Vol. 05, No. 3 (2023) 503-524, doi: 10.24874/PES05.03.014

Proceedings on Engineering Sciences

www.pesjournal.net

MODELLING FRAMEWORK FOR CRITICAL SUCCESS FACTORS OF GREEN SUPPLY CHAIN MANAGEMENT-AN INTEGRATED APPROACH OF PARETO, ISM AND SEM

Vanishree Beloor[1]
T. S. Nanjundeswaraswamy
D. R. Swamy

Received 09.03.2023.
Accepted 31.07.2023.
UDC – 005.523

Keywords:

Green Supply chain, factors, Pareto analysis, SSIM, Transitivity matrix, Digraph, ISM Framework, MICMAC analysis.

A B S T R A C T

The study aimed in identifying Green supply chain critical success factors, develop and validate the framework through integrated approach of ISM, MICMAC and SEM so as to promote green practices throughout the supply chain activities in Indian manufacturing sectors. Interpretive structural modelling(ISM) is applied to develop hierarchical contextual relationship among identified critical success factors via Pareto analysis. The methodology then follows classification of success factors into four clusters by Matrice d' Impacts Croisés-Multiplication Appliquée á un Classement (MICMAC) and statistical validation of the ISM model through Structural Equation Modelling(SEM) by AMOS. In this study, 16 critical success factors of Green supply chain practices for manufacturing industries were identified, followed by development of an ISM model using 16 critical success factors, later the model was statistically verified that identified nine CSF's responsible for generating SEM model by satisfying all the model fit indices.The linkage variables identified are Green manufacturing, Green Procurement, Green marketing and Distribution, Green purchasing, Supplier cooperation, Customer cooperation, Environmental strategies and management, Environmental Participation and Green training that are forming the driving force for practicing green supply chain. Research limitations/implications: The results of the study are restricted to manufacturing industries, which might vary when applied for other sectors. The developed model on green supply chain management practices would help policy makers, decision makers, researchers and industry professionals to anticipate potential success factors to implement green supply chain practices. Accordingly, the focus on critical success factors would be prioritized for obtaining better performance of supply chain and greening the chain.

[1] Corresponding author: Dr. Vanishree Beloor
Email: vanishreeblr@jssateb.ac.in

1. INTRODUCTION

Modern manufacturing industries are striving hard to develop a supply chain process which can minimize the negative impact on environment. Industrial impact on the environment is not only confined to greenhouse gas emissions but also leads to water shortages, difficulties in usage of the land, hazardous waste, water contamination, deforestation, pollution levels, and energy use are all essential issues that are important to bring it in the light. (Maertens et al 2012, Memia 2018, De Carvalho et al 2020, Vijayvargy et al 2017). The noteworthy truth is that the leading 2500 global corporations contribute to more than 20% of global greenhouse gas emissions, and their supplier networks constitute a significant share of emission levels arising from business operations. As a result of globalization, distribution systems for goods and services have become extremely complicated, (Reuter et al., 2010). Therefore, in order to manage the supply chain and minimize its negative impact on environment the theory of Green Supply Chain Management (GSCM) was created which also address these ecological consequences.

Through the exhaustive literature survey, 28 GSCM factors are identified including both external and internal factors influencing Green practices in manufacturing supply chain. Identification and quantification of these factors is more challenging and important also for the sustainable development of the organization. Therefore, our Research is an effort to find the most relevant factors of GSCM and it is called as Critical Success Factors.

Pareto chart was constructed to identify the critical success factors. Therefore, by using the 80-20 rule, we narrowed down the 28 GSCM factors to 16 critical success factors. The success factors are analysed using interpretive structural modelling(ISM) and then a proposed model is built considering MICMAC that specifies the association among them. ISM methodology typically develops a compact model based on the results from Delphi technique. The Delphi panel consisted the experts from Industry as well as Academia. The Expert opinion from Industry as well as academia together is considered to build an ISM model that indicates the position and importance of success factors along with the alternatives that converts the fuzzy information into responsive model based on discussions during Delphi technique. Further Structural Equation modelling (SEM) was applied for the theoretical ISM model to statistically validate the results. The current study aimed in developing a hybrid model that combines ISM and SEM. The distinctive feature of the study is that offers a combined approach for ISM-SEM for analysing the factors influencing Green Supply chain practices in Indian manufacturing industries. In the present study, structural relationship SEM approach has been used to validate the ISM based model.

2. LITERATURE REVIEW

The Literature has been reviewed from the perspectives of Green supply chain factors, ISM and SEM applications as presented in Tables 1-3 (see Appendix).

From the literature review several factors are identified that require considerable amount of time and energy for managers to get adapted to Green supply chain practices. With the development of concise set of GSCM factors, which may provide quicker and easier support to take initiation for practising GSCM in manufacturing industries. The major problem with the available GSCM models is that the factors themselves need an understanding of being applied in the defined sector and also the measurement of the model through statistical techniques. Therefore, this gap led to the formation of three main objectives

1) To identify the key Green supply chain factors of the Indian manufacturing industries from the literature and expert opinion.
2) To develop an appropriate hierarchy and contextual relationship of identified factors using interpretive structural modelling (ISM) and to classify these factors using Matrice d' Impacts Croisés-Multiplication Appliquée á un Classement (MICMAC)
3) To validate the ISM model using structural equation modeling (SEM).

The subsequent tables 1,2 and 3 present literatures with respect to Green supply chain in Manufacturing industries, SEM applications and ISM applications.

Based on the literature review on ISM, it is understood that there exists scope for selecting appropriate number of facilitators to simplify the situation. Literature also identifies that SEM being implemented independently fails to build a model on logical interpretation. Also applying only ISM model fails to provide the statistical results. Therefore, the integration of ISM and SEM technique builds a model that proves the logical interpretation from experts by subjecting it to statistical validation. ISM model developed based on expert opinion will identify factors which can be further statistically verified. This has been expressed by various authors in their study Balon (2016), Chin (2015), Deng et al (2019), Mahmoudi et al(2016). Now the challenge lies in validation of theoretical model developed from ISM due to the limitation, of strong theory to interpret the developed model. The integration of ISM and SEM offers a complete solution to the above problem. In the current study authors have made an attempt to develop one such model that is statistically valid.

3. METHODOLOGY

A trianalysis method was carried out in this study analyzing both quantitative, qualitative data obtained from study. The measureable analysis was based on Questionnaire survey, while qualitative was on Delphi technique on having semi structured interview with panel consisting of members from Industry and academicians. The study consisted of trifold analysis ISM, MICMAC and SEM within Indian manufacturing industries. Although ISM is a competent method to model the facilitators but it increases the complexity of the system by raising the number of facilitators. Therefore, the facilitators modelled from ISM and Micmac needs a statistical validation. In order to overcome this problem SEM and ISM are combined to validate the relationship between success factors. The MICMAC analysis helps to cluster the factors in four quadrants and group them accordingly based on driving and dependence power.

The critical success factors (CSF) are identified from literature review and expert opinion survey. A thorough literature review has been carried out referring research articles for the period 2008 to 2022 from Scopus, Emerald, Taylor and Francis database. This was followed by summarizing expert's opinion from academics and industry. Based on the opinion from academicians and industry experts 28 factors were identified. In order to reduce the factor intricacy and develop a framework further Interpretive structural modelling to conceptually validate the model and Structural

Equation modelling(SEM) has been used to statistically validate the ISM model.

3.1 Frequently used GSCM factors from Literature study

Firms have many objectives such as better image of brand, to get competitive advantage, better utilization of sources, increased profits, etc. In the process of achieving these objectives firms apply various strategies, one such strategy would be to implement GSCM practices. GSCM might be a more effective means to balance ecological, financial and societal performances. (Diabat, Govindan, 2011). Supply chain management has significant impacts on the environment which includes- release of pollutants and emissions, health hazards affecting the workers, wastage of materials, etc. Hence firms are trying to reduce the negative environmental impact by including environmentally friendly strategies into the supply chain. (Sarkis, 2012) Therefore the work carried out focuses on bringing out the most important environmental concerns and strategies pertaining to them and to generate a generalized framework that may be applicable to industries. Therefore, from the literature frequently used factors of GSCM by various authors are identified and listed in table 4.

From the literature the identified 28 GSCM factors are as depicted in table 4 (see Appendix), Further these 28 factors are subjected to Pareto analysis to identify vital few that are critical ones and responsible for implementation of green practices in manufacturing industries.

3.2 Pareto chart

A Pareto analysis helps to prioritize decisions and identify the major critical factors that might be responsible for firm's performance. Brooks et al (2014), McDermott et al., (2022). It is also defined as 80/20 rule as it explains about 80% of the firm's benefit is from 20% of the factors. With this approach among the frequently identified factors of Green supply chain only vital few that is 20% of the critical factors are responsible for 80% of the firm's success are identified through Pareto analysis. A Pareto chart is constructed as shown in Figure 1 that highlights 20% of the green supply chain factors constituting about 16 factors responsible for 80% of the firm's outcome.

Based on the literature review, we identified nearly 28 GSCM factors in our study. Pareto chart to find out the critical success factors. On the Pareto diagram as shown in figure 1, 28 factors are listed on the x-axis in the order of their contribution to the overall influences in descending order. Hence, using the 80-20 rule, we narrowed down the 28 GSCM factors to 16 critical success factors.

3.3 Interpretive Structural Modelling

Structural Self-Interactive Matrix(SSIM)

The SSIM matrix was developed by plotting the relationship between two facilitators i.e., i and j. The relations were coded with V, A, X and O. SSIM matrix is depicted in table 6.

V is represented when GSCMF i will assist GSCMF j.
A is represented when GSCMF j will assist GSCMF i.
X is represented when GSCMF i and j assist each other.
O is represented when both GSCMF i and j are not related to each other.
An example of the application of GSCMF-
GSCMF 6 assists GSCMF 16 and hence it is coded as V.
GSCMF 14 assists GSCMF 7 and hence it is coded as A.
GSCMF 5 and GSCMF 15 assist each other and hence, they are coded as X.
GSCMF 6 and GSCMF 8 are not related to each other and hence they are coded as O.

3.4 Initial Reachability Matrix

The Structural Self-Interactive Matrix is followed by Initial Reachability Matrix where the relationships between two facilitators are binary coded for codes V, A, X and O respectively, the coding procedure is as shown in table 5. Table 7 represents Initial reachability matrix that follows the binary coding for SSIM.

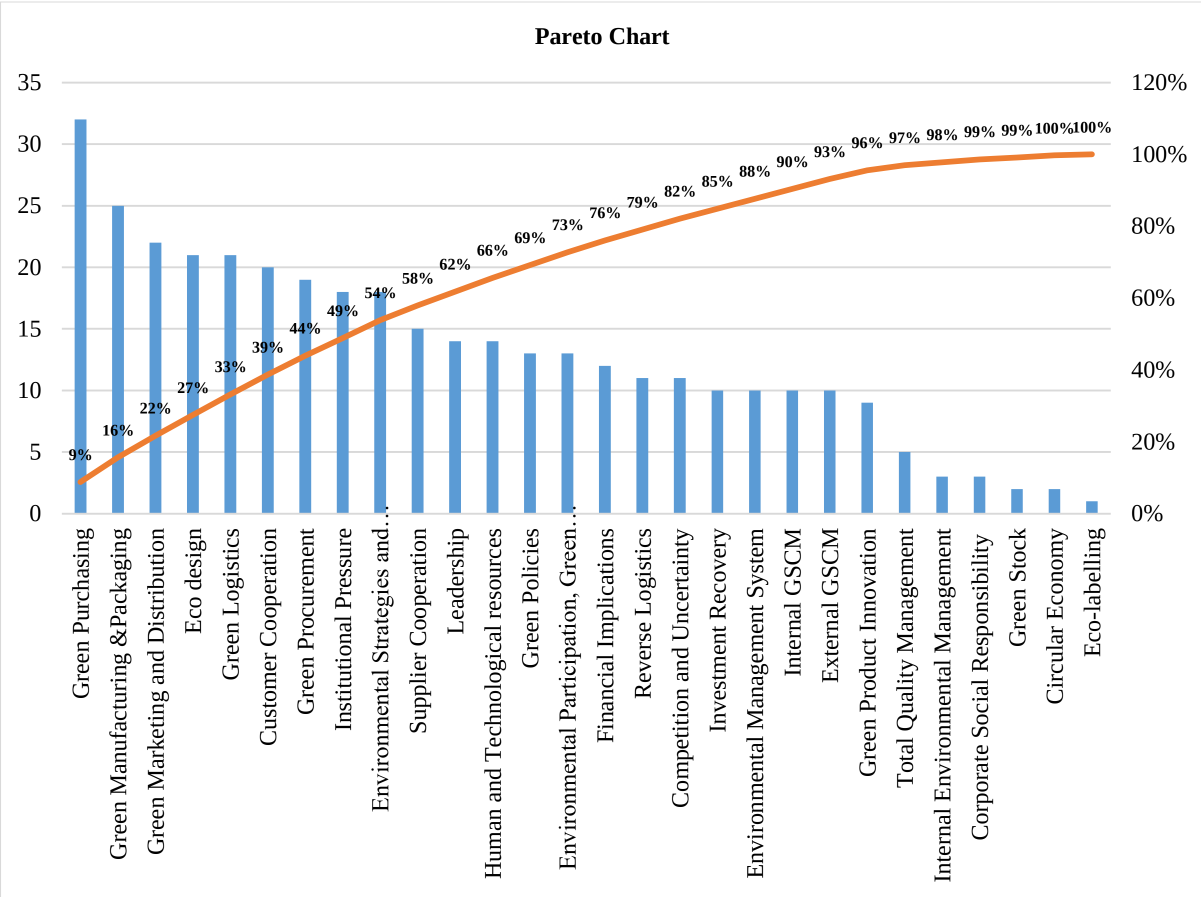


Figure 1. Pareto chart for GSCM Factors

Table 5. Binary coded table

	(i, j)	(j, i)
V	1	0
A	0	1
X	1	1
O	0	0

Table 6. Structural Self-Interaction Matrix

GSCMF Code	RL16	FI15	EPG14	GP13	HT12	L11	SC10	EM9	IP8	GP7	CC6	ED5	GL4	GMD3	GMP2	GP1
GP1	V	X	A	A	A	A	X	A	A	X	V	A	X	V	X	.
GMP2	X	X	A	A	A	A	A	A	A	A	A	A	V	X	.	X
GMD3	X	X	A	A	A	A	O	A	A	A	V	A	X	.	X	V
GL4	X	X	A	A	A	A	O	A	A	X	X	O	.	X	V	X
ED5	O	X	A	A	A	A	A	A	A	X	V	.	O	A	A	A
CC6	V	X	A	O	O	V	O	V	O	O	.	V	X	V	A	V
GP7	X	X	A	A	A	A	X	A	A	.	O	X	X	A	A	X
IP8	V	O	X	V	V	X	V	V	.	A	O	A	A	A	A	A
EM9	V	V	X	V	V	A	V	.	V	A	V	A	A	A	A	A
SC10	X	X	V	A	A	A	.	V	V	X	O	A	O	O	A	X
L11	V	V	X	V	V	.	A	A	X	A	V	A	A	A	A	A
HT12	V	X	V	A	.	V	A	V	V	A	O	A	A	A	A	A
GP13	V	V	V	.	A	V	A	V	V	A	O	A	A	A	A	A
EPG14	V	O	.	V	V	X	V	X	X	A	A	A	A	A	A	A
FI15	X	.	O	V	X	V	X	V	O	X	X	X	X	X	X	X
RL16	.	X	V	V	V	V	X	V	V	X	V	O	X	X	X	V

Table 7. Initial Reachability Matrix

GSCMF Code	RL16	FI15	EPG14	GP13	HT12	L11	SC10	EM9	IP8	GP7	CC6	ED5	GL4	GMD3	GMP2	GP1
GP1	1	1	0	0	0	0	1	0	0	1	1	0	1	1	1	1
GMP2	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1
GMD3	1	1	0	0	0	0	0	0	0	0	1	0	1	1	1	0
GL4	1	1	0	0	0	0	0	0	0	1	1	0	1	1	0	1
ED5	0	1	0	0	0	0	0	0	0	1	1	1	0	1	1	1
CC6	1	1	0	0	0	1	0	1	0	0	1	0	1	0	1	0
GP7	1	1	0	0	0	0	1	0	0	1	0	1	1	1	1	1
IP8	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1
EM9	1	1	1	1	1	0	1	1	0	1	0	1	1	1	1	1
SC10	1	1	1	0	0	0	1	0	0	1	0	1	0	0	1	1
L11	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
HT12	1	1	1	0	1	0	1	0	0	1	0	1	1	1	1	1
GP13	1	1	1	1	1	0	1	0	0	1	0	1	1	1	1	1
EPG14	1	0	1	0	0	1	0	1	1	1	1	1	1	1	1	1
FI15	1	1	0	0	1	0	1	0	0	1	1	1	1	1	1	1
RL16	1	1	0	0	0	0	1	0	0	1	0	0	1	1	1	0

Table 8. Transitivity Matrix

GSCMF Code	GP1	GMP2	GMD3	GL4	ED5	CC6	GP7	IP8	EM9	SC10	L11	HT12	GP13	EPG14	FI15	RL16
GP1	1	1	1	1	1*	1	1	0	1*	1	1*	1*	0	1*	1	1
GMP2	1	1	1	1	1*	1*	1*	0	0	1*	0	1*	0	0	1	1
GMD3	1*	1	1	1	1*	1	1*	0	1*	1*	1*	1*	0	0	1	1
GL4	1	1*	1	1	1*	1	1	0	1*	1*	1*	1*	0	0	1	1
ED5	1	1	1	1*	1	1	1	0	1*	1*	1*	1*	0	0	1	1*
CC6	1*	1	1*	1	1*	1	1*	1*	1	1*	1	1*	1*	1*	1	1
GP7	1	1	1	1	1	1*	1	0	0	1	0	1*	0	1*	1	1
IP8	1	1	1	1	1	1*	1	1	1	1	1	1	1	1	1*	1
EM9	1	1	1	1	1	1*	1	1*	1	1	0	1	1	1	1	1
SC10	1	1	1*	1*	1	1*	1	1*	1*	1	1*	1*	0	1	1	1
L11	1	1	1	1	1	1*	1	1	1	1	1	1	1	1	1	1
HT12	1	1	1	1	1	1*	1	1*	1*	1	1*	1	0	1	1	1
GP13	1	1	1	1	1	1*	1	1*	1*	1	1*	1	1	1	1	1
EPG14	1	1	1	1	1	1	1	1	1	1*	1	1*	1*	1	1*	1
FI15	1	1	1	1	1	1	1	0	1*	1	1*	1	0	1*	1	1
RL16	1*	1	1	1	1*	1*	1	0	0	1	0	1*	0	1*	1	1

3.5 Level partitions

The reachability set and antecedent set for each GSCMF are determined using the final reachability matrix. The reachability set includes GSCMFs and other GSCMFs that may aid in their attainment, while the antecedent set comprises GSCMFs and other GSCMFs that aid in their attainment. The intersection of these sets is then calculated for each GSCMF. The top-level GSCMFs in the ISM hierarchy are those with the same reachability and intersection sets. The hierarchy's top-level GSCMFs would not assist in the achievement of any GSCMFs beyond their own level. It is isolated from the other GSCMFs once the top-level GSCMFs have been discovered (Step 4: Partitioning of reachability matrix). The method is then restarted to determine the GSCMF in the next level. This procedure is repeated until the level of each GSCMF is determined (Step 4: Partitioning of reachability matrix). These stages contribute to the construction of the diagraph and the final Framework.

Table 9. Level Partitioning Matrix

GSCMF CODE	**REACHABILITY SET**	**ANTECEDENT SET**	**INTERSECTION SET**	**LEVEL**
GP1	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16	1,2,3,4,5,6,7,9,10,11,12,14,15,16	1,2,3,4,5,6,7,9,10,11,12,14,15,16	L3
GMP2	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16	1,2,3,4,5,6,7,10,12,15,16	1,2,3,4,5,6,7,10,12,15,16	L8
GMD3	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16	1,2,3,4,5,6,7,9,10,11,12,15,16	1,2,3,4,5,6,7,9,10,11,12,15,16	L3

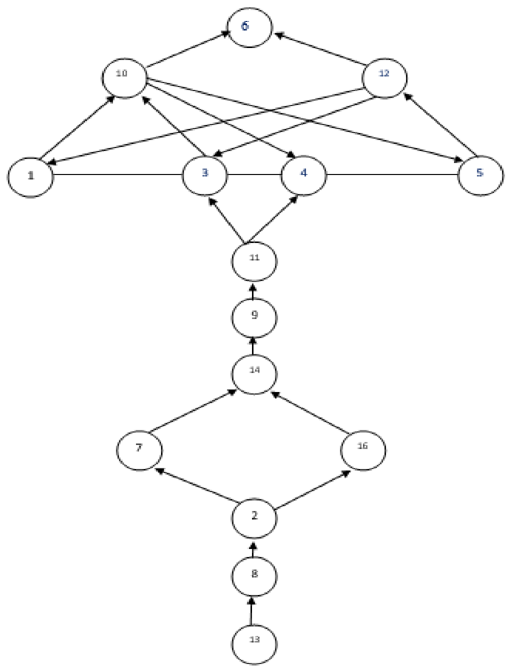
GL4	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16	1,2,3,4,5,6,7,9,10,11,12,15,16	1,2,3,4,5,6,7,9,10,11,12,15,16	L3
ED5	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16	1,2,3,4,5,6,7,9,10,11,12,15,16	1,2,3,4,5,6,7,9,10,11,12,15,16	L3
CC6	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16	L1
GP7	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16	1,2,3,4,5,6,7,10,12,14,15,16	1,2,3,4,5,6,7,10,12,14,15,16	L7
IP8	6,8,9,10,11,12,13,14	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16	6,8,9,10,11,12,13,14	L9
EM9	1,3,4,5,6,8,9,10,11,12,13,14,15	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16	1,3,4,5,6,8,9,10,11,12,13,14,15	L5
SC10	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16	1,2,3,4,5,6,7,8,9,10,11,12,14,15,16	1,2,3,4,5,6,7,8,9,10,11,12,14,15,16	L2
L11	1,3,4,5,6,8,9,10,11,12,13,14,16	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16	1,3,4,5,6,8,9,10,11,12,13,14,16	L4
HT12	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16	1,2,3,4,5,6,7,8,9,10,11,12,14,15,16	1,2,3,4,5,6,7,8,9,10,11,12,14,15,16	L2
GP13	6,8,9,11,13,14	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16	6,8,9,11,13,14	L10
EPG14	1,6,7,8,9,10,11,12,13,14,15,16	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16	1,6,7,8,9,10,11,12,13,14,15,16	L6
FI15	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16	1,2,3,4,5,6,7,9,10,11,12,14,15,16	1,2,3,4,5,6,7,9,10,11,12,14,15,16	L3
RL16	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16	1,2,3,4,5,6,7,10,12,14,15,16	1,2,3,4,5,6,7,10,12,14,15,16	L7

3.6 Building the ISM model

The structural model is created using the final reachability matrix (Step 3: Transitivity matrix). An arrow pointing from i to j indicates, there is a relationship between the GSCMFs i and j. A directed graph, or digraph, is what this graph is called. The digraph (Figure 2) is turned into the ISM-based framework when the transitivity is removed (Figure 3).

ISM based Framework

A digraph is used to illustrate the factors and their relationships in the form of nodal representation. (Mahmoudi et al., 2013)



1. Green Purchasing
2. Green Manufacturing and Packaging
3. Green Marketing and Distribution
4. Green Logistics
5. Ecodesign
6. Customer Cooperation
7. Green Procurement
8. Institutional Pressure
9. Environmental strategies and Management
10. Supplier cooperation
11. Leadership
12. Human and Technological resources
13. Green Policies
14. Environmental participation and green training
15. Financial implications
16. Reverse logistics

Figure 2. Digraph

From the reachability matrix, a digraph was constructed that represents the facilitators and their interdependence with each other. In the digraph that obtained, Green Supply Chain critical success factors have been classified into 10 levels according to the level partitioning matrix. According to the diagraph, the highest success factor is positioned at the top of the digraph and the second-level facilitator is placed at the second position and so on until the bottom level is placed at the lowest position in the digraph. Here, GSCMF 6 lies in the topmost level- Level 1 while GSCMF 13 in the bottom most level, the 10th level.

Interpretive structural modelling Framework

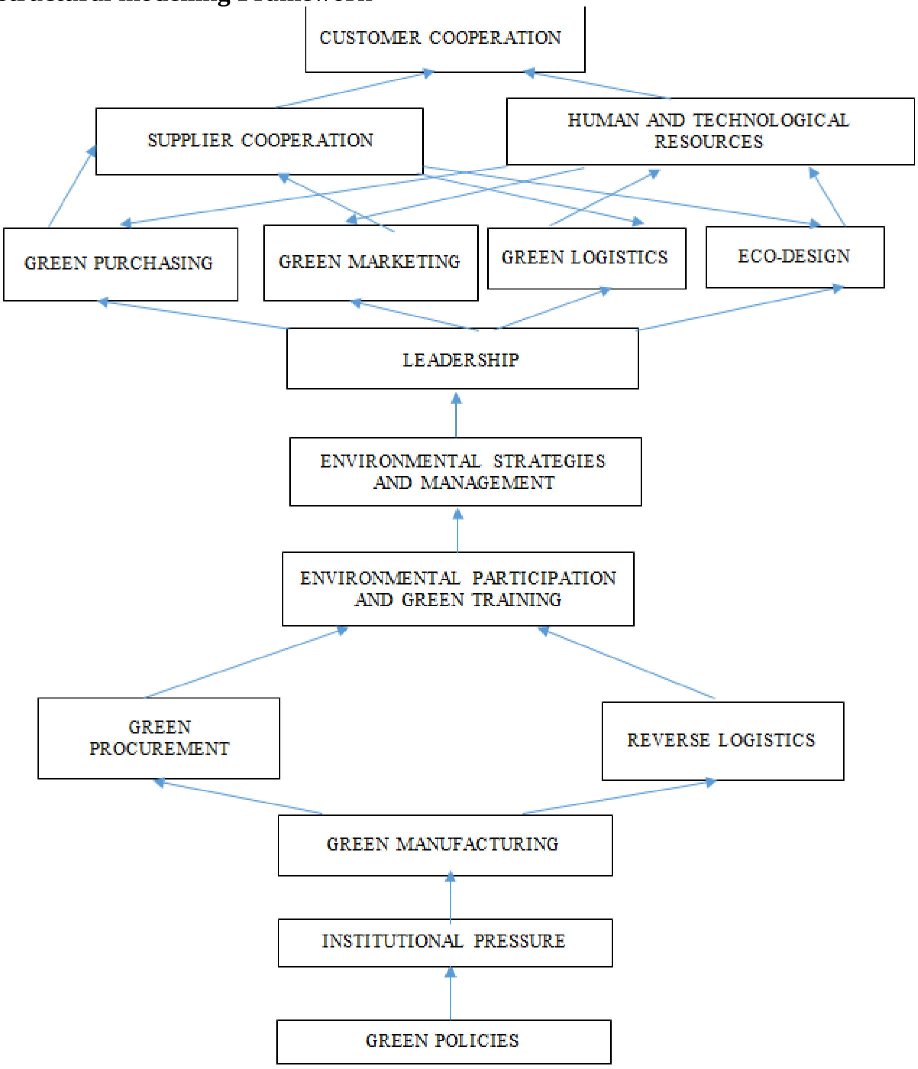


Figure 3. ISM based Framework

The digraph is transformed into an ISM model by replacing the nodes of the facilitators with their respective names. From this framework, it can be seen that the facilitators are arranged according to their levels. Customer cooperation lies in level one being the most highly independent facilitator whereas green policies lie in the 10th level being the most highly dependent facilitator.

3.7 MICMAC Analysis

Matrice d'impacts croisés multiplication appliquée á un classment (Cross impact matrix-multiplication applied to classification), was developed by Duperrin and Godet (1973) at the CEA between 1972 and 1974 (Sexana et al,1990) to investigate the distribution of associates through response paths and loops for developing hierarchies for members of an element set (Purohit,2017) and is a structural prospective analysis used to investigate indirect relationships (Sexana et al,1990). MICMAC analysis can be used to identify and investigate the elements in a sophisticated and complex system with the goal of separating the variables' driving and dependency powers (Faisal et al. 2007). Variable X affects Y, variable Y affects Z, X and Z have no direct influence on Y, but their association with Y is a cross-correlation, where any modification in X impacts Z. Gray area exploration is another name for this type of analysis (Dubey et al,2014).

This analysis enhances the ISM technique by examining limitations that are commonly associated with the ISM method: it examines the connection "yes" or "no" and ignores the "gray area" between 0 and 1. (Sushil et al,2012). The construction of a graph that classifies components based on driving and dependence power is a part of the MICMAC analysis. To get at the study's findings and conclusions, MICMAC analysis is utilized to characterize the components and validate the interpretive structural model factors. (Ahmad et al,2019). According to Figure 4, the Micmac analysis shows that most of the facilitators have high driving and dependence power, they were found to be linkage variables, they work as a catalyst to the dependant variables while they are relative to independent variables.

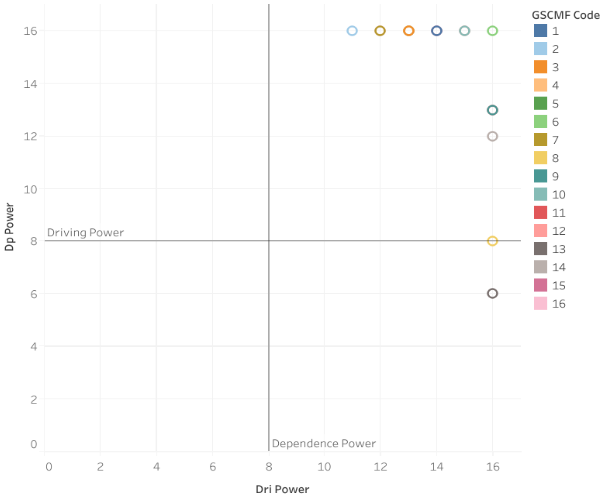


Figure 4. MICMAC Graph

Facilitator 2, 7, 3, 1, 10, 6, 9, 14, i.e., Green Manufacturing, Green Procurement, Green Marketing and Distribution, Green Purchasing, Supplier Cooperation, Customer Cooperation, Environmental Strategies and Management, Environmental Participation and Green Training respectively were found to be the linkage variables through the analysis. Facilitator 8 and 13, i.e., Institutional Pressures and Green Policies respectively, has a higher driving power than the depending power. The dependent variables are related to the independent variables and this is possible because of linkage variables.

3.8 Model analysis using Structural Equation Modelling (SEM)

Structural Equation Modelling is a combined technique applying regression and factor analysis to validate survey based results statistically. Exploratory factor analysis(EFA) is applied on sample size of 511 units (n=511) for the 16 barriers of green supply chain to extract the factors that are Principal factors using SPSS. In the study Principal component analysis with varimax rotation was used to group the items under common factor by following the principle of Eigen value criterion. The Eigen values with greater than one are considered A total of six factors with Eigen value greater than 1 are considered as shown in Table 11. The factors are grouped into six sections namely Green manufacturing, Green logistics, Customer cooperation, Environmental strategies and management, Supplier cooperation, Reverse logistics all of which have an Eigen value of greater than 1 and factor loading of greater than 0.5 with more than three items for each factor. Cronbach's alpha was used to measure the internal consistency of the instrument. Kaiser Mayer Olkin(KMO) test was conducted to check the adequacy of the collected data. The table 10 presents the statistics of KMO result showing that the data are adequate.

Table 10. KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.811
Bartlett's Test of Sphericity	Approx. Chi-Square	4191.255
	df	253
	Sig.	.000

3.9 Factor analysis

The outline of Principal Component Analysis is depicted in table 11 that explains the total variance accumulated by six components is 71.9%.

Based on EFA, subsequent six Principal components were selected based on Eigen values greater than 1. Further in order to assess the significance of the data through the items, the commonalities derived from the factor analysis were reviewed. The item loading greater than 0.5 were considered (Fornell et al,1981)). For the final instrument 23 items were extracted based on those variables having a loading of atleast 0.5 on single factor. Table 11 summarized the extraction of six components through factor analysis.

Table 11. Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.520	23.999	23.999	5.520	23.999	23.999	3.501	15.221	15.221
2	3.883	16.883	40.882	3.883	16.883	40.882	3.370	14.650	29.871
3	2.547	11.074	51.956	2.547	11.074	51.956	2.706	11.767	41.638
4	1.658	7.208	59.164	1.658	7.208	59.164	2.444	10.625	52.263
5	1.525	6.632	65.796	1.525	6.632	65.796	2.412	10.488	62.751
6	1.405	6.108	71.904	1.405	6.108	71.904	2.105	9.153	71.904
7	.845	3.673	75.577						
8	.637	2.768	78.345						
9	.609	2.650	80.995						
10	.550	2.390	83.385						
11	.511	2.221	85.606						
12	.443	1.928	87.533						
13	.392	1.703	89.236						
14	.376	1.636	90.872						
15	.350	1.522	92.394						
16	.309	1.345	93.740						
17	.267	1.160	94.900						
18	.249	1.081	95.980						
19	.210	.912	96.893						
20	.194	.843	97.736						
21	.187	.814	98.550						
22	.172	.747	99.297						
23	.162	.703	100.00						

Table 12. Rotated Component matrix

	Components					
	1	2	3	4	5	6
GM1	.811					
GM2	.805					
GM3	.804					
GM4	.789					
GM5	.637					
GL1		.916				
GL2		.910				
GL3		.895				
GL4		.875				
CC1			.845			
CC2			.832			
CC3			.751			
CC4			.576			
CC5			.538			
ESM1				.855		
ESM2				.828		
ESM3				.818		
SC1					.857	
SC2					.848	
SC3					.826	
RL1						.838
RL2						.771
RL3						.764
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.						
a. Rotation converged in 6 iterations.						

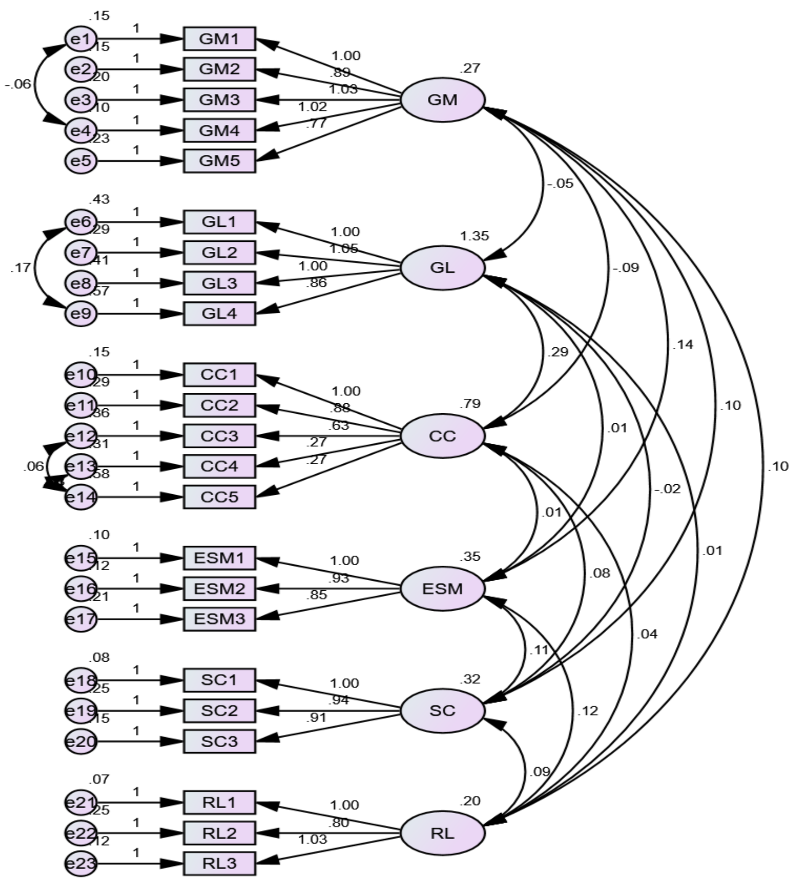


Figure 5. Measurement model of Green supply chain management

Table 13. Model fit summary

Model tested	χ2/Cmin	GFI	AGFI	CFI	TLI	RMSEA
Performance of model	2.317	.907	.952	.932	.918	.064
Criterion for Goodness of Fit	≤ 3	≥ 0.90	≥ 0.90	≥ 0.90	≥ 0.90	≤ 0.08

The values of the model fit are fully satisfactory as per social science research. All the fit indices are within the acceptable range as shown in table 13. (Hair et al 2009).

4. RESULTS AND DISCUSSION

The study has identified 28 key Green Supply Chain Management Facilitators by reviewing a number of research articles, which were run through Pareto analysis that resulted in the identification of 16 predominant factors.

It is moreover evident that no single GSCM factor would be self-determining for green supply chain implementation in an organization, therefore, it becomes more important to identify the relationship of GSCM factor with each other. ISM methodology is used to develop relationship among various factors for each dimension of GSCM implementation. The practitioners need to concentrate on these factors more cautiously during GSCM implementation in their organizations. On the other hand, academicians may be encouraged to categorize different other issues, which are important in addressing these GSCMF.

ISM model identifies the hierarchy of actions to be taken by practitioners in order to maximize the effect of these GSCMF in order to implement GSCM successfully. Based on the level partitioning matrix, it was found that framework is divided into ten levels where facilitator 13 (Level 10) which is Green Policies was the most dependent while facilitator 6 (Level 1) Customer Cooperation is the most independent.

Micmac Analysis identified 8 facilitators to be linkage variables and 2 facilitators to be dependent variables. The linkage variables were Green Manufacturing, Green Procurement, Green Marketing and Distribution, Green Purchasing, Supplier Cooperation, Customer Cooperation, Environmental Strategies and Management, Environmental Participation and Green Training and Dependent variables were found to be Institutional

Pressures and Green Policies. The factors were statistically verified using structural equation modelling and the model fit satisfied all the fit indices thereby proving the factors to be critically responsible for implementation of Green supply chain.

The ISM model was further validated statistically through Structural equation modelling, where EFA resulted in six components whose Eigen values are greater than 1, The six success factors resulted from EFA are GM, GL, CC, ESM, SC, RL. A final six component model was developed through statistical validation.

5. CONCLUSION

Manufacturing industries are finding it difficult to focus on green supply chain practices due to its multifarious environment. The authors in the study developed a model to address the issue of practicing green supply chain activities. The model is built considering the opinion from experts and through literature study, this helped in identification of frequently used success factors which were further confirmed from respective subject experts from industries. Then Interpretive structural modelling was applied to know the relationship between the success factors. 28 success factors identified from literature study were narrowed down to 16 through ISM MICMAC approach. The 16 factor ISM model was statistically validated through structural equation modelling that resulted in critical success factors. The model exhibiting the inter relationship may be used by policy and decision makers to implement green supply chain practices in manufacturing industries. The model developed in limited to its use only to manufacturing sectors in Indian scenario, the results may vary if the model is applied to other sectors. Future studies can be carried out in other sectors to implement green practices in their supply chain.

Data availability Statement: Data available on request due to privacy/ethical restrictions**.** The data that support the findings of this study are available on request from the corresponding author, [Dr. Vanishree Beloor]. The data are not publicly available due to [restrictions e.g. their containing information that could compromise the privacy of research participants].

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Appendix

Table 1. Review on Green Supply Chain Manufacturing

Author and Year	Objectives	Methodology	outcomes
Lin et al.,(2011)	To identify the elements that influence the performance of automobile industries through Fuzzy DEMATEL approach.	Fuzzy DEMATEL approach.	Findings show that use of eco material is the significant factor.
Bhool et al.,(2013)	To identify enablers and barriers of GSCM in different sectors of manufacturing industries.	Questionnaire based survey and mean, SD of GSCM drivers through SPSS.	Government rules & legislation' have more important and crucial for adoption of GSCM for 4-wheeler industries
Zhu et al.,(2007)	To determine GSCM practices and implementation strategies to obtain the associated link and measure the efficiency of the obtained relationship.	Statistical analysis by ANOVA Test.	Electrical and electronic industry practise Green supply chain more effectively than other industries in China.
Surajit et al.,(2014)	To build a GSCM framework for the rubber industry.	ISM and MICMAC approach	A tenfold framework was developed that might assist rubber manufacturing industries.
Panpatil et al.,(2022)	To obtain the association between GSCM practices and measure its impact on performance of Industry.	Fuzzy MICMAC.	Developed an integrated model that reveals direct and incidental effect on GSCM practices. The results also showed that driver GSCP's have deliberate importance and dependant GSCP's are more performance oriented.
Venkatesa Narayanan et al.,(2021)	To know the relationship between elements of learning organization and green supply chain practices in manufacturing sector.	Multiple Linear Regression, ISM and MICMAC approach.	Findings of the study identified Green distribution and reverse logistics as driving factors.
Diabat et al.,(2011)	To develop and validate a GSCM model for a manufacturing company.	ISM, MICMAC approach.	The developed model results in increasing the overall cost of the product.
Waqas et al.,(2020)	To determine the association between RL barriers in manufacturing industries, Pakistan.	ISM and MICMAC approach	The model developed identified the obstacles and will help policymakers to frame strategies focusing on major obstacles identified through ISM, MICMAC.
Paul et al.,(2022)	To examine critical Success factors for sustainability in Bangladesh wood industries.	Principal Component Analysis(PCA), ISM and MICMAC Approach.	The findings reveal that research and development, supplier relations, and using eco-friendly technology are the most significant CSFs of the Bangladeshi wood industry.

Table 2. Literature study on SEM applications

Author and Year	**Objectives**	**Methodology**	**outcomes**	**Sector applied**
Thirupathi et al(2016)	To develop hybrid model using ISM and SEM techniques.	ISM and SEM	Findings of the study show that strong relationship exists between sustainable manufacturing enablers.	Automotive component manufacturing organisation
Masoumik et al(2015)	To develop a conceptual model on GSCM initiatives.	ANP , SEM	A conceptual framework on Green supply chain imitativeness is developed.	Business Sector
Khaksar et al(2016)	To determine the relationship between GSCM Factors.	Correlation and SEM	There is a positive and significant relationship between GSCM factors and organizational performance.	Cement Industry
Agarwal et al(2021)	To find out the different barriers of GSCM practices	SEM	A contextual relationship among the identified barriers is developed and model is statistically validated using SEM approach.	Rubber Industry.
Umar et al(2021)	To determine the influence of industry performance in terms of technology, environment through GSCM practices acting as mediating element.	SEM	The outcomes indicate that green supply chain practices mediate the economic and environment performance.	Manufacturing firms.
Juma et al(2022)	To identify the barriers that hinder from implementing GSCM practices.	SEM	SEM identified and statistically validated the factors of GSCM practices that influence green organizational performance.	Jordan manufacturing firms
Amjad et al(2022)	To investigate the influential effect of GSCM practices in leather industry considering competitiveness and investment recovery as mediating factors.	PLS SEM	Findings of the study reveal that GSCM practices effect organizational performance.	Leather Industries.
Nureen et al(2022)	The study attempts to develop a conceptual model between GSCM practices as mediating factors and institutional pressure as moderating factor on organizational performance.	PLS SEM	Findings of the analysis show that technical practices and performance are moderated by institutional pressure.	Manufacturing industries.

Table 3. Review on ISM applications

Author and Year	Objectives	Methodology	outcomes	Sector applied
Mandal et al(1994)	To develop an ISM model that shows the interrelationship between different criteria level in vendor selection.	Dickson's study identified vendor selection criteria. Out of 23 identified criteria's 11 have been finalized as most important.	Developed vendor selection process framework based on qualitative and quantitative approach.	Vendor selection for Purchasing department in Indian Engineering Industries.
Raut et al(2017)	To investigate CSF for cloud computing adoption in Indian SME's.	Interpretive structural modelling and Multi criteria decision making model MICMAC analysis.	Previous technological experience is identified as most influential critical success factor for harnessing the benefits of Cloud computing.	Indian micro, small and medium enterprises.
Beikkhakhian et al(2015)	To evaluate agile supplier selection criteria and rank the suppliers.	Interpretive structural modelling, Fuzzy AHP, Fuzzy TOPSIS.	Supply chain agility model is developed by ISM procedure that identified delivery speed as highest driving variable.	Manufacturing industries.
Ali et al(2020)	To build a model by identifying barriers to lean supply chain.	ISM to identify the contextual relationship and MICMAC analysis to determine Supply chain barriers.	Developed model that shows the contextual relationship between the barriers.	Apparel manufacturing Industries.
Talib et al(2011)	To develop a hierarchy of TQM barriers that identifies the relationship between the identified barriers.	ISM approach to know the mutual dependency of one barrier over the other. MICMAC to cluster the barriers and know their dependency.	Developed ISM based TQM barriers model and determined driver, dependent cluster of TQM barriers.	Service sectors.
Khan etal(2015)	To model the interrelationships among retail brand experience variables.	ISM to develop the framework and MICMAC approach to cluster the variables.	Findings of the study revealed that retail brand experience is influenced by variables with high driving power and weak driving power.	Retail sectors.
Attri et al(2017)	To develop a 5S hierarchy based model and identify the dependency of one barrier over the other.	ISM to identify the relationship among identified barriers and MICMAC to know dependent and independent barriers	Developed a hierarchy based model.	Indian manufacturing industries.
Shibin et al(2017)	To develop a Flexible Green supply chain model both barrier and enabler based.	Total interpretive structural modelling(TISM) to identify the relationship between barriers and enablers.	Developed Barrier, enabler framework for Flexible Green supply chain	Manufacturing organizations.
Thakur et al(2016)	To identify and analyse the interrelationships among medical waste disposal care barriers	ISM and Fuzzy MICMAC to prioritize barriers of health care waste management system.	Hierarchical ISM framework developed identifies the interrelationship between the identified barriers.	Health care sector
Nandal et al(2019)	To examine solar power implementation in thermal plants by establishing hierarchical framework that determines the interrelationship between solar power barriers.	ISM to determine the circumstantial relationships among key barriers and MICMAC approach to validate the ISM model.	Developed contextual framework that is validated through MICMAC and identified the most influential barriers that are hindering the installation of solar power in thermal power plants.	Indian thermal power plants.

Table 4. GSCM factors used by the various researchers

Sl No	Components	Researchers	Frequency
1	Green Purchasing	Famiyeh (2017), Feng (2017), Khan (2017), Khan (2017), Laari (2015), Sharma (2016), Vijayvargy et al., (2017), Younis (2016), Liu (2018), Agi (2017), Ahmad et al., (2021), Abdel-Baset et al., (2019)., Çankaya et al., (2018), Cousins et al., (2019)., Badi et al., (2019), Sellitto et al., (2019), Seman et al., (2019), Sahar et al., (2020), Ilyas et al., (2020), Novitasari et al., (2021), Younis et al., (2019), Zhu (2010), Thipparat (2011), Choudhary (2011), Azevedo (2012), Babu (2012), Laosirihongthong et al., (2013), Jabbour et al., (2015), Jabbour (2014), Chin et al., (2015), Lee et al., (2013), Hasan (2013)	32
2	Green Manufacturing &Packaging	Feng (2017), Khan (2017), Khan (2017), Laari (2015), Sharma (2016), Liu (2018), Ahmad et al., (2021), Dev et al., (2020), Xie et al., (2019), Cousins et al., (2019)., Badi et al., (2019), Sellitto et al., (2019), Seman et al., (2019), Deng et al., (2019), Ilyas et al., (2020), Novitasari et al., (2021), Younis et al., (2019), Shanga (2010), Kumar (2012), Babu (2012), Laosirihongthong et al., (2013), Jabbour (2014), Chin et al., (2015), Lee et al., (2013), Hasan (2013)	25
3	Green Marketing and Distribution	Feng (2017), Khan (2017), Laari (2015), Liu (2018), Esfahbodi (2017), Ahmad et al., (2021), Dev et al., (2020), Çankaya et al., (2018), Sellitto et al., (2019), Burki (2018), Seman et al., (2019), Shanga (2010), Kumar (2012), Choudhary (2011), Perotti (2012), Yang et al., (2013), Laosirihongthong et al., (2013), Jabbour (2014), Chin et al., (2015), Lee et al., (2013), Hasan (2013), Sezan et al., (2013)	22
4	Eco design	Khan (2017), Khan (2017), Sharma (2016), Vijayvargy et al., (2017), Younis (2016), Esfahbodi (2017), Çankaya et al., (2018), Badi et al., (2019), Sahar et al., (2020), Al-Sheyadi et al., (2019), Zhu (2010), Xie et al., (2012), Andreas et al., (2011), Shanga (2010), Zhu (2012), Kumar (2012), Thipparat (2011), Perotti (2012), Caniato (2012), Choi et al., (2015), Jabbour et al., (2015)	21
5	Green Logistics	Feng (2017), Laari (2015), Khan (2018), Sharma (2016), Liu (2018), Ahmad et al., (2021), Çankaya et al., (2018), Cousins et al., (2019)., Badi et al., (2019), Trivellas et al., (2020), Seman et al., (2019), Sahar et al., (2020), Ilyas et al., (2020), Novitasari et al., (2021), Younis et al., (2019), Kumar (2012), Laosirihongthong et al., (2013), Jabbour (2014), Chin et al., (2015), Lee et al., (2013), Hasan (2013)	21
6	Customer Cooperation	Khan (2017), Sharma (2016), Vijayvargy et al., (2017), Zhu (2016), Wang (2018), Agi (2017), Çankaya et al., (2018), Sellitto et al., (2019), Kumar et al., (2019)., Zhu (2010), Xie et al., (2012), Andreas et al., (2011), Thipparat (2011), Perotti (2012), Azevedo (2012), Yang et al., (2013), Jabbour et al., (2015), Hsu et al., (2013), Ye et al., (2013), Yu et al., (2014)	20
7	Green Procurement	Feng (2017), Laari (2015), Liu (2018), Esfahbodi (2017), Ahmad et al., (2021), Çankaya et al., (2018), Cousins et al., (2019)., Seman et al., (2019), Ilyas et al., (2020), Novitasari et al., (2021), Younis et al., (2019), Kumar (2012), Caniato (2012), Sehnem (2012), Laosirihongthong et al., (2013), Jabbour (2014), Chin et al., (2015), Lee et al., (2013), Hasan (2013)	19
8	Institutional Pressure	Govindan (2016), Sharma (2016), Yang (2017), Chu (2017), Vanalle (2017), Gandhi (2016), Esfahbodi (2017), Sriyakul et al., (2019), Saberi et al., (2018), Tseng et al., (2019), Burki (2018), Kumar et al., (2019)., Kumar et al., (2019)., Zhu et al., (2013), Lee et al., (2013), Ye et al., (2013), Wolf (2013), Dubey et al., (2014)	18
9	Environmental Strategies and Management (Eg 3R)	Khan (2017), Khan (2017), Haseeb (2018), Vanalle (2017), Badi et al., (2019), Sellitto et al., (2019), Al-Sheyadi et al., (2019), Babu (2012), Caniato (2012), Kumar (2012), Huo et al., (2021), Andreas et al., (2011), Choudhary (2011), Azevedo (2012), Sehnem (2012), Yang et al., (2013), Muduli et al., (2013), Laosirihongthong et al., (2013)	18
10	Supplier Cooperation	Sharma (2016), Khaksar (2015), Agi (2017), Sriyakul et al., (2019), Sellitto et al., (2019), Burki (2018), Xie et al., (2012), Kumar (2012), Azevedo (2012), Yang et al., (2013), Wu et al., (2015), Lee et al., (2014), Dubey et al., (2014), Yu et al., (2014), Tachizawa et al., (2014)	15
11	Human and Technological resources	Zaid (2018), Agi (2017), Jabbour (2017), Singh et al., (2020), Kusi-Sarpong et al., (2019), Sellitto et al., (2019), Sahar et al., (2020), Kumar et al., (2019)., Kumar (2012), Balasubramanian (2012), Perotti (2012), Wang et al., (2013), Muduli et al., (2013), Hsu et al., (2013)	14
12	Leadership	Govindan (2016), Agi (2017), Ahmad et al., (2021), Huo et al., (2021), Sriyakul et al., (2019), Zulkefli et al., (2019), Singh et al., (2020), Tseng et al., (2019), Kumar et al., (2019)., Ilyas et al., (2020), Xie et al., (2012), Balasubramanian (2012), Muduli et al., (2013), Dubey et al., (2014)	14
13	Green Policies	Govindan (2016), Gandhi (2016), Tseng et al., (2019), Ilyas et al., (2020), Zhu (2012), Andreas et al., (2011), Arimura (2011), Perotti (2012), Azevedo (2012), Yang et al., (2013), Laosirihongthong et al., (2013), Hsu et al., (2013), Govindan et al., (2014)	13

14	Environmental Participation, Green Training	Govindan (2016), Younis (2016), Kirchoff et al., (2017), Agi (2017), Jabbour (2017), Tseng et al., (2019), Kusi-Sarpong et al., (2019), Çankaya et al., (2018), Shanga (2010), Balasubramanian (2012), Perotti (2012), Wu et al., (2015), Muduli et al., (2013)	13
15	Financial Implications	Feng (2017), Laari (2015), Wang (2018), Gandhi (2016), Esfahbodi (2017), Kusi-Sarpong et al., (2019), Xie et al., (2019), Sahar et al., (2020), Lina (2011), Balasubramanian (2012), Wang et al., (2013), Ortas et al., (2014)	12
16	Reverse Logistics	Sharma (2016), Younis (2016), Abdel-Baset et al., (2019)., Sellitto et al., (2019), Deng et al., (2019), Perotti (2012), Azevedo (2012), Laosirihongthong et al., (2013), Hasan (2013), Ye et al., (2013), Govindan et al., (2014),	11
17	Competition and Uncertainty	Govindan (2016), Sharma (2016), Khaksar (2015), Gandhi (2016), Tseng et al., (2019), Balasubramanian (2012), Chiou (2012), Yang et al., (2013), Lee et al., (2014), Hsu et al., (2013), Ye et al., (2013)	11
18	Investment Recovery	Vijayvargy et al., (2017), Esfahbodi (2017), Çankaya et al., (2018), Sellitto et al., (2019), Zhu (2010), Zhu (2012), Thipparat (2011), Perotti (2012), Choi et al., (2015), Jabbour et al., (2015)	10
19	Environmental Management System	Famiyeh (2017), Khan (2018), Tseng et al., (2019), Abdel-Baset et al., (2019)., Al-Sheyadi et al., (2019), Testa (2012), Arimura (2011), Perotti (2012), Wang et al., (2013), Jabbour (2014)	10
20	Internal GSCM	Zaid (2018), Yang (2017), Wang (2018), Saberi et al., (2018), Burki (2018), Zhu (2012), Zhu et al., (2013), Yang et al., (2013), Jabbour et al., (2015), Yu et al., (2014)	10
21	External GSCM	Zaid (2018), Yang (2017), Wang (2018), Gandhi (2016), Saberi et al., (2018), Çankaya et al., (2018), Al-Sheyadi et al., (2019), Zhu (2012), Zhu et al., (2013), Yang et al., (2013)	10
22	Green Product Innovation	Khaksar (2015), Singh et al., (2020), Xie et al., (2019), Çankaya et al., (2018), Sellitto et al., (2019), Novitasari et al., (2021), Chiou (2012), Muduli et al., (2013), Sezan et al., (2013)	9
23	Total Quality Management	Haseeb (2018), Agi (2017), Sriyakul et al., (2019), Jabbour (2014), Dubey et al., (2014)	5
24	Internal Environmental Management	Sharma (2016), Vijayvargy et al., (2017), Çankaya et al., (2018)	3
25	Corporate Social Responsibility	Govindan (2018), Anil Kumar et al., (2019)., Wolf (2013)	3
26	Circular Economy	Govindan (2016), Liu (2018).	2
27	Green Stock	Feng (2017), Shanga (2010)	2
28	Eco-labelling	Zhu (2012)	1