International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 04, April-2023

Green and Sustainable Supply Chain Design

Using MCDM Techniques

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***Abstract* - The term sustainable or green supply chain refers to the thought of integrating sustainable environmental processes/practices into the quality supply chain. This might include processes like supplier selection and buying material, product design, product manufacturing and assembling, distribution, instead of mitigating the harmful impact of business and supply chain operations, green supply chain involves value addition and/or value creation through the operations of the complete chain. Undeniably, reducing air pollution, other forms of pollution in general is the main goal of green supply chain, while green operations also enhance performance in terms of less waste manufacturing, reuse and recycling of products, greater efficiency of assets, positive image building, and greater customer satisfaction. Increasing pressures from stakeholders, government and non-government agencies are forcing the industries to implement Green Supply Chain Management (GSCM) initiatives. Successful implementation of GSCM is extremely important for industries to increase economic-environmental performances and to form sure sustainability in business. The prime objective of this research is to gauge the key factors associated with the successful implementation of GSCM.**

Keywords: GSCM, Sustainable, Supply Chain, Environment.

I. INTRODUCTION

Supply Chain Management (SCM) is one of the foremost promising research fields within the area of Operations Management. SCM includes various activities ranging from the gathering of stuff from the sources until the ultimate product reaches the hands of the customer. Curbing the ill effects caused by the industries by their traditional SCM practices is one of the main objectives of all nations and environmental regulatory bodies. One of the best and most effective ways to attain this objective is by integrating the standard supply chain practices with environmentally friendly practices, which ends up in a very novel concept named Green Supply Chain Management (GSCM). GSCM is defined as, "incorporating environmental thinking into SCM, including product design, material sourcing and selection, manufacturing practices, delivery of the ultimate products to the consumers, and end-of-life management of the merchandise after its intended life."

There is an increasing role for organizations to minimize impacts on the environment by reducing packaging and waste, assessing vendors on the environmental performance, developing environmentally friendly products, and reducing carbon emissions when goods are shipped. To both reduce costs and maintain a good environment, green supply chain management (GSCM) has emerged as an approach for organizations to balance these competing requirements. Reducing environmental pollution from upstream to downstream during procuring raw materials, producing, distributing, selling products, and product depreciation is the most vital goal of green supply chain management (GSCM). Supply Chain managers could minimize the products` environmental impact by supporting some related environmental criteria. Supply chain managers must consider the whole environmental impact of a product during its entire life cycle, including material, manufacturing/assembly processes, distribution, use, and disposal.

The objectives of this project are:

a. Study Literature on Green and Sustainable Supply Chains.
b. Devise a case study to figure out the crucial factors in GSCM.
c. Analysis of the model.
d. Strategies for converting traditional Supply chains into sustainable ones.

One of the foremost obvious gaps by considering previous studies is that the sizable amount of mathematical and quantitative models that are applied for choosing green suppliers like AHP (Analytic Hierarchy Process) technique, fuzzy comprehensive evaluation, and comprehensive grade model [3], grey widespread evaluation, so forth. In fact, the character of supplier selection is both quantitative and qualitative; therefore, the quantitative models could not be dependable enough. On the opposite hand, a number of these quantitative methods have complicated calculations, while others cannot avoid subjective presumption. Also, there is not any consideration to the complex causal relationship between criteria of the system together with dependencies and feedback among criteria and alternatives simultaneously [4]. Therefore, the DEMATEL and Fuzzy DEMATEL techniques are applied during this project to look at both direct and indirect effects among green practices and visualize the causal relationships among them.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 04, April-2023

II. LITERATURE SURVEY

A. *Supply Chain*

Supply chain management is the handling of the whole production flow of an honest or service, ranging from the raw components all the thanks to delivering the ultimate product to the patron. A corporation creates a network of suppliers that move the merchandise along from the suppliers of raw materials to those organizations that deal directly with users. The provision chain has been known to comprise of suppliers, manufacturers, retailers, transporters, warehouses, and customers; these are all directly or indirectly helped in customer request fulfillment. The provision chain includes not only suppliers and makers, but also warehouses, retailers, transporters, and consumers themselves. A supply chain may be a distribution and facility network that conducts the activities of fabric procurement and its reformation into finished and intermediary products still because the finished products distribution to customers. [5]

B. *Hazards due to Supply Chain and some Solutions:*

Environmental impacts from supply chains can include waste products, pollution, loss of biodiversity, deforestation, long-term damage to ecosystems, hazardous air emissions like gas emissions, and energy use. There is an increasing need to combine environmentally friendly choices with supply-chain management. Companies are now implementing sustainability programs to assist the environment by reducing miles, reducing production costs, and reducing product waste further as unplanned activities. Environmental leaders and organizations are creating practical guides for companies to follow sustainability practices. For businesses to transfer to the "green" of their supply chain, motivators should diverge. Although some are more radical for the change of the environment while others might not, researchers have reported that reduction in cost and profitability are a number of the major business motivators to become "green" within the supply chain. [6]

C. *Green Supply Chain Management (GSCM):*

The term 'Green supply chain management' (GSCM) refers to the concept of joining economical natural forms into the conventional supply chain. This will incorporate forms such as item plan, fabric sourcing and choice, fabrication and generation, operation, and end-of-life administration. Rather than essentially endeavoring to relieve the natural effect of the supply chain, GSCM includes driving esteem creation through the supply chain associations to decrease the natural effect.[6] Whereas the particular objective of GSCM is regularly the diminishment of CO2 outflows, other substantial benefits for an association incorporate; more prominent proficiency of resources, less squander generation, more noteworthy advancement, a decrease of generation costs, reuse of crude materials, expanded productivity, discernment of included esteem to the client base, and so on. Fundamental to the victory of GSCM is the approach taken by each party to their upstream and downstream accomplices within the supply chain. A much more noteworthy degree of collaboration, straightforwardness, and integration of supply chain forms and frameworks is required for the activity to be effective.[1]

GSCM increases numerous opportunities for buyers by increasing their target of improving the environment which not only enhances the method of greening the environment but also increases environmental-economic performances within the supply chain [9].

Rao and Holt [9], in their work, expressed that GSCM is an important organizational attitude, which acts as a significant player in encouraging efficiency and constructive collaboration between allies. The implementation of GSCM generates several gains in an industrial context, which might be listed as maximization of environmental performance, minimum waste generation, cost savings leading to increased profit and market-share objectives, etc. the appliance of green initiatives within the supply chain also helps in improving the ecological proficiency of organizations and their associates. Besides that, an efficient implementation of GSCM in any organization plays a significant role in acquiring and maintaining competitive gains [8]. Therefore, many researchers had made it evident in their work that the GSCM implementation is incredibly vital and result oriented that keeps seeable the environmental aspects of the organization yet.

D. *Need for GSCM:*

Green Supply chain has become necessary, looking at the increasing environmental crisis due to global warming. It also helps companies in incorporating eco-friendly techniques in their supply chains, this in-turn keeps the stakeholders happy who have environmental awareness. Green Supply Chain can also be beneficial for organizations as they can show it as Corporate Social Responsibility and avoid taxes. Even in the longer run, Green Supply Chain has vivid benefits compared to its counterparts with carbon footprints.

E. *Green Supplier Evaluation Criteria:*

It includes several concepts such as quality of services, modern technologies, organization levels, and so forth. That is, the level of relationship cooperation and attitudes are the major factors for GSC supplier suitability. The organizational cultural agreement and level of fitness are the sum of the attribute's desires. Moreover, one major part of GSE has been green consumption, its services and related products which respond to the basic needs with better quality of life while natural resources and toxic material are maximized preventing future generation exposure to pollutants.

F. *Importance of Supplier Selection*

Suppliers are the sellers that provide the stuff, services, or components which a company might not be able to provide within the present manufacturing environment for supply chains. The supplier is a major part of the corporation. An appropriate supplier can offer the corporation the proper quality products and quantity at affordable prices at the simplest time. The emergence of supply relationships has shown that suppliers are needed for a collection of competences that form a part of the availability system, which can face market competition.

G. *Multi Criteria Decision Making Techniques(MCDM):*

MCDM which is the acronym for multi-Criteria Decision-Making may be a strategy that mixes alternative's execution

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 04, April-2023

over various, negating, subjective and/or quantitative criteria and comes about in an exceedingly arrangement requiring an agreement. Information gathered from numerous areas, including behavioral choice hypothesis, computer innovation, financial matters, data frameworks and science is employed.
SCM is a MCDM problem since within the whole SC cycle, we must consider diverse criteria related to each sub-criterion of the SC cycle. To oversee the whole SC, we must distinguish the relationship of each measure, which in turn impacts the execution of the SC. Based on the pointers distinguished, we at that point make choices. This shows that decision- making is basic in overseeing the SC cycle, which SCM is an MCDM issue. Supply chain administration choices are made beneath the clashing criteria of maximizing benefit and client responsiveness while minimizing SC chance. Numerous criteria decision-making in supply chain administration gives a comprehensive diagram of multi-criteria optimization models and strategies that can be utilized in SC decision-making.

III. METHODOLOGY

MCDM (Multi Criteria Decision Making) Methods are necessary to manage these kinds of problems. The Green supplier selection problem is a complex problem and requires both quantitative and qualitative factors and hence we have used the DEMATEL method here.

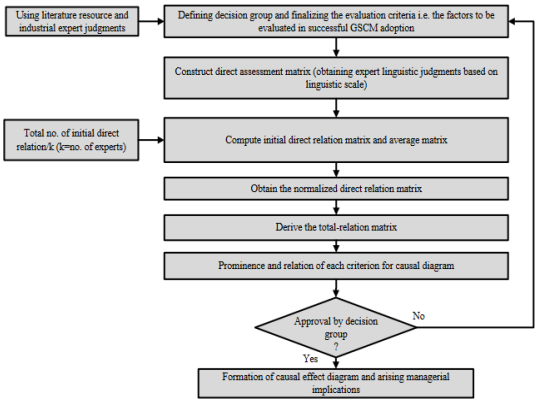
DEMATEL	ISM	AHP
DEMATEL reveals the relationships among factors and prioritizing the criteria based on the type of relationships and severity of their effects on each other criteria.	ISM enables establishing of relationships among specific items/elements to define a problem by means of their dependency and driving power.	AHP does not consider indirect effects for each criterion and assumes that criteria are independent

CRITERIA -The seven important concepts we have reviewed are - Green Logistics (GL), Organizational Performance (OP), Green Organizational Activities (GOA), Environment Protection (EP), Green Supplier Evaluation (GSE), Financial Factors (FF) and Adoption of New Practices (N&T). These factors will help us in determining the key GSCM strategies.

From a mathematical point of view:

$$GSE = f(EP, GOA, GL, OP),$$
$$EP = f(GSE, GOA, GL, OP),$$
$$GOA = f(GSE, EP, GL, OP),$$
$$GL = f(GSE, EP, GOA, OP),$$
$$OP = f(GSE, EP, GOA, GL).$$

MODEL:



Step 1: Defining the Decision Group and the evaluation criteria - This step is the most crucial. Here we need to do a thorough study of literature and gather relevant data. Here, the expert's judgement is vital and so it is necessary to have a decision group of experts to form for discussion to achieve the objective. All the factors are collected and based on the information gathered we continue. In our project, on thorough research we got the ratings of five experts in the automotive industry to figure out the objective. The tactic of DEMATEL was chosen to assess the inner dependence level existence of green supply chain management, for selected practice indicators. Four scales are used to figure the values of relationships among varied factors according to the opinion of the experts': 0 = no influence, 1 = low influence, 2 = medium influence, 3 = high influence, 4 = remarkably high influence.

The causal relationship among dimensions using the DEMATEL method is depicted below. The computation is based upon these ten respondents, and these ten 7 x 7 matrices are.

$$X^1 = \begin{bmatrix} 0 & 1 & 3 & 2 \\ 1 & 0 & 3 & 2 \\ 3 & 3 & 0 & 3 \\ 2 & 2 & 3 & 0 \end{bmatrix}, \quad X^2 = \begin{bmatrix} 0 & 1 & 3 & 2 \\ 1 & 0 & 1 & 3 \\ 2 & 2 & 0 & 2 \\ 1 & 3 & 2 & 0 \end{bmatrix}, \quad X^3 = \begin{bmatrix} 0 & 2 & 3 & 1 \\ 1 & 0 & 3 & 2 \\ 3 & 2 & 0 & 1 \\ 1 & 2 & 1 & 0 \end{bmatrix}, \quad X^4 = \begin{bmatrix} 0 & 2 & 2 & 3 \\ 2 & 0 & 3 & 2 \\ 2 & 3 & 0 & 3 \\ 3 & 2 & 3 & 0 \end{bmatrix},$$
$$X^5 = \begin{bmatrix} 0 & 2 & 3 & 1 \\ 2 & 0 & 3 & 2 \\ 3 & 3 & 0 & 2 \\ 1 & 2 & 2 & 0 \end{bmatrix}, \quad X^6 = \begin{bmatrix} 0 & 3 & 3 & 3 \\ 3 & 0 & 2 & 3 \\ 3 & 2 & 0 & 1 \\ 2 & 3 & 1 & 0 \end{bmatrix}, \quad X^7 = \begin{bmatrix} 0 & 1 & 2 & 3 \\ 1 & 0 & 1 & 1 \\ 2 & 1 & 0 & 2 \\ 3 & 1 & 2 & 0 \end{bmatrix}, \quad X^8 = \begin{bmatrix} 0 & 2 & 3 & 2 \\ 2 & 0 & 2 & 3 \\ 3 & 2 & 0 & 2 \\ 2 & 3 & 2 & 0 \end{bmatrix},$$
$$X^9 = \begin{bmatrix} 0 & 2 & 2 & 3 \\ 1 & 0 & 3 & 1 \\ 3 & 3 & 0 & 2 \\ 1 & 2 & 3 & 0 \end{bmatrix}, \text{ and } X^{10} = \begin{bmatrix} 0 & 1 & 2 & 3 \\ 1 & 0 & 1 & 2 \\ 2 & 3 & 0 & 3 \\ 1 & 2 & 2 & 0 \end{bmatrix}.$$

The average matrix *A* by aggregating ten respondents is described by the following equation:

$$A = \begin{bmatrix} 0 & 1.7 & 2.6 & 2.3 \\ 1.5 & 0 & 2.2 & 2.1 \\ 2.6 & 2.4 & 0 & 2.1 \\ 1.7 & 2.2 & 2.1 & 0 \end{bmatrix}.$$

H experts and n factors (criteria) must be considered. Each expert answers certain questions to demonstrate the degree of a criterion effect based on her or his beliefs. [aij] denotes pairwise comparisons between any two criteria and it is assigned a score ranging from 0 - 4. The scores are given by each expert and answers to each of them make the nonnegative matrix.

$x^k = [x^k]$ *nxn* with 1<k<H. A high score indicates a belief that greater improvement in i is required to improve j. Then it is possible to calculate the average matrix on account of all expert's opinions by averaging their scores as follows:

$$[a_{ij}]_{n\times n} = \frac{1}{H}\sum_{k=1}^{H}[x_{ij}^k]_{n\times n}.$$

The initial direct effects that each criterion exerts on and receives from other criteria are exposed in the average matrix, which is also called the initial direct influenced. Moreover, in this level, gaining the causal effect between each pair of criteria in a system by drawing an influence map will be possible, also as follows:

If aij <1 (independent is identified among all criteria; otherwise, non-independent will be identified).

Wherever the value of a cell is greater than the threshold value, we can determine a relationship between those criteria.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 04, April-2023

Step 2: Normalize the initial direct- relation matrix - Normalized initial direct relation matrix D is obtained by normalizing the average matrix A, by using the following formulas:

$$S = \max\left\{\max\sum_{j=1}^{n} a_{ij}, \max\sum_{i=1}^{n} a_{ij}\right\},$$

$$D = \frac{A}{S}.$$

As a result, total direct influences that criterion i gives to the other criteria are gained by sum of each row i of matrix A as well as the sum of each column j represent most direct effects on others by total direct effects of the criterion. Likewise, since the sum of each column j of matrix A represents the total direct effects received to other criteria by criterion i, $\sum_{i=1}^{n} a_{ij}$ represents the total direct effects that the criterion j receives the most direct effects from other criteria and the positive numerical s takes the smaller of the two as the upper bound, and the matrix D is obtained by dividing each element of A by the scalar s. Each element dij of matrix D is between zero and less than 1: $0 < dij < 1$.

Step 3: Calculating the Total - relation matrix- It can be calculated by doing the following,

$$D^2, D^3, \ldots, D^{\infty},$$

$$\lim_{m\to\infty} D^m = [0]_{n\times n},$$

$[0]_{n\times n}$ is a $(n \times n)$ null matrix.

T = D (I - D)-1, Where I represent an identity matrix.

The total relation matrix $T_{n\times n}$ is achieved as follow:

$$\sum_{m=1}^{\infty} D_i = D + D^2 + D^3 \cdots D^m$$

$$= D\left(I + D + D^2 + \cdots + D^{m-1}\right)$$

$$= D(I-D)^{-1}(I-D)\left(I + D + D^2 + \cdots + D^{m-1}\right)$$

$$= D(1-D)^{-1}\left(I - D^m\right) = D(I-D)^{-1}.$$

Calculate the summation of rows and columns of the total relation matrix T. If, ri be the sum of the ith row in matrix T, then ri summarizes both direct and indirect impacts given by factor i to the other factors. If cj denotes the sum of the jth column in matrix T, then cj shows both direct and indirect impacts received by factor j from the other factors. The sum (ri + cj) is known as 'Prominence,' and shows the total effects given and received by factor i. The (ri +cj) indicates the degree of importance for factor i in the entire system. On the contrary, the difference (ri - cj) is known as 'Relation,' which represents the net effect that factors i contributes to the system.

Specifically, if (ri - cj) is positive, factor i is a cause factor. The factor i is a receiver factor, if (ri-cj) is negative.[17]

I: identity matrix, T: total-relation matrix ($[T]_{n\times n}$).

Step 4: Setting up a threshold value - The average of the elements in total relation matrix T gives the threshold value. Since matrix T provides instances on how one factor affects another, threshold value assists to filter out some insignificant or negligible effects in this context.

Further, the effects, which are greater than the threshold value would be chosen and shown in the digraph. The digraph can be acquired by mapping the dataset of (r + c, r - c).[18]

A. FUZZY DEMATEL METHOD

Decision makers experience uncertainties within the decision-making process thanks to the subjective manner of their judgments. To pander to this subjectivity and vagueness inhuman judgment, [19] introduced fuzzy pure mathematics to demonstrate the linguistic terms used when addressing a call process within the theory, mathematical operators and programming also is allowed to use to the fuzzy domain.

In this method we make use of triangular fuzzy numbers (TFN). The TFN's are represented as (l, i, j) where the parameters represent the smallest possible, the most probable and the highest possible values respectively that characterizes a fuzzy event.

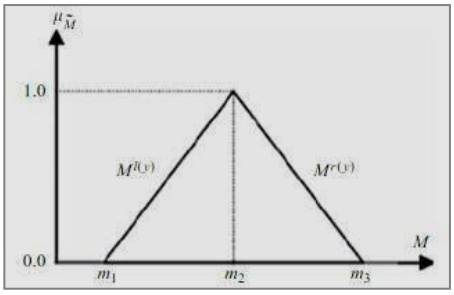


Fig 1 - Triangular Fuzzy Numbers

The most popular de- fuzzification method is the Center of Gravity Method. However, it had a major issue. The method could not distinguish between two same crisp valued fuzzy values even if they had different shapes. So therefore, the CFCS method is used in this project, and it is indeed the method that is widely used as well.

The CFCS method was proposed by Ogrizovic and Tzeng (2003) [20], and its procedure is subject to identifying the left and right scores by fuzzy minimum and fuzzy maximum. Five Stepped Algorithm is proposed as follows:

Step1: Normalization

$$xl_{ij}^{k} = \left(l_{ij}^{k} - \min l_{ij}^{k}\right)/\Delta_{\min}^{\max},$$

$$xm_{ij}^{k} = \left(m_{ij}^{k} - \min l_{ij}^{k}\right)/\Delta_{\min}^{\max},$$

$$xr_{ij}^{k} = \left(r_{ij}^{k} - \min l_{ij}^{k}\right)/\Delta_{\min}^{\max},$$

where $\Delta_{\min}^{\max} = \max r_{ij}^{k} - \min l_{ij}^{k}$.

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ISSN: 2278-0181
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Step 2: Calculating the Left and Right Normalized Values

$$xls_{ij}^{k} = xm_{ij}^{k} / \left(1 + xm_{ij}^{k} - xl_{ij}^{k}\right),$$

$$xrs_{ij}^{k} = xr_{ij}^{k} / \left(1 + xr_{ij}^{k} - xm_{ij}^{k}\right).$$

Step 3: Calculate the total normalized crisp value.

$$x_{ij}^{k} = \left[xls_{ij}^{k}\left(1 - xls_{ij}^{k}\right) + xrs_{ij}^{k} xrs_{ij}^{k}\right] / \left[1 - xls_{ij}^{k} + xrs_{ij}^{k}\right].$$

Step 4: Calculating the crisp values.

$$z_{ij}^{k} = \min l_{ij}^{k} + x_{ij}^{k} \Delta_{\min}^{\max}.$$

Step 5: Integrating the crisp values.

$$z_{ij}^{k} = \frac{1}{p}\left(z_{ij}^{1} + z_{ij}^{2} + \cdots + z_{ij}^{p}\right).$$

Procedure for Fuzzy DEMATEL method:

Identifying the choice goal and forming a committee. Decision-making process involves the subsequent steps: describing the choice goals, collecting the relevant data identifying the possible alternatives, assessing the alternatives with relevancy their advantages and drawbacks, selecting the most effective alternative, and monitoring the results whether the choice goals are attained or not. For this reason, the decision-making process starts with the determination and outline of the choice goals.

Developing evaluation criteria and designing the fuzzy linguistic scale is important, thanks to the character of cause-effect relationships of the factors as they involve many complex aspects. The DEMATEL method creates a structural model to divide the numerous criteria into cause group and effect group. To manage the subjectivity and vagueness of human judgment, the degree of influence of every criterion over others is expressed by one among five linguistic terms: no influence (No), extremely low influence (VL), low influence (L), high influence (H), and high influence (VH). These linguistic terms are described in positive TFNs as shown below:

Linguistic Terms				Triangular Fuzzy Numbers		
Very High Influence	VH			0.7	0.9	1
High Influence	H			0.5	0.7	0.9
Low Influence	L			0.3	0.5	0.7
Very Low Influence	VL			0.1	0.3	0.5
No Influence	NO			0	0.1	0.3

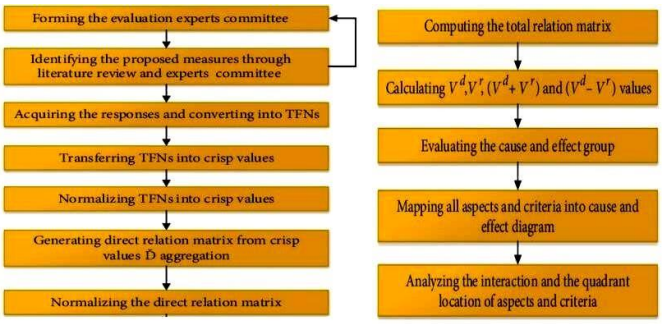
Fig 2 – TFNs

After gathering the direct relation matrix, Z, by the formulas, the normalized direct relation matrix, X, is acquired. The overall relation matrix, T, can then be obtained. The row totals and the column totals of the entire relation matrix, T, are represented as D and R. A cause-effect diagram is obtained by graphing the information set, within which the (D+R) represents the horizontal axis, and is comprised of summation of D with R, and(D−R) represents the vertical axis, and is comprised of subtracting R from D. (D+R) and (D−R) are called "Prominence," and "Relation," respectively. Prominence represents the degree of importance of the criterion, and the Relation distinguishes the standards between the cause or effect criteria. If the (D−R) is positive, the criterion falls into the cause group, and if negative, into the effect group. Hence, the cause-effect diagrams clarify the complex relationships among a collection of criteria and enable the visualization of the structural model. Appropriate decisions may well be reached by determining the cause group and effect group and distinguishing the differences between cause criteria and the effect criteria, supported by the cause-effect diagrams.

The Factors we reviewed for this method are:

- Government Regulations and Standards (F1)
- Top Management Commitment (F2)
- Environmental Certifications (F3)
- Globalization (F4)
- Competitiveness (F5)
- Customer Requirements (F6)
- Role of Supplier (F7)
- Financial Factors (F8)
- Brand Image Building (F9)
- Employee Involvement (F10)
- Role of Stakeholders, NGO, and Media (F11)
- Human Technical Expertise (F12)
- Adoption of New Technology and Processes (F13)
- Sustainability (F14)
- Reverse Logistics (F15)
- Training of Suppliers and Employees (F16)

- Flowchart for Fuzzy Dematel:



International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
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IV. IMPLEMENTATION

First, the ratings given by our experts is represented in tabular form. This illustrates the values of relationships criteria determined by comparisons made by experts according to their opinion are assigned in the range of 0 to 4.

Total Relation Matrix T = Y (inv(I-Y))

								Ri
	0.058168938	0.220840672	0.021682613	0.06793873	0.017275197	0	0.189117946	0.575024097
	0.210531773	0.100340222	0.038134471	0.22817852	0.020868772	0	0.228458137	0.826511896
	0.052818489	0.207091263	0.031542727	0.217108684	0.014777982	0	0.16178001	0.685119155
	0.059372598	0.209612542	0.1070198	0.083008158	0.019818595	0	0.216961463	0.695793157
	0.248644329	0.316567662	0.191867071	0.28303777	0.026243216	0	0.287294151	1.3536542
	0.308283372	0.385180811	0.22550553	0.345262056	0.178774583	0	0.378163854	1.821170205
	0.153909413	0.186509702	0.11067886	0.203166096	0.100753443	0	0.10298506	0.858002573
Ci	1.091728913	1.626142875	0.726431073	1.427700014	0.378511788	0	1.564760621	

Step: 1 Initial direct-relations ships for all matrix of responses

Column	OP	GL	GOA	EP	GSE	FF	N&T	Sum
Organisational Performance	0	3.7	0	0	0	0	2.8	6.5
Green Logistics	3.5	0	0	3.6	0	0	3	10.1
Green Organisational Activities	0	3	0	3.2	0	0	1.8	8
Environmental Performance	0	3.1	1.7	0	0	0	3.2	8
Green Supplier Evaluation	3.4	3.6	3	3.3	0	0	3	16.3
Financial factors	3.7	3.8	3	3.5	3	0	3.8	20.8
Adoption of New Practices	2	1.8	1.5	2.6	1.9	0	0	9.8

Direct Relation Matrix 20.8

	OP	GL	GOA	EP	GSE	FF	Adoption of New Practices
Organisational Performance	0	0.177884615	0	0	0	0	0.134615385
Green Logistics	0.168269231	0	0	0.173076923	0	0	0.144230769
Green Organisational Activities	0	0.144230769	0	0.153846154	0	0	0.086538462
Environmental Performance	0	0.149038462	0.081730769	0	0	0	0.153846154
Green Supplier Evaluation	0.163461538	0.173076923	0.144230769	0.158653846	0	0	0.144230769
Financial factors	0.177884615	0.182692308	0.144230769	0.168269231	0.144230769	0	0.182692308
Adoption of New Practices	0.096153846	0.086538462	0.072115385	0.125	0.091346154	0	0

Identity Matrix

1	0	0	0	0	0	0
0	1	0	0	0	0	0
0	0	1	0	0	0	0
0	0	0	1	0	0	0
0	0	0	0	1	0	0
0	0	0	0	0	1	0
0	0	0	0	0	0	1

And we calculate the total relationship matrix.

I - Y

1	-0.17788462	0	0	0	0	-0.13461538
-0.16826923	1	0	-0.17307692	0	0	-0.14423077
0	-0.14423077	1	-0.15384615	0	0	-0.08653846
0	-0.14903846	-0.08173077	1	0	0	-0.15384615
-0.16346154	-0.17307692	-0.14423077	-0.15865385	1	0	-0.14423077
-0.17788462	-0.18269231	-0.14423077	-0.16826923	-0.14423077	1	-0.18269231
-0.09615385	-0.08653846	-0.07211538	-0.125	-0.09134615	0	1

Inverse of (I-Y)

1.058168938	0.220840672	0.021682613	0.06793873	0.017275197	0	0.189117946
0.210531773	1.100340222	0.038134471	0.22817852	0.020868772	0	0.228458137
0.052818489	0.207091263	1.031542727	0.217108684	0.014777982	0	0.16178001
0.059372598	0.209612542	0.1070198	1.083008158	0.019818595	0	0.216961463
0.248644329	0.316567662	0.191867071	0.28303777	1.026243216	0	0.287294151
0.308283372	0.385180811	0.22550553	0.345262056	0.178774583	1	0.378163854
0.153909413	0.186509702	0.11067886	0.203166096	0.100753443	0	1.10298506

Thus, by going through the above-mentioned framework, we can see that GSE (Green supplier evaluation), and Financial Factors (FF) have a significant effect on all the other criteria but do not receive effects from any of them. Another observation we can make is that GOA (Green Organizational Activities) receives and influences all the criteria. FF has the greatest R - C score of 1.82 and hence is the biggest cause group and GSE has the R - C score of 0.97being the only other cause group. In addition to this, we see that GL (Green Logistics) has a maximum R + C value of 2.45 and the lowest R - C value. R is the degree of influential impact, which shows how much this factor influences other factors whereas, C is the degree of influenced impact showing how much the factor gets influenced by the others. FF has the highest R factor whereas GL has the highest C factor.

The cause group factors are vital due to their direct impact on the system. Thus, it would be significant to focus on the cause group factors. Among the two cause factors, financial factors have the highest R - C value which implies it has a major influence on the entire system. The other cause factor is GSE with a higher R + C value as well. This shows it can receive influence in return as well.

Ri	Ci	-	Ri + Ci	Ri - Ci	--	Identify As
0.575024097	1.091728913		1.666753011	**-0.516704815**	Organisational Performance	Effect
0.826511896	1.626142875		2.45265477	**-0.799630979**	Green Logistics	Effect
0.685119155	0.726431073		1.411550228	**-0.041311918**	Green Organisational Activities	Effect
0.695793157	1.427700014		2.123493172	**-0.731906857**	Environmental Performance	Effect
1.3536542	0.378511788		1.732165987	0.975142412	Green Supplier Evaluation	Cause
1.821170205	0		1.821170205	1.821170205	Financial factors	Cause
0.858002573	1.564760621		2.422763195	**-0.706758048**	Adoption of New Practices	Effect

- Based on the T matrix and the threshold hold value we calculated we can draw the digraph of the following.
- The cells colored in blue show the factors which have a relation between each other. If the value of the cell is greater than the threshold value, then a relation between the two factors can be identified. The Following is depicted in the Digraph above.

A. For Fuzzy Dematel

We have the values of six respondents for this method. However, for the sake of simplicity and the lack of pages we must publish for this report we look at the calculations for one respondent here. The rest of the calculations are present in the Excel sheet.

Respondent 1:

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16
F1	NO	H	VH	H	H	L	H	H	L	VL	L	VL	VH	H	VH	H
F2	VL	NO	VH	H	VH	VH	VH	VH	VH	H	VL	L	H	H	VH	VH
F3	L	VL	NO	VH	H	L	H	L	VH	L	VH	H	L	H	VL	L
F4	H	H	L	NO	VH	L	L	H	VH	H	H	L	H	H	H	VL
F5	VL	H	H	VL	NO	H	L	VH	VH	H	L	H	L	VH	H	L
F6	L	L	L	VL	VL	NO	H	VH	VH	VL	H	VL	VH	H	VH	VL
F7	L	L	L	H	VH	L	NO	H	H	VL	L	L	L	H	VH	H
F8	L	VH	L	VL	VL	H	VL	NO	VH	H	VL	VH	VH	H	H	VH
F9	H	VH	H	H	H	H	VL	VH	NO	VH	VH	H	H	H	H	H
F10	VL	VH	L	VL	L	L	L	VL	VH	NO	VL	H	VH	VH	L	H
F11	VH	VH	VL	VL	L	VH	H	H	VH	L	NO	VL	L	L	H	VL
F12	H	VH	L	VL	L	L	VH	H	VH	H	VL	NO	VH	VH	H	VH
F13	H	H	VL	H	VH	VL	VL	VH	VH	L	L	VH	NO	H	H	H
F14	VL	H	L	VL	H	H	H	H	VH	L	L	H	H	NO	VL	H
F15	L	VH	VL	H	H	L	H	VH	VH	L	H	L	H	L	NO	VL
F16	VL	VH	VL	L	H	L	VH	H	H	H	VL	VH	H	VH	H	NO

International Journal of Engineering Research & Technology (IJERT)
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So now, based on the ratings given we get Step1:

	F1		
F1	0	0.1	0.3
F2	0.1	0.3	0.5
F3	0.3	0.5	0.7
F4	0.5	0.7	0.9
F5	0.1	0.3	0.5
F6	0.3	0.5	0.7
F7	0.3	0.5	0.7
F8	0.3	0.5	0.7
F9	0.5	0.7	0.9
F10	0.1	0.3	0.5
F11	0.7	0.9	1
F12	0.5	0.7	0.9
F13	0.5	0.7	0.9
F14	0.1	0.3	0.5
F15	0.3	0.5	0.7
F16	0.1	0.3	0.5
	0	***0.1***	***0.3***

	F2		
F1	0.5	0.7	0.9
F2	0	0.1	0.3
F3	0.1	0.3	0.5
F4	0.5	0.7	0.9
F5	0.5	0.7	0.9
F6	0.3	0.5	0.7
F7	0.3	0.5	0.7
F8	0.7	0.9	1
F9	0.7	0.9	1
F10	0.7	0.9	1
F11	0.7	0.9	1
F12	0.7	0.9	1
F13	0.5	0.7	0.9
F14	0.5	0.7	0.9
F15	0.7	0.9	1
F16	0.7	0.9	1
	0	***0.1***	***0.3***

We do this for all the sixteen factors but here for the sake of simplicity, we show the calculations for only the F1 factor vs all sixteen factors.

Step 2:

DELTA

Max -Min **1**

Step 2: normalizing these TFNs

$$xa_{ij}^k = \left(a_{ij}^k - \min a_{ij}^k\right) / \Delta_{\min}^{\max}$$
$$xa_{2ij}^k = \left(a_{2ij}^k - \min a_{2ij}^k\right) / \Delta_{\min}^{\max}$$
$$xa_{3ij}^k = \left(a_{3ij}^k - \min a_{3ij}^k\right) / \Delta_{\min}^{\max}$$
Where $\Delta_{\min}^{\max} = \max r_{ij}^n - \min r_{ij}^n$

F1	0	0	0
F2	0.1	0.2	0.2
F3	0.3	0.4	0.4
F4	0.5	0.6	0.6
F5	0.1	0.2	0.2
F6	0.3	0.4	0.4
F7	0.3	0.4	0.4
F8	0.3	0.4	0.4
F9	0.5	0.6	0.6
F10	0.1	0.2	0.2
F11	0.7	0.8	0.7
F12	0.5	0.6	0.6
F13	0.5	0.6	0.6
F14	0.1	0.2	0.2
F15	0.3	0.4	0.4
F16	0.1	0.2	0.2

Step 3:

Step 3: computing the left $\left(xls_{ij}^k\right)$ and right $\left(xrs_{ij}^k\right)$ normalized values

$$xls_{ij}^k = xa_{2ij}^k / \left(1 + xa_{2ij}^k - xa_{1ij}^k\right)$$
$$xrs_{ij}^k = xa_{3ij}^k / \left(1 + xa_{3ij}^k - xa_{2ij}^k\right)$$

F1		0	0
F2		0.1818182	0.2
F3		0.3636364	0.4
F4		0.5454545	0.6
F5		0.1818182	0.2
F6		0.3636364	0.4
F7		0.3636364	0.4
F8		0.3636364	0.4
F9		0.5454545	0.6
F10		0.1818182	0.2
F11		0.7272727	0.77778
F12		0.5454545	0.6
F13		0.5454545	0.6
F14		0.1818182	0.2
F15		0.3636364	0.4
F16		0.1818182	0.2

Step 4: acquiring the crisp values $\left(x_{ij}^k\right)$

$$x_{ij}^k = \left[xls_{ij}^k\left(1 - xls_{ij}^k\right) + xrs_{ij}^k \times xrs_{ij}^k\right] / \left(1 - xls_{ij}^k + xrs_{ij}^k\right)$$

F1		0
F2		0.1853896
F3		0.3776715
F4		0.576489
F5		0.1853896
F6		0.3776715
F7		0.3776715
F8		0.3776715
F9		0.576489
F10		0.1853896
F11		0.7646659
F12		0.576489
F13		0.576489
F14		0.1853896
F15		0.3776715
F16		0.1853896

Step 5:

Step 5: generating the total normalized crisp values $\left(\bar{\omega}_{ij}^k\right)$

$$\bar{\omega}_{ij}^k = \min a_{ij}^n + x_{ij}^n \Delta_{\min}^{\max}$$

F1		0
F2		0.1853896
F3		0.3776715
F4		0.576489
F5		0.1853896
F6		0.3776715
F7		0.3776715
F8		0.3776715
F9		0.576489
F10		0.1853896
F11		0.7646659
F12		0.576489
F13		0.576489
F14		0.1853896
F15		0.3776715
F16		0.1853896

We do the same for all the sixteen factors and get sixteen such tables. After we get these values, we make a new table where we take the sums of all these values.

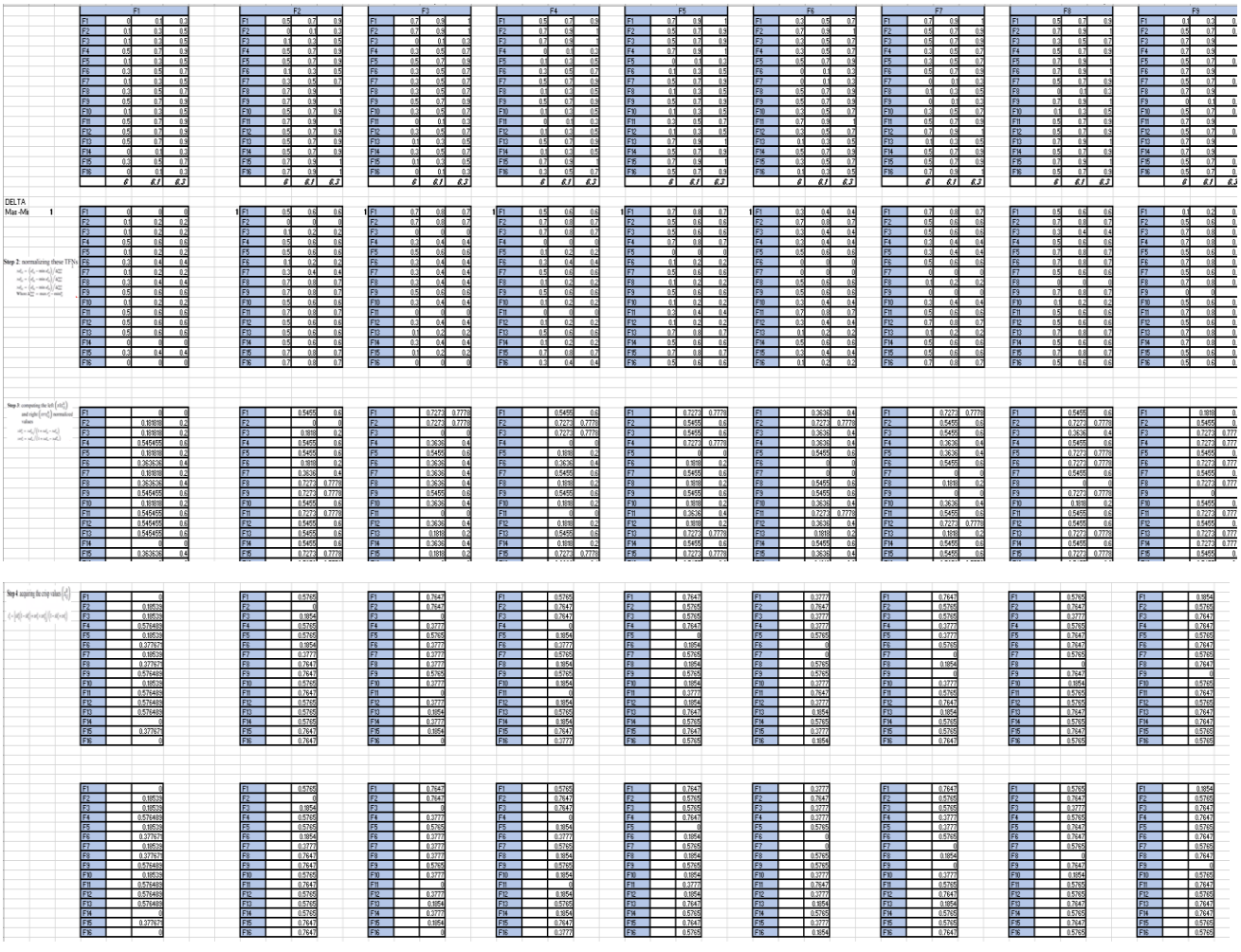
The table thus formed gives us the values that we will use to conduct the DEMATEL method.

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16		ROW
F1	0	0.21618	0.27499	0.21618	0.25147	0.12961	0.25147	0.21618	0.11419	0.08154	0.14163	0.09337	0.26323	0.21618	0.28675	0.22794		2.98092
F2	0.06952	0	0.27499	0.25147	0.25147	0.27499	0.25147	0.28675	0.24481	0.25147	0.06952	0.10235	0.21618	0.21618	0.27499	0.28675		3.32291
F3	0.10557	0.06952	0	0.28675	0.21618	0.14163	0.21618	0.14163	0.29252	0.14163	0.28675	0.20953	0.14163	0.21618	0.06952	0.14163		2.67685
F4	0.20376	0.20376	0.14163	0	0.28675	0.14163	0.14163	0.21618	0.28076	0.25147	0.21618	0.15442	0.21618	0.22794	0.22794	0.06952		2.97976
F5	0.06952	0.21618	0.21618	0.06952	0	0.21618	0.14163	0.28675	0.25724	0.22794	0.11759	0.22794	0.14163	0.28675	0.21618	0.14163		2.83288
F6	0.14163	0.10557	0.14163	0.10557	0.06952	0	0.21618	0.28675	0.29252	0.06952	0.21618	0.06952	0.28675	0.21618	0.28675	0.06952		2.57381
F7	0.10557	0.14163	0.11802	0.21618	0.25147	0.09442	0	0.21618	0.22388	0.06952	0.14163	0.12961	0.14163	0.21618	0.28675	0.21618		2.56885
F8	0.14163	0.28675	0.14163	0.06952	0.06952	0.21618	0.06952	0	0.29252	0.21618	0.06952	0.28675	0.28675	0.21618	0.21618	0.25147		2.83031
F9	0.21618	0.27499	0.21618	0.21618	0.22794	0.22794	0.0588	0.28675	0.00446	0.28675	0.27499	0.23217	0.22794	0.21618	0.20376	0.25147		3.4227
F10	0.06952	0.25147	0.14163	0.06952	0.10557	0.14163	0.14163	0.06952	0.25724	0	0.06952	0.21618	0.28675	0.28675	0.14163	0.21618		2.46474
F11	0.25147	0.28675	0.03476	0.03476	0.14163	0.28675	0.21618	0.21618	0.29252	0.14163	0	0.10696	0.14163	0.10557	0.21618	0.06952		2.54249
F12	0.22794	0.25147	0.14163	0.06952	0.10557	0.14163	0.27499	0.21618	0.269	0.21618	0.06952	0.04688	0.28675	0.28675	0.21618	0.28675		3.10694
F13	0.21618	0.21618	0.05793	0.21618	0.27499	0.06952	0.06952	0.28675	0.29252	0.14163	0.14163	0.27201	0	0.21618	0.21618	0.21618		2.90361
F14	0.03476	0.21618	0.12961	0.06952	0.21618	0.21618	0.21618	0.21618	0.29252	0.10557	0.10557	0.21618	0.21618	0	0.06952	0.21618		2.53655
F15	0.14163	0.28675	0.06952	0.25147	0.25147	0.14163	0.21618	0.28675	0.25724	0.14163	0.21618	0.14301	0.25147	0.14163	0	0.06952		2.86606
F16	0.03476	0.28675	0.03476	0.14163	0.21618	0.10557	0.28675	0.22794	0.22388	0.21618	0.06952	0.28675	0.21618	0.28675	0.21618	0		2.8498
																		3.4227

For respondent 2:

Linguistic Terms				Triangular Fuzzy Numbers		
Very High Influenc	VH			0.7	0.9	1
High Influence	H			0.5	0.7	0.9
Low Influence	L			0.3	0.5	0.7
Very Low Influence	VL			0.1	0.3	0.5
No Influence	NO			0	0.1	0.3

E2	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16
F1	NO	H	VH	H	VH	L	VH	H	VL	VL	L	VL	H	H	VH	H
F2	VL	NO	VH	VH	H	VH	H	VH	H	VH	VL	L	H	H	VH	VH
F3	VI	VL	NO	VH	H	L	H	L	VH	L	VH	VH	L	H	VL	L
F4	H	H	L	NO	VH	L	L	H	VH	VH	H	L	H	H	H	VL
F5	VL	H	H	VL	NO	H	L	VH	H	H	VL	H	L	VH	H	L
F6	L	VL	L	L	VL	NO	H	VH	VH	VL	H	VL	VH	H	VH	VL
F7	VL	L	L	H	H	NO	NO	H	H	VL	L	L	L	H	VH	H
F8	L	VH	L	VL	VL	H	VL	NO	VH	H	VL	VH	VH	H	H	H
F9	H	VH	H	H	H	H	NO	VH	NO	VH	VH	H	H	H	H	VH
F10	VL	H	L	VL	VL	L	L	VL	H	NO	VL	H	VH	VH	L	H
F11	H	VH	NO	NO	L	VH	H	H	VH	L	NO	VL	L	VL	H	VL
F12	H	H	L	VL	VL	L	VH	H	H	H	VL	NO	VH	VH	H	VH
F13	H	H	VL	H	VH	VL	VL	VH	VH	L	L	VH	NO	H	H	H
F14	NO	H	L	VL	H	H	H	VH	VL	VL	H	H	NO	VL	H	
F15	L	VH	VL	VH	VH	L	H	VH	H	L	H	VL	VH	L	NO	VL
F16	NO	VH	NO	L	H	VL	VH	H	H	H	VL	VH	H	VH	H	NO



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ISSN: 2278-0181
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After we get this matrix, we conduct the DEMATEL method explained earlier, and we got these results:

	D	R	D+R	D-R
F1	5.27695	3.64465	8.92161	1.632302921
F2	5.83814	5.93473	11.7729	-0.096583388
F3	4.76542	3.86797	8.63338	0.897449827
F4	5.30138	4.11078	9.41216	1.190595966
F5	5.03651	5.21148	10.248	-0.174970421
F6	4.60629	4.60622	9.21252	0
F7	4.61904	4.79121	9.41025	-0.172166488
F8	5.11	6.1849	11.2949	-1.074905793
F9	6.034	6.82823	12.8622	-0.794228352
F10	4.45741	4.68985	9.14725	-0.232440423
F11	4.5913	3.91913	8.51044	0.672170921
F12	5.53416	5.10105	10.6352	0.433107442
F13	5.25282	5.89751	11.1503	-0.644691502
F14	4.57826	5.91717	10.4954	-1.338906793
F15	5.14983	5.53987	10.6897	-0.390040456
F16	5.10431	5.01108	10.1154	0.093233111

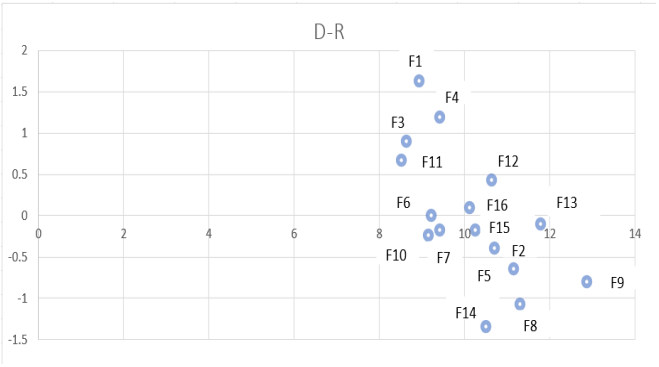
V. RESULTS AND DISCUSSION

The factors are arranged in terms of the degree of their importance based on their respective (r + d) scores.

The Brand Image Building (F9) factor with (r + d) score of 12.8622 has the highest degree of importance followed by F2 > F8 > F13 > F15 > F12 > F14 > F5 > F16 > F4 > F7 > F6 > F10 > F1 > F3 > F11.

CAUSE FACTORS	EFFECT FACTORS
Government regulations and standards	Financial Factors
Top Management Commitment	Brand Image building
ISO 4001 Certifications	Adoption of modern technologies and processes
Globalization	Sustainability
Competitiveness	Reverse Logistics
Customer Requirements	
Role of Supplier	
Employee Involvement	
Role of stakeholder, NGO, and Media	
Technical Expertise	
Training of Supplier and Employees	

- The cause group factors are very vital due to their direct impact on the overall system.
- Among all the cause group factors, **Government Regulations and Standards (F1)** has the highest (d - r) score with 1.6323, which implies that (F1) has more impact on the entire system.
- But its (r + d) score (equals to 8.921) is comparatively low, which can be justified by the fact that Government regulations and standards can have influence over the other factors but receive comparatively less influence in return.
- The second highest factor in (d – r) column is Globalization **(F4)** with score of 1.1905, which also has a reasonable power to influence other factors as given by influential impact index (r) value.
- Globalization is acting as thrust to adopt GSCM in a supply chain context.
- Further, export norms and increased pressure from the environmental bodies and developed nations makes



this fact evident and influences the organizations to adopt green practices.

- **Training of Suppliers and Employees (F16)** with (d – r) score of 0.0932 is especially important to increase the performance of GCSM in business. It will help to achieve sustainable business development.
- **Top Management Commitment (F2)** with (d – r) score of -0.09 acts as an initiation and decision power for any concept to be introduced within the organization.
- **Sustainability (F14)** obtains a least (d – r) score i.e., -1.3389, which implies that this factor receives the maximum impact from all other factors.
- Further **Brand Image Building (F9)** is the most influencing cause group factors.
- GSCM initiatives play a crucial role in improving the brand image and value from an industrial context.

VI. CONCLUSION AND FURTHER WORK

- The present study aims to build a structural model for analyzing the interrelationships among factors relevant to GSCM adoption.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
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- Using literature and expert's inputs, sixteen factors, important in initiation and implementation of successful GSCM initiatives were identified.
- An empirical case study was conducted to show the real-life applicability of the proposed FUZZY DEMATEL based model.
- It would be significant to focus on the cause group factors in the beginning, and the factors in the effect group need to be discussed to find out their contribution in the overall manner.
- **Top Management Commitment (F2), Human Technical Expertise (F12), Financial Factors (F8),** come out to be the most principal factors in successful implementation of GSCM.
- The models proposed in the research work may provide useful learning insights into understanding and analysis of factors to implement GSCM in a most efficient way.
- Implementation of GSCM aspects will help case organization to achieve a gain in environmental and economic performances in the supply chain.
- Different strategies were identified from the analysis to convert traditional supply chain to green and sustainable supply chain.
- One could be of selection of factors in successful GSCM implementation, as only sixteen factors were identified.

Future research can be conducted to understand the hierarchical intertwined relations among the GSCM success factors using ANP and TOPSIS.

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