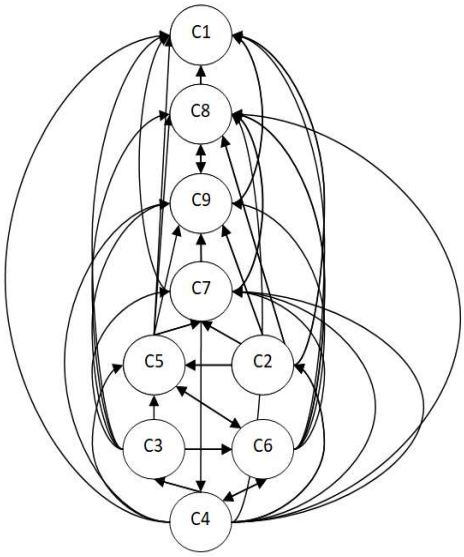

Figure 4.2: Diagraph for different GSCM Criteria (without transitivity removal)

From above diagraph, after removal of all transitivity elements, following diagraph was obtained.

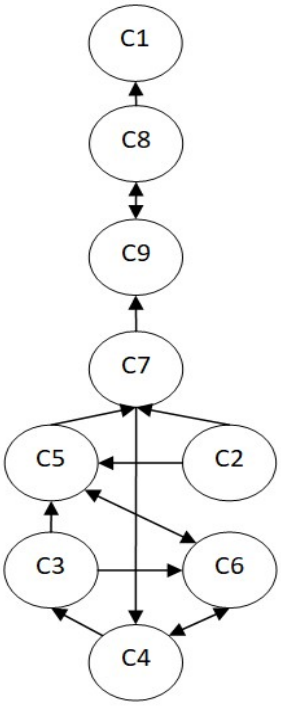

Figure 4.3: Diagraph for different GSCM Criteria (with transitivity removal)

Figure 4.4 shows the ISM model showing the relationships among different criteria.

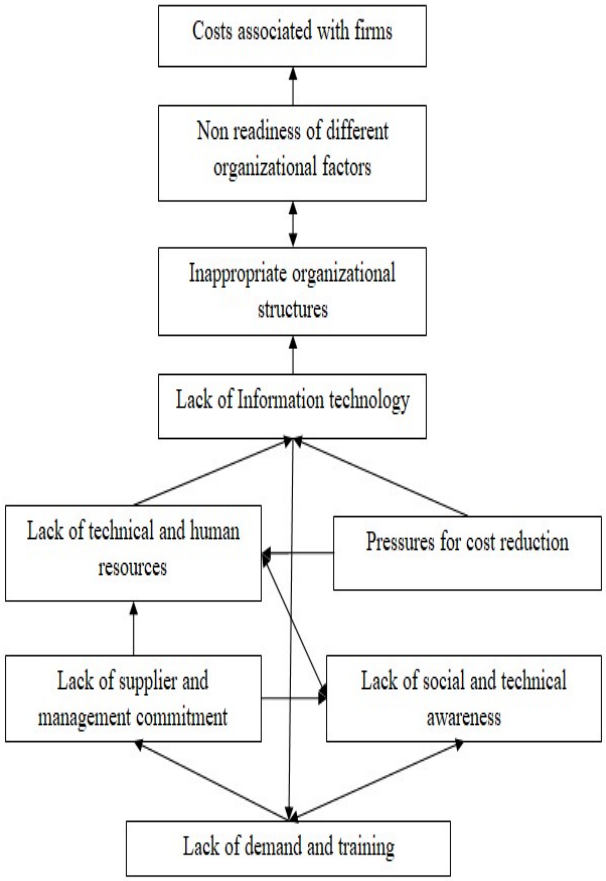

Figure 4.4: ISM Model showing relationships among different Criteria

In next stage, *prioritization of criteria* was accomplished. For, this purpose, a systematically designed questionnaire was sent to industries personnel. The same questionnaire was used for evaluation of alternatives. Following are the details of responses obtained:

Table 4.13: Details of responses collected for prioritization of criteria, and evaluation of alternatives

S. No	Item	Output
1.	Type of scale used	5-point Likert scale
2.	Total number of questionnaire sent	150
3.	Number of industries covered	90
4.	Type of industries covered	Manufacturing industries
5.	Number of responses obtained	127
6.	Number of complete responses obtained	127

7.	Response ratio	85%
8.	Number of industries covered	74
9.	Regions covered	5 districts of MP

Following are the demographic details of respondents:

Table 4.14: Demographic details of Respondents

S.No	City	Industries covered	Responses collected
1.	Pithampur	31	31
2.	Ujjain	15	15
3.	Dewas	9	9
4.	Ratlam	8	8
5.	Mandsaur	11	11
Total		**74**	**74**

In order to prioritize the criteria (principal components), average value of responses scored by different criteria from all the respondents were recorded. Following are the details:

Table 4.15: Average values of responses for criteria prioritization

S. No	Criteria	Abbreviation	Average value
1	Costs associated with firms	C1	3.912
2	Pressures for cost reduction	C2	3.888
3	Lack of supplier and management commitment	C3	4.163
4	Lack of demand and training	C4	4.263
5	Lack of technical and human resources	C5	3.836
6	Lack of social and technical awareness	C6	3.900
7	Lack of Information technology	C7	3.883
8	Non readiness of different organizational factors	C8	3.836
9	Inappropriate organizational structures	C9	3.830

As a next stage, the average values of criteria obtained from Table 4.16 was sent to a group of experts in the form of systematically designed questionnaire to get pair wise comparisons, opinions from which are shown in the form of pair wise comparison matrix, given below:

Table 4.16: Pair wise comparison Matrix for Criteria

From/To	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	**1**	2	1	5	4	8	6	7	6
C2		**1**	2	1	2	3	2	6	7
C3			**1**	1	2	2	4	5	7
C4				**1**	2	3	2	4	6
C5					**1**	2	1	5	8
C6						**1**	2	5	7
C7							**1**	1	6
C8								**1**	2
C9									**1**

For the purpose of prioritization of criteria, a renounced MCDM technique, *analytical hierarchy process* (AHP) is used. Table 4.17 shows the details of AHP aspects adopted for this purpose:

Table 4.17: Details of AHP aspects adopted for prioritization of criteria

S. No	AHP Aspect	Details
1.	AHP Version	Crisp AHP
2.	Scale used	9-Point Saaty's scale
3.	Type of scale	Pair wise comparison type
4.	Software used	Super decisions software

In next stage, pair wise comparison values from Table 4.18 .were fed to the AHP software, which gave the values of priorities of different criteria. Following are the details of results obtained:

Table 4.18: Priorities of Criteria

S. No	Criteria	Abbreviation	Priority Value	Percentage
1.	Costs associated with firms	C_1	0.303169	30.32
2.	Pressures for cost reduction	C_2	0.157255	15.7
3.	Lack of supplier and management commitment	C_3	0.15044	15.1
4.	Lack of demand and training	C_4	0.124874	12.5
5.	Lack of technical and human resources	C5	0.0889139	8.9

6.	Lack of social and technical awareness	C_6	0.0722053	7.2
7.	Lack of Information technology	C_7	0.0559199	5.6
8.	Non readiness of different organizational factors	C_8	0.028997	2.9
9.	Inappropriate organizational structures	C_9	0.018226	1.8
C.R. = 0.069701 < 0.10 (from CI=0.1011)				

Table 4.11 shows equal participation of the criteria towards goal, as well as consistency of the results. Figure 4.5 .shows the contribution of each criterion towards the goal, below.

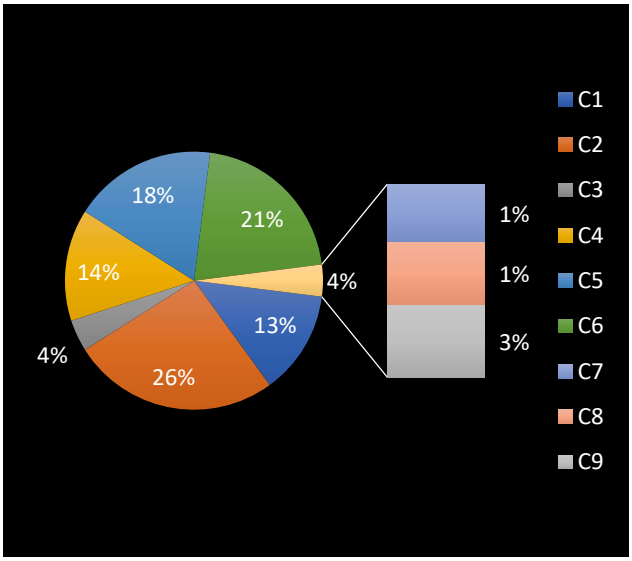

Figure 4.5: Contribution of criteria towards the goal

d) Evaluation of alternatives using AHP

In the last stage of solution methodology, evaluation of alternatives is accomplished by a MCDM approach. The MCDM approaches used was *analytical hierarchy process* (AHP). In order to obtain scores of industries from different cities, first of all, average of summation values of responses scored by cities under different criteria, obtained from questionnaire were recorded. For the purpose of prioritization of alternatives using AHP, scores of different alternatives shown in Table 4.19 were structured in the form of questionnaire to a group of experts. Experts provide their opinions on the basis of pair wise comparison. On the basis of opinions, AHP was implemented, various aspects of which are given as follows:

Table 4.19: Details of AHP aspects adopted for prioritization of Alternatives

S. No	AHP Aspect	Details
1.	AHP Version	Crisp AHP
2.	Scale used	9-Point Saaty's scale
3.	Type of scale	Pair wise comparison type
4.	Software used	Super decisions software

Following are the details of pair wise comparison matrices and investigated priorities for different criteria:

Table 4.20: Pairwise Comparison Matrix for GSCM Barrier "Costs associated with firms"

From/To	Ratlam	Pithampur	Mandsaur	Dewas	Ujjain
Ratlam	1	5	1/6	5	2
Pithampur		1	1/8	1/2	1/4
Mandsaur			1	7	7
Dewas				1	1/3
Ujjain					1

Table 4.21: Local and Global Priorities for Different Industrial Areas for the GSCM Barrier "Costs associated with firms"

Industrial Area	Local Priorities	Global Priorities
Ratlam	0.185411	0.05621087
Pithampur	0.0390309	0.01183296
Mandsaur	0.604588	0.18329234
Dewas	0.0553617	0.01678395
Ujjain	0.115609	0.03504906
C.R. = 0.094087< 0.10 (from CI= 0.0840062 and RI = 1.12)		

Table 4.22: Pairwise Comparison Matrix for GSCM Barrier "Pressures for cost reduction"

From/To	Ratlam	Pithampur	Mandsaur	Dewas	Ujjain
Ratlam	1	5	1/6	5	2
Pithampur		1	1/8	1/2	1/2
Mandsaur			1	7	7
Dewas				1	1/2
Ujjain					1

Table 4.23: Local and Global Priorities for Different Industrial Areas for GSCM Barrier "Pressures for cost reduction"

Industrial Area	Local Priorities	Global Priorities
Ratlam	0.192217	0.03022708
Pithampur	0.0449731	0.00707224
Mandsaur	0.608505	0.09569045
Dewas	0.0614225	0.009659
Ujjain	0.0928821	0.01460617
C.R. = 0.073257< 0.10 (from CI= 0.0654077 and RI = 1.12)		

Table 4.24.: Pairwise Comparison Matrix GSCM Barrier "Lack of supplier and management commitment"

From/To	Ratlam	Pithampur	Mandsaur	Dewas	Ujjain
Ratlam	1	5	1/4	4	3
Pithampur		1	1/8	1/2	1/3
Mandsaur			1	6	7
Dewas				1	1/4
Ujjain					1

Table 4.25: Local and Global Priorities for Different Industrial Areas for GSCM Barrier "Lack of supplier and management commitment"

Industrial Area	Local Priorities	Global Priorities
Ratlam	0.219558	0.033030306
Pithampur	0.0423457	0.006370487
Mandsaur	0.557491	0.083868946
Dewas	0.0604598	0.009095572
Ujjain	0.120146	0.018074764
C.R. = 0.0855661 < 0.10 (from CI=0.0855661 and RI = 1.12)		

Table 4.26: Pairwise Comparison Matrix for GSCM Barrier "Lack of Demand and Training"

From/To	Ratlam	Pithampur	Mandsaur	Dewas	Ujjain
Ratlam	1	4	1/5	4	2
Pithampur		1	1/8	1/2	1/3
Mandsaur			1	6	8
Dewas				1	1/4
Ujjain					1

Table 4.27: Local and Global Priorities for Different Industrial Areas for GSCM Barrier "Lack of Demand and Training"

Industrial Area	Local Priorities	Global Priorities
Ratlam	0.179036	0.02235694

Pithampur	0.0436442	0.00545003
Mandsaur	0.594305	0.07421324
Dewas	0.0601194	0.00750735
Ujjain	0.122896	0.01534652
C.R. = 0.09941< 0.10 (from CI=0.0887587 and RI = 1.12)		

Table 4.28: Pairwise Comparison Matrix for GSCM Barrier "Lack of technical and human resources"

From/To	Ratlam	Pithampur	Mandsaur	Dewas	Ujjain
Ratlam	1	4	1/5	4	1
Pithampur		1	1/8	1/2	1/3
Mandsaur			1	6	8
Dewas				1	1/4
Ujjain					1

Table 4.29: Local and Global Priorities for Different Industrial Areas for GSCM Barrier "Lack of technical and human resources"

Industrial Area	Local Priorities	Global Priorities
Ratlam	0.155872	0.01385919
Pithampur	0.0439295	0.00390594
Mandsaur	0.600671	0.053408
Dewas	0.0603213	0.0053634
Ujjain	0.139206	0.01237735
C.R. = 0.094948 < 0.10 (from CI= 0.0847753and RI = 1.12)		

Table 4.30: Pairwise Comparison Matrix for GSCM Barrier "Lack of social and technical awareness"

From/To	Ratlam	Pithampur	Mandsaur	Dewas	Ujjain
Ratlam	1	4	1/5	4	1
Pithampur		1	1/8	1/2	1/3
Mandsaur			1	6	7
Dewas				1	1/4
Ujjain					1

Table 4.31: Local and Global Priorities for Different Industrial Areas for GSCM Barrier "Lack of social and technical awareness"

Industrial Area	Local Priorities	Global Priorities
Ratlam	0.159596	0.01152368
Pithampur	0.0447321	0.00322989
Mandsaur	0.589561	0.04256943
Dewas	0.0613016	0.0044263
Ujjain	0.14481	0.01045605
C.R. = 0.085044 < 0.10 (from CI=0.0759 and RI = 1.12)		

Table 4.32: Pairwise Comparison Matrix for GSCM Barrier "Lack of Information Technology"

From/To	Ratlam	Pithampur	Mandsaur	Dewas	Ujjain
Ratlam	1	3	1/5	3	1
Pithampur		1	1/8	1/2	1/3
Mandsaur			1	6	7
Dewas				1	1/4
Ujjain					1

Table 4.33: Local and Global Priorities for Different Industrial Areas for GSCM Barrier "Lack of Information technology"

Industrial Area	Local Priorities	Global Priorities
Ratlam	0.142843	0.00798777
Pithampur	0.0479661	0.00268226
Mandsaur	0.594648	0.03325266
Dewas	0.0656751	0.00367255
Ujjain	0.148867	0.00832463
C.R. = 0.073208 < 0.10 (from CI=0.0653641 and RI = 1.12)		

Table 4.34.: Pairwise Comparison Matrix for GSCM Barrier "Non readiness of different organizational factors"

From/To	Ratlam	Pithampur	Mandsaur	Dewas	Ujjain
Ratlam	1	3	1/5	3	1
Pithampur		1	1/8	1/2	1/4
Mandsaur			1	6	7
Dewas				1	1/4
Ujjain					1

Table 4.35: Local and Global Priorities for Different Industrial Areas for GSCM Barrier "Non readiness of different organizational factors"

Industrial Area	Local Priorities	Global Priorities
Ratlam	0.141007	0.00408878
Pithampur	0.0450189	0.00130541
Mandsaur	0.594299	0.01723289
Dewas	0.064361	0.00186628
Ujjain	0.155314	0.00450364
C.R. = 0.076023 < 0.10 (from CI= 0.0679 and RI = 1.12)		

Table 4.36: Pairwise Comparison Matrix for GSCM Barrier "Inappropriate organizational structures"

From/To	Ratlam	Pithampur	Mandsaur	Dewas	Ujjain
Ratlam	1	3	1/5	3	1
Pithampur		1	1/8	1/2	1/4
Mandsaur			1	6	7

Dewas				1	1/2
Ujjain					1

Table 4.37: Local and Global Priorities for Different Industrial Areas for GSCM Barrier "Inappropriate organizational structures"

Industrial Area	Local Priorities	Global Priorities
Ratlam	0.147191	0.002682703
Pithampur	0.04648	0.000847144
Mandsaur	0.59711	0.010882927
Dewas	0.0738977	0.001346859
Ujjain	0.135321	0.002466361
C.R. =0.051575 < 0.10 (from CI=0.0460488 and RI = 1.12)		

Following are the details of overall results obtained:

Table 4.38: Ranking of Alternatives

S. No	City	Criteria									Sum Of Priorities For	Ranking of
		C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9		
		Global Priority Values										
1	**Ratlam**	0.056211	0.030227	0.03303	0.022357	0.013859	0.011524	0.007988	0.004089	0.002683	0.182	**2**
2	**Pithampur**	0.011833	0.007072	0.00637	0.00545	0.003906	0.00323	0.002682	0.001305	0.000847	0.043	**5**
3	**Mandsaur**	0.183292	0.09569	0.083869	0.074213	0.053408	0.042569	0.033253	0.017233	0.010883	0.594	**1**
4	**Dewas**	0.016784	0.009659	0.009096	0.007507	0.005363	0.004426	0.003673	0.001866	0.001347	0.060	**4**
5	**Ujjain**	0.035049	0.014606	0.018075	0.015347	0.012377	0.010456	0.008325	0.004504	0.002466	0.12	**3**
Summation		**0.30317**	**0.15725**	**0.15044**	**0.12487**	**0.08891**	**0.07221**	**0.05592**	**0.029**	**0.01823**	**1**	
CR		0.094087	0.073257	0.085566	0.09941	0.094948	0.085044	0.073208	0.076023	0.051575		

5. Results and Discussion

Present section tells about the details of results obtained and discussion made about the results, as shown in upcoming sub-sections.

5.1 Results

Present research work is focused on two types of operations on GSCM barriers; investigations on relationship among the barriers and prioritization of industrial areas on the basis of GSCM barriers, for which two techniques, namely, ISM modeling and AHP were, the results of which are as follows:

5.1.1 Results of Principal Component Analysis

Following set of GSCM barriers was obtained as the result of application of principal components analysis:

a) Costs associated with firms
b) Pressures for cost reduction
c) Lack of supplier and management commitment
d) Lack of demand and training
e) Lack of technical and human resources
f) Lack of social and technical awareness
g) Lack of Information technology
h) Non readiness of different organizational factors
i) Inappropriate organizational structures

5.1.2 Results of ISM Modeling

Following points represent the results of application of ISM modeling approach:

Driving Variables:

a) Pressures for cost reduction
b) Lack of supplier and management commitment
c) Lack of demand and training
d) Lack of social and technical awareness

Linkage Variables:

a) Lack of technical and human resources
b) Lack of Information technology

Dependent Variables:

a) Costs associated with firms
b) Non readiness of different organizational factors
c) Inappropriate organizational structures

5.1.3 Results of AHP

Analysis of AHP for ranking of GSCM barriers shows the following results:

a) Barrier costs associated with firms scores rank I with the maximum priority of 0.303;
b) Barrier Pressures for cost reduction scores rank II with second highest priority of 0.157;

c) Barrier Lack of supplier and management commitment scores rank III with third rank with the priority of 0.151.

Analysis of AHP for ranking of industrial areas on GSCM barriers shows the following results:
a) Industrial area of Mandsaur shows highest rank on GSCM barriers with the priority value of 0.594
b) Industrial area of Ratlam scores second highest rank with the priority value of 0.182;
c) Pithampur industrial area scores rank five by scoring priority value of 0.04.

5.2 Discussion

Application principal component analysis on the list of identified barriers, yielded justified numbers of barriers for further analyses, and covered all the dimensions of GSCM.

The results of ISM modeling tells about the basic facts behind the driving, linkages and dependent variables. From the model one can easily investigate the importance of the barriers, pressures for cost reduction, lake of supplier and management commitment, lack of demand and training and lack of social and technical awareness. All these parameters show the vision of the firms and according to their visions, firms work. Enhancement in the competitions among the firms, even for their survivals, puts the pressures for the reduction of cost, which acts as one of the most important driving variables for the other ones, due to all the parameters get affected.

The second driving variable is the lack of supplier and management commitment, which also acts as a major problem in the implementation of green supply chain in the firm. There may be many reasons behind this barrier. Many a times, it can be seen that management personnel as well as suppliers deny their promises for small profits, due to which desired results cannot be obtained.

Lack of demand and training as well as lack of social and technical awareness act as other barriers in GSCM implementation, due to which industries fear to implement GSCM in their routing procedures, as a result of which there exists a large gap between industries and implementation of GSCM. From above discussion, it can be seen above mentioned barriers affect severely the implementation of GSCM and also activate other barriers.

GSCM barriers, lack of technical and human resources and lack of information technology, were found as linkage variables. These two act between driving and dependent variables. Technical and human resources are considered as the backbone of any organization, and if these two are absent, organization can't survive. In case of GSCM, if the employees are not aware about its importance, plus they don't have the technology to handle GSCM affairs, the firm shall not adopt it. Considering the importance of GSCM, firms should provide

considerable focus on these two, because, if these two are not eliminated, the firm shall not be able to implement GSCM in its culture.

GSCM barriers, costs associated with firms, non readiness of different organizational factors, and inappropriate organizational structures were found as dependent variables. These are called depended because they exist due to driving and linkage variables. Anybody can understand the importance of cost reduction for a firm. It has already been discussed due to huge competition, every firm tries to reduce the cost as much as possible, and GSCM exerts extra cost bourdon on the firms due to which they hesitate to adopt GSCM practices, in their regular procedures.

Non readiness of different organizational factors and inappropriate organizational culture are other barriers in the implementation of GSCM. These two are based on other barriers like lack of technical and human resources, lack of information technology, lack of training, lack of commitments and awareness, costs, etc. These two can be minimized and even eliminated by proper creating awareness among the employees among GSCM, proper training, prioritizing GSCM over conventional SCM, reforming industrial procedures, and other such practices.

Results of prioritization of GSCM barriers shows the maximum priority of barrier, costs associated with the firms, and the second rank holder is the barrier, pressures for cost reduction. Both barriers, directly affect all the operations, procedures and practices of firms, and decide the intensity of all other barriers.

Lack of supplier and management commitment and lack of demand and training are the other barriers which greatly affect the implementation of GSCM in industries. Out of these two, the barrier, supplier and management commitment, is difficult to handle. The barrier lack of demand and training can be eliminated by creating awareness about the importance of GSCM for a firm.

GSCM barriers, lack of technical and human resources and lack of social and technical awareness scored rank V and VI. These two can also be eliminated by creating awareness about GSCM. It can also be found that the if the barrier, lack of social and technical awareness is minimized, it can lead to the minimization of other barriers, too, because many barriers are existing only due to lack of awareness for GSCM in the society and firms.

Barriers, lack of information technology, non readiness of different organizational factors and inappropriate organizational structures, scored for ranks VII, VIII and IX. It can be realized that these are the barriers which can be easily eliminated, by making considerable changes in the management commitments, realizing the importance of GSCM and creating awareness for it.

Rankings of industrial sectors show the level of adoption of GSCM practices and status of GSCM barriers in their industries. Industrial area of Mandsaur shows the maximum intensity of GSCM barriers and scores rank I, whereas Pithampur industrial area shows minimum intensity of GSCM barriers and scores rank V. All other industrial areas, namely, Ratlam, Ujjain and Dewas, score rank II, III and IV, which tells about the conditions of GSCM barriers in their industries. There may be many factors behind such reasons but the main factors are size of firms, lack of awareness, connectivity of other industrial areas, and adherence to the government norms.

In Pithampur and Dewas, majority of the firms are renounced ones and big exporters due to which, they are financially strong as well as they realize the importance of GSCM. Plus, they also compulsorily remain stick to the government norms, due to which they face very less GSCM barriers. On the other hand, firms belonging to Ujjain, Ratlam and Mandsaur, are mainly micro and small scale industries, which either primarily focus on local markets or working as vendors of major firms situated in Dewas or Pithampur, due to which they have limited finance, which lead to lack of adoption of GSCM in their culture. Plus, due to lack of awareness and other factors, levels of GSCM barriers are high, in these industrial areas.

6. Conclusion, Limitations and Future Scope of the Research

Present section portrays about the conclusion of the research work as well as its limitations and future scope, the details of which are presented in upcoming sections.

6.1 Conclusion

Following points represent the conclusion of the research work:

a) Following set of barriers was obtained as one of the results of the research:

- Costs associated with firms
- Pressures for cost reduction
- Lack of supplier and management commitment
- Lack of demand and training
- Lack of technical and human resources
- Lack of social and technical awareness
- Lack of Information technology
- Non readiness of different organizational factors
- Inappropriate organizational structures

b) GSCM barriers, pressures for cost reduction, lack of supplier and management commitment, lack of demand and training and lack of social and technical awareness are the driving variables for any firm;

c) GSCM barriers, lack of technical and human resources and lack of information are the linkage variables;

d) Cost associated with firms, non readiness of different organizational factors and inappropriate organizational structures are the dependent variables;
e) Barrier, cost associated with firms and pressures for cost reduction show maximum priority;
f) Industrial areas of Mandsaur shows highest ranking for GSCM barriers in its industries whereas Pithampur industrial area shows the lowest ranking for GSCM barriers in its industries.

6.2 Limitations and Future Scope of the Research

Following points represent the limitations of the research, due to financial and time constraints:
a) Present research focuses on considerable number of GSCM barriers;
b) The research focuses on the analysis of limited number of industrial areas, at state level;
c) The research work is based on application of only one MCDM technique, i.e., AHP.

Following points represent the future scope of the research work:
a) A new research may be initiated considering a broader set of barriers;
b) An extensive research may be conducted considering a bigger set of industrial areas at national as well as international levels, too;
c) A new research may be initiated considering a broader set of MCDM techniques, and others too.

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