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Green supplier selection and evaluation of medium scale enterprises by using Fuzzy AHP and TOPSIS technique.

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Abstract

Selection of sustainable or green supplier is one of the most challenging activities for any of the Small and Medium Scale Enterprises. These Industries are trying hard for selecting suppliers who are supplying greener materials. Sustainable selection of suppliers is a Multi Criteria Decision Making Problem. Quantitative as well as Qualitative criteria factors are involved in this type of problem. This paper basically explains the selection of green suppliers for Small and Medium Scale Enterprises. The Fuzzy Analytic Hierarchy Process and Technique for order of preference by similarity to ideal solution technique is applied and evaluated for selection and rating of the best supplier. The identification of criteria for green supplier selection is made by discussing with academicians and experts from the Small and Medium Scale Enterprises. Further the literature review on sustainable supplier selection for this type of organizations is made. Based on the opinion from the experts of the corporates, academicians, and reviewing the literature the final criteria for green supplier selection is chosen. Using Analytic Hierarchy Process technique, the weights to the multicriteria are assigned and ranking of greener suppliers is done by applying Fuzzy Analytic Hierarchy Process and Technique for order of preference by similarity to ideal solution technique method. The research findings from the study showed that green supplier X1 ranks top by using Fuzzy Analytic Hierarchy Process technique and green supplier B is in top ranking by using the Technique for order of preference by similarity to ideal solution technique method. From the results obtained Fuzziness may be more appropriate and accurate than the available techniques for solving the green supplier selection issues.

Keywords: Small and Medium Scale Enterprises (SME) Green Supplier Selection, Fuzzy Analytic Hierarchy Pro-cess(F-AHP), Technique for order of preference by similarity to ideal solution technique (TOPSIS)

1. Introduction

Small and medium scale enterprises are very essential for the dynamics and health of the global economy. More and more employment opportunities are provided by small and medium scale industries and supports large scale enterprises. Due to the advancement of Technology, Science and variations in global environment in social, political and economic factors the conditions and erosion of trade borders, even the smaller companies are having the more potential for making trading activities.[1] Small and Medium scale Enterprises (SMEs) account for the majority of the organizations in most of the developed economies.[2,3] The main aim of this research work is to empirically examine the practices of green supplier's selection for SMEs and evaluating it by multicriteria decision making techniques (MCDM). In this case Fuzzy Analytical Hierarchy Process(F-AHP) and Technique for order of Preference by Similarity to Ideal Solution (TOPSIS)are used. There is ample evidence that closer cordial relationships among the suppliers who are often called as Supply Partnerships are needed for the chain of supply network for operating to the maximum benefit of all partners, thus necessitating the establishment of the realistic standard of working and partnering between the organizations of all types which is not limited to bigger organizations.[4] Small and Medium enterprises are in dire need of gaining competitive advantage by greater Buyer-Supplier interaction and controlling the unit cost.[5] As on today more research work is done on large scale industries than on SMEs as far as Green Supplier Selection is concerned. So, on the one hand SMEs contribute greatly to the overall production of goods and service organizations. But on the other hand, they were blamed as the biggest polluters and a source of 60-70% of total pollution in the region. Due to this ecological concern, it is important and critical that their manufacturing activities should be eco-friendly. The greening activity of the supply chain initiative which is to green all the desired stakeholders in the supply chain network, many of the SME sectors can solve the greening problem for the SMEs in their region.[6,7,8]

2. Supplier selection in SME context

Supply Chain Management (SCM) mainly focuses on the organization on Supplier's Process Technology usage and the ability to increase competitive advantage. Supplier's commitment, competency is needed for a SME company for competing in the global market. The purchasing department's main goal is to establish a networking activity of suitable suppliers.[9,10] The prime importance of selecting the suppliers comes as it provides necessary resources while simultaneously undertaking the activities such as managing the inventory, manufacturing planning and also controlling the manufacturing activity, quality of the product, cash flow requirement, and finally organization's performance of the business can be influenced. Selection of suppliers involves some of the factors that an organization utilizes during the process of selection and evaluation of key or preferred supplier's performance.[11]

Supplier selection criteria helps an organization for proper identification of suppliers who will guarantee excellent quality of the product, consistent delivery and performance availability.[12] An organization's ability is to produce the right product at the right and most reasonable price at the right time, under the influence of its capabilities and performance is considered as one of the determinants of business success.[9,11,13.14] The results of the work undertaken by Tracey and Vonderembse,[15] revealed that the role of supplier has a significant and direct impact on the supplier's performance and finally it directly affects the production activity performance. The integration of supply chain activities for SMEs is one of the most important challenges of today's supply chain management philosophy.[16,4] Among the large-scale manufacturingfirms, a growing number of Small and Medium Enterprises are under pressure to change and revisit the management strategies for both operational and organizational styles for the sustainability of sustainable global competition.[17,18,4] Strategically managing the supply chains to help small businesses spread new technologies very quickly, by passing government restrictions and to enter new markets and to learn quickly from key players in a particular sector. SMEs having the limited resources will benefit most from the network of Supply Chain Management as they can leverage the expertise of other members in the supply chain.[19]

2.1 Green supplier selection criteria

Selection of green supplier for small and medium scale enterprises (SMEs) is a multi-criteria decision-making process (MCDM) involving both qualitative and quantitative data. From the discussions with the academicians and from the managers of SMEs the criteria selected for greensupplier selection are Quality of the Product, Cost of the Product, Environmental Performance, Delivery aspect of the product, and Service Performance. The variations of the criteria depend mainly on the products and contain many facts of judgement. The other various criteria which play a key role during the selection of sustainable suppliers as evident from the discussions with the experts include criteria for Technology, Design and Development, Greener logistics, Service for the Customers, Environmental Management Systems, Research and Development management, Production/ Operational performance and Cooperation from the Customers.[9]

Due to the rapid development of business in the international market, outsourcing should be done for some of the businesses for establishing the supply chain network. Supply chain administrators within the organization should accept both conventional and environmental performance criteria.[8] Because of the global awareness of sustainability and ecological issues, strict government rules, the business entities cannot solve the sustainability issues.[20]

Table 1: Criteria and sub criteria for green supplier selection

Criteria	Sub Criteria	Definition of Sub criteria with references
Criteria for Economical Component	Cost of Product	Product cost, logistical activity cost, Terms and conditions cost for payments.[21-25]
	Quality of Product	Installation of ISO-9000 quality standards, award for quality performance of the product, claim policies, warranties, return rate of item and repair of item.[26,27,23,24, 28]
	Delivery Aspect	Timely Delivery, Lead time period, security and safety aspect of components, and packaging of the product.[22, 24,29,30]
Criteria fo**r** Environment Component	Pollution due to Production	Air Pollutants, Average Volume, Water wastage and solid wastage of material, and release of harmful materials due to Production activity.[31,23.32]
	Resource Consumption	Resource consumption like raw materials, energy and water.[31,32]
	Environmental friendly Design	Designing the product or process for efficiency of resources, Product designing for 3Rs i.e., reusing, recycling and recovery of the material, Designing the product or process for reduction, or elimination of materials which are hazardous in nature.[33,32,34,35]
	Environmental Management system (EMS)	Environmental certification like ISO 14000, policies concerned to environmental aspect, continuous monitoring, regulatory compliances, eco-friendly process planning, and internal process control.[36,31,33,32,37,38]
	Green image	It is the ratio of green customers to total customers and social responsibility.[36.32.33]
	Greener Product	Usage of recycled and non-toxic materials, eco-friendly packaging, and reduction in excess packaging.[39,32,37]
	Environmental training for staff	Training of staff members concerned to environmental issues.[37]
	Management	Commitment of top-level managerial cadre for supporting

	commitment	and improvising green supply chain management initiatives.[32,37]
	Greener Technology	Conservation of the natural environment and resources forcurbing the negative impact of human involvement by applying the theory of environmental science.[39,32]

According to Bhutta & Huq,[40] there are some of the common methods used for the selection of suppliers in any manufacturing organization. These methods are Total Cost Approach, Multiple Attribute Utility theory, which is abbreviated as MAUT, Multiple Objective Programming and Total Cost of Ownership (TCO). There are so many multi-criteria decision- making techniques (MCDM) like AHP, Decision Making Trial and Evaluation Laboratory (DEMETAL), TOPSIS, Elimination of Choice Translating Reality (ELECTRE), Preference Ranking Organization Method for Enrichment of Evaluation (PROMETHE), Generalized Method of Moments (GMM) etc. Recently MCDM techniques are used in a greater number of studies. These studies utilize MCDM techniques either single or combination of one or more techniques like AHP- TOPSIS, DEMETAL -TOPSIS, AHP – PROMETHE.[41] In my research study Fuzzy AHP and TOPSIS techniques are applied for the selection and evaluation of green suppliers for SMEs.

3.Materials and methods

In an ABC Medium scale organization which is operating in the automobile supplier industry is considered for this research study. This industry is an export-oriented unit which is located in Pune. In the following paragraph AHP, Fuzzy AHP and TOPSIS method which has been used is clearly explained and its implementation steps are given.

3.1 Analytical hierarchy process (AHP)

This AHP technique was introduced by Satty in the year 1980. AHP technique is formulated for analyzing decision-making problems. Now for solving the problem by the application of AHP the decision maker must follow the four steps

i) In the first step the problem of decision-making is broken down into a hierarchy that is easily understandable by subproblems.

ii) In the second step pairwise, comparison is made for generating the input data which is based on a 9-point weighing scale.

iii) The pairwise input for the development of the comparison matrix is used in this step, followed by the four main axioms underlying the theoretical validity of the comparison matrix.

iv) In the fourth step the final weight of the decision plans based on local priorities for each plan and attributes is calculated and then rated.

For calculating and suggesting the plan which is more relevant is possible by making the comparisons.[42]

3.2 Fuzzy set theory

In the year 1965 Prof. Lofty Zadeh formalized this Fuzzy Set Theory. According to Prof. Lofty Zadeh's definition, it is a set of elements or items or objects which are lagging a definite set of boundaries among them. The theory of Fuzzy sets is useful for defining the elements that are characterized by its imprecision contexts, more of uncertainty and by its vagueness. It is a theory of multivalued and its intermediate values are usually expressed in a range. The range may be neither True or False, Yes or No, low, moderate or high as expressed in crisp logical theory. The fuzzy sets are defined by its membership functions which represents the grade of any Space X object or element 'x' that is a member of partial A, where A is a Fuzzy set. (μ_A) is defined (Zadeh, 1965) and is between the values of 0 and 1 and is the degree to which the object belongs to the set μ_A(Zadeh, 1965).[43]

TFN which stands for Triangular Fuzzy Number is a special class fuzzy number and its membership is defined by (l, m, u), which are the three real numbers.[44]

l= lower possible value of a fuzzy number

m=most possible value of a fuzzy number

u= upper possible value of a fuzzy number

In the fuzzy set if the element or the object falls before or beyond them, then it will be not having the membership in the fuzzy set.[45]

Fuzzy arithmetic operations on TFN are given below.

Now let A and B be two TFN's (Triangular Fuzzy numbers) were,

A +B = $(l_a + l_b, m_a + m_b, u_a + u_b)$

A - B = $(l_a - l_b, m_a - m_b, u_a - u_b)$

A. B= $(l_a . l_b, m_a . m_b, u_a . u_b)$

Inverse $A^{-1} = (\frac{1}{u_a} . \frac{1}{m_a} . \frac{1}{l_a})$

Step 1: The decision maker compares the criteria or the alternatives via linguistic terms.

Now according to the corresponding triangular fuzzy numbers of these linguistic terms, take for example if the decision maker states that the criterion1(C1) is weakly important than the criterion2(C2), then it takes the fuzzy triangular scale as (2,3,4). On the contrary in the pairwise contribution matrix of the criteria, Now the comparison of C2 to C1 will take the fuzzy triangular scale as (1/4,1/3, 1/2).

The pairwise contribution matrix is given in below equation I

Through Triangular fuzzy Number (TFN), $dk\ ij$ represents the choice of k^{th} decision makers of the i^{th} criterion over j^{th} criterion.

The symbol "tidle" here reflects the demonstration of triangular number

Now for instance d_{12}^{1} indicates the choice of the first criterion by the first decision maker over the second criterion and equivalent to d_{12}^{1} = (2,3,4).

$$\tilde{A}k = \begin{bmatrix} \tilde{d_{11}}k & \tilde{d_{12}}k & \cdots & \tilde{d_{1n}}k \\ \tilde{d_{21}}k & \cdots & \cdots & \tilde{d_{2n}}k \\ \cdots & \cdots & \cdots & \cdots \\ \tilde{d_{n1}}k & \tilde{d_{n2}}k & \cdots & \tilde{d_{nn}}k \end{bmatrix} \quad \text{(I)}$$

Step2: In this step, $d_{ij}^{\tilde{k}}$ should be averaged and $d_{\tilde{ij}}$ is calculated if for more than one decision maker and is shown in below equation II

$$\frac{\sum_{k=1}^{k} dij\sim k}{K} \quad \text{(II)}$$

Step3: The pairwise contribution matrix is updated according to averaged preferences as shown in below equation III.

$$\bar{A} = \begin{bmatrix} d_{\tilde{11}} & \cdots & d_{\tilde{1n}} \\ \vdots & \ddots & \vdots \\ d_{\tilde{n1}} & \cdots & d_{\tilde{nn}} \end{bmatrix} \quad \text{(III)}$$

Step4: As shown in below equation IV the geometric mean of fuzzy comparison values of each criterion is determined (Buckley 1985).[46]

Now here $r_i^{\sim} = \left(\prod_{j=1}^{n} d_{ij}{}^{\sim}\right) 1/n,\ i$=1, 2……., n (IV)

Step5.By incorporating next three sub steps of 5(a), 5(b), and 5(c)The fuzzy weights of each criterion can be found and is given in below equation V.

Step5(a): The vector summation of each $r_i^{\sim}$ should be found out.

Step5(b): The (-1) power of vector summation is to be found out. To make it in an increasing order substitute the triangular fuzzy number.

Step 5(c): In this step find out the ($w_i^{\sim}$) fuzzy weight of criterion I, then multiplying each of the $r_i^{\sim}$ with this reverse vector.

$$w_i^{\sim} = r_i^{\sim} \otimes (r_1^{\sim} \oplus r_2^{\sim} \ldots \oplus r_n^{\sim})^{-1}$$

$$= (l_{w1}, m_{w1}, u_{w1}) \quad \text{(v)}$$

Step6: $w_i^{\sim}$ are still TFN (Triangular Fuzzy Numbers) then defuzzification can be performed by the application of the Centre of Area method as suggested by Chou and Chang in the year 2008,[47] and is given in below equation VI

$$M_i = \frac{l_{w1} + m_{w1} + u_{w1}}{3} \quad \text{(VI)}$$

Step7: M_i(Non-Fuzzy Number) needs normalization by using the below equation VII.

$$N_i = \frac{M_i}{\sum_{i=1}^{n} M_i} \quad \text{(VII)}$$

The above seven steps are now carried out to calculate the normalized weights of the parameters and their alternatives. Then the scores of each alternative is then determined by simply multiplying each alternative weight with the corresponding criteria. Fuzzy logic has difficulty producing valid answers in decision-making. The numerical representation of judgments in the AHP is already fuzzy. Making fuzzy judgments fuzzier does not lead to a better more valid outcome and it often leads to a worse one. The compatibility index of the AHP is used to illustrate how the answers obtained by fuzzifying AHP judgments do not produce better results than direct derivation of the principal eigen vector. There is no mathematical validity for using Fuzzy number crunching in the AHP (T.L. Saaty 1997).[42] A case study of medium scale manufacturing organization is explained in the next section for understanding the methodology and to see its applicability.

3.3 Fuzzy AHP application for a SME

The Fuzzy AHP technique is applied for a medium scale automotive industry based in Pune. Previously one study was conducted for the evaluation of the green supplier for this medium scale automotive organization by using DEMATEL technique. Due to confidentiality of their business the company's name and their alternative green suppliers' names are not disclosed. Based on the previous study the most frequently used raw material for making the gear is taken into consideration. The best green supplier from the three alternative suppliers with respect to criteria based upon five attributes like Quality of product (QOP), Cost of the product (COP), Environmental Performance (EP), Delivery Aspect (DA), and Service Performance (SP) is considered for the selection and evaluation of the green supplier. The hierarchy of the criteria and its alternatives is shown in fig (1)

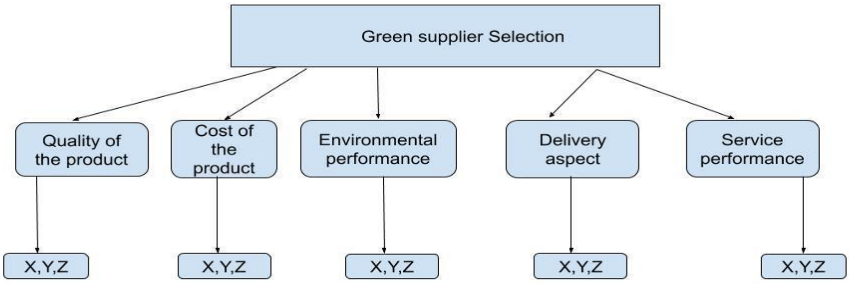

Fig1. The hierarchy of the criteria and its alternatives

3.4 Determining the weights of the criteria

For selection and evaluation of green suppliers, a meeting was conducted with the purchasing manager and production manager of a medium scale automotive industry. It was agreed from the meeting to find out the pairwise comparison of the criteria based on the preferences provided by the units Production Manager and Purchasing Manager. In the below table 2 comparison matrix for green supplier selection criteria is given

Table 2: Comparison matrix for green supplier selection criteria

Criteria	Quality of Product	Cost of Product	Environmental Performance	Delivery Aspect	Service Performance
Quality of Product	(1,1,1)	(1,1,1)	(6,7,8)	(4,5,6)	(4,5,6)
Cost of Product	(1,1,1)	(1,1,1)	(6,7,8)	(4,5,6)	(4,5,6)
Environmental Performance	(1/8,1/7,1/6)	(1/8,1/7,1/6)	(1,1,1)	(1/4,1/3,1/2)	(2,3,4)
Delivery Aspect	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(2,3,4)	(1,1,1)	(1/8,1/7,1/6)
Service Performance	(1/6,1/5,1/4)	(1/6,1/5,1/4	1/4,1/3,1/2)	(6,7,8)	(1,1,1)

After completing the three steps of the Fuzzy AHP methodology then in coming step, the geometric mean ($r_1^{\sim}$) is computed by applying equation number IV. Now for Quality of Product (QOP) criterion

($r_1^{\sim}$) is then calculated by using the equation VIII.

$$r_1^{\sim} = \left(\prod_{j=1}^{n} d_{ij}^{\sim}\right)^{\frac{1}{n}} = [(1*1*6*4*4)^{\frac{1}{5}}, \left(1*1*7*5*5\right)^{\frac{1}{5}}, (1*1*8*6*6)^{\frac{1}{5}}] \ ;$$

=[2.49, 2.80, 3.10] (VIII)

The geometric mean values for the respective green supplier selection criteria are shown in the below Table 3. Also, the summation of the values and their inverse values, Fuzzy triangular numbers are shown in below table3.in the increasing order format.

The fuzzy weight of Quality of Product (QOP) $w_1^{\sim}$ is computed by using equation (V), and is shown in equation (IX)

$$w_1^{\sim} = [(2.49 * 0{,}121); (2.81 * 0.140); (3.28 * 0.159)]$$

$$= [0.302, 0.393, 0.495,] \quad \text{(IX)}$$

Table 3: Geometric mean values Green Supplier Selection Criteria

Green Supplier Selection Criteria	Geometric Mean Values $\tilde{r_1}$
Quality of Product	2.49, 2.80, 3.10
Cost of Product	2.49. 2.80, 3.28
Environmental Performance	0.378, 0.459, 0.560
Delivery Aspect	0.370, 0.443, 0.529
Service Performance	0.529, 0.622, 0.757
Total	6.257 7.124 8.226
In Reverse	0.159 0.140 0.121
In increasing order	0.121 0.140 0.159

The relative Fuzzy weights with respect to each criterion are calculated and presented in table4

Table 4: Relative Fuzzy weights with respect to each criteria

Criteria		$\tilde{w_1}$	
Quality of Product	0.302	0.393	0.495
Cost of Product	0.302	0.393	0.524
Environmental Performance	0.0459	0.0644	0.0894
Delivery Aspect	0.0449	0.0621	0.0845
Service Performance	0.0643	0.0873	0.129

By applying step no 6 and 7 (M_i) and $(N)_i$ are calculated where (M_i) stands for relative non-fuzzy weight of each criterion that is actually determined by the average of each criterion fuzzy numbers $(N)_i$ stands for normalized weights of each criterion. Both the values of (M_i) and $(N)_i$ are presented in below table 5

Table 5: Average and Normalized relative weights of respective criteria(M_i&N_i)

Criteria	M_i	N_i
Quality of Product	0.396	0.387
Cost of Product	0.406	0.396
Environmental Performance	0.066	0.064
Delivery Aspect	0.063	0.062
Service Performance	0.090	0.088

3.5 Calculation of the weights of the alternatives with concerned to criteria

once the normalized non fuzzy relative weights for the alternatives are calculated, then by using the same above methodology, the weights for the alternatives with concern to the attributes are calculated. With regard to the Quality of the Product (QOP) and other alternatives such as COP, EP, DA, and SP, the pairwise comparison of alternatives can be computed by conducting an interview with the Purchasing Officer and Production Manager of the medium scale unit. The comparison matrix of alternatives concerned with Quality of product is given in below Table6.

Table 6 Comparison matrix of Alternatives with concerned to Quality of Product Attribute

Alternatives	X1	X2	X3
X1	(1,1,1)	(3/2,2,5/2)	(1/2, 1, 3/2)
X2	(2/5,1/2,2/3)	(1,1,1)	(1/2, 1, 3/2)
X3	(2/3, 1,2)	(2/3, 1,2)	(1,1,1)

By applying the Criterion computation methodology, Geometric means ($r_1^{\sim}$) and Fuzzy weights of alternatives for each criterion ($w_1^{\sim}$)are then calculated and given in below Table 7.

Table 7: ($r_1^{\sim}$)and($w_1^{\sim}$) of alternatives with respect to Quality of Product criterion

Alternatives		$r_1^{\sim}$			$w_1^{\sim}$	
X1	0.909	1,257	1.546	0.220	0.411	0.798
X2	0.587	0.795	1.000	0.142	0.260	0.516
X3	0.441	1.000	1.580	0.106	0.327	0.815
Total	1.937	3.052	4.126			
In Reverse	0.516	0.327	0.242			
In increasing order	0.242	0.327	0.516			

By using the method of Centre of area M_i&$N_i$values are obtained and are shown in below Table8.

Table 8: Average and Normalized Relative weights with respect to Quality of Product criterion

Alternatives	M_i	N_i
X1	0.476	0.397
X2	0.306	0.255
X3	0.416	0.347

The computation for the alternatives of the other criteria like Cost of the Product, Environmental Performance, Delivery Aspect, and Service Performance with its Comparison Matrices, Geometric means, Fuzzy Weights, and Normalized Non-Fuzzy Weights are made and given below in the following tables from table 9 to table12

Table 9 Comparison matrix of Suppliers (Alternatives), with their Geometric Means($\tilde{r}i$), Fuzzy weights($\tilde{w}i$), and Normalized weights of Suppliers with concerned to Cost of the Product Criterion

Alternatives	X1	X2	X3	Geometric means $\tilde{r}i$	Fuzzy weights $\tilde{w}i$	Normalized Non fuzzy weights
X1	(1,1,1)	(1/2,1,3/2)	(1/2,1,3/2)	0.632 ,1, 1.30	0.153,0.327,0.569	0.313
X2	(2/3,1,2,)	(1,1,1)	(3/2, 2, 5/2)	1, 1.257, 1.70	0.243,0.411,0.744	0.418
X3	(2/3,1,2,)	(2/5,1/2,2/3,	(1,1,1)	0.646,0.795,1.099	0.156,0.259,0.481	0.267

Table 10: Comparison matrice of Suppliers(Alternatives), with their Geometric Means($\tilde{r}i$), Fuzzy weights ($\tilde{w}i$) , and Normalized weights of Suppliers with Concerned to Environmental Performance Criterion

Alternatives	X1	X2	X3	Geometric means $\tilde{r}i$	Fuzzy weights $\tilde{w}i$	Normalized Non fuzzy weights
X1	(1,1,1)	(1/2,1,3/2)	(2,5/2,3)	1,1.353,1.642	0.291,0.408,0.620	0.431
X2	(2/3,1,2)	(1,1,1)	(5/2,3,7/2)	1.183,1.436,1.202	0.344,0.433,0.454	0.402
X3	(3/2,2/5,1/2)	2/7,1/3,2/5)	(1,1,1)	0.460,0.514,0.587	0.113,0.155,0.221	0.166

Table 11: Comparison matrice of Suppliers(Alternatives), with their Geometric Means($\tilde{r}i$), Fuzzy weights($\tilde{w}i$), and Normalized weights of Suppliers with concerned to Delivery Aspect criterion

Alternatives	X1	X2	X3	Geometric means $\tilde{r}i$	Fuzzy weights $\tilde{w}i$	Normalized Non fuzzy weights
X1	(1,1,1)	(1/2,1,3/2)	(1,3/2, 2)	0.795,1.143,1.436	0.194,0.357,0.572	0.357
X2	(2/3, 1,2)	(1,1,1)	(5/2,3,7/2)	1.183,1.436,1.900	0.289,0.449,0.758	0.475
X3	(1/2,2/3,1)	(2/7,1/3,2/5)	(1,1,1)	0.526,0.608,0.739	0.128,0.190,0.209	0.167

Table 12 Comparison matrix of Suppliers(Alternatives), with their Geometric Means($\tilde{r}i$), Fuzzy weights($\tilde{w}i$), and Normalized weights of Suppliers with concerned to Service Performance Criterion

Alternatives	X1	X2	X3	Geometric means $\tilde{r}i$	Fuzzy weights $\tilde{w}i$	Normalized Non fuzzy weights
X1	(1,1,1)	(1/2,1,3/2)	(1/2,1,3/2)	0.632,1.00,1.306	0.153,0.323,0.558	0.318
X2	(2/3.1,2)	(1,1,1)	(2, 5/2, 3)	1.099,1.353,1.806	0.267,0.437,0.469	0.362
X3	(2/3,1,2)	(1/3,2/5,1/2)	(1,1,1)	0.608, 0.739,1.00	0.147,0.238,0.427	0.250

Table13: Normalized non-Fuzzy relative weights of each alternative for each attribute.

Alternatives	Quality of Product	Cost of Product	Environmental Performance	Delivery Aspect	Service Performance
X1	0.397	0.313	0.431	0.357	0.318
X2	0.255	0.418	0.402	0.475	0.362
X3	0.347	0.267	0.166	0.167	0.250

Table 14 Aggregated results for each of the alternative concerned for each criteria

Criteria	Scores of Alternatives with concerned to related criteria			
	Weights	X1	X2	X3
Quality of Product	0.387	0.397	0.255	0.347
Cost of Product	0.396	0.313	0.418	0.267
Environmental Performance	0.064	0.431	0.402	0.166
Delivery Aspect	0.062	0.357	0.475	0.167
Service Performance	0.088	0.318	0.362	0.250
Total		0.355	0.351	0.282

3.6 Sensitivity Analysis based on Fuzzy AHP results

For testing the priority ranking the sensitivity analysis is done. The performance of the Green Supplier and the quantities of the order are recognized by this sensitivity analysis. One of the criteria is assigned a weight of 90% and the remaining 10% of the weight is distributed for another criterion.

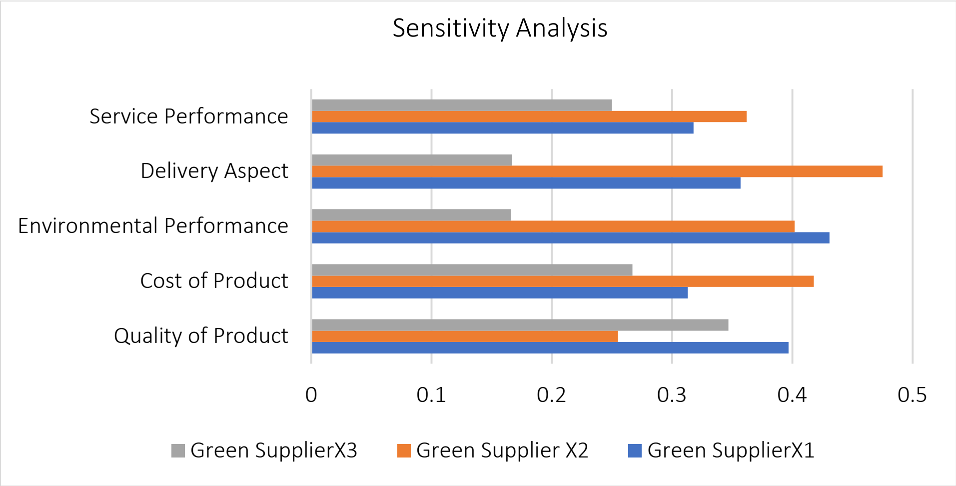

Fig 3: Sensitivity analysis of Alternatives with concerned to the Criteria

4.5 TOPSIS technique for green supplier selection

Multicriteria Decision Making Technique helps the decision makers of the organization to evaluate the best alternatives. TOPSIS is a Multi- attribution Decision making model (MADM). TOPSIS (Technique for order preference by similarity to ideal solution.) was introduced by Hwang and Yoon in the year 1981. The logic of TOPSIS is rational and understandable. TOPSIS concept says that the alternative which is chosen must have the shortest geometrical distance from the PIS (Positive Ideal Solution) and must have the longest geometrical distance from the NIS (Negative Ideal Solution). Like any other multicriteria decision making technique (MCDM) the initial step is selection of criteria and alternatives. Once the criteria are selected with its alternatives then the decision makers give the criteria certain weights for it. After this the scores are given for the alternatives for each of the criteria for creating the decision matrix.

The TOPSIS method is one of the well-known MCDM methods that considers positive and negative ideal solutions in decision making. The reason for this popular method is the fact that TOPSIS method is easier to understand and simpler to implement as compared with other outranking methods such as PROMETHEE and ELECTRE [Rezaei J 2015]

Step 1: By using the below equation (A)the decision matrix which is denoted as DM is formed

$$DM=\begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mn} \end{bmatrix} \text{--------------} \qquad (A)$$

Step2: Normalization of Decision matrix is done by using equation(B)

$$\text{Normalized decision matrix (NDM)} = rij = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^2}} \text{ --------} \qquad (B)$$

Step3: From the below equation (C)weighted normalized decision matrix is formed

$$V = v_{ij} = w_j . r_{ij} \text{ -----------} \qquad (C)$$

Step4: PIS &NIS are determined for each criterion by using the below equations D and E

$$PIS = v_j^{+} = MAX_{\,i}(Vij) \text{ ----------} \qquad (D)$$

$$NIS = v_j^{-} = MIN_i\,(Vij) \text{ ------------} \qquad (E)$$

Step5: Calculation of separation measures for each of the alternative from the (PIS) and (NIS) by using the equations (F) and (G)

$$Si^{*} = \sqrt{\sum_{j=1}^{n} (Vj^{+} - Vij)^2} \text{ ---------} \qquad (F)$$

$$Si^{1} = \sqrt{\sum_{j=1}^{n} (Vj^{-} - Vij)^2} \text{ -------} \qquad (G)$$

Step 6: Calculation of Relative Closeness to the Ideal Solution

Now the relative closeness to the ideal solution is determined by using equation (H)

$$Relative\ Closeness = c_i^{*} = \frac{s_i'}{s_i' + si^{*}} \quad 0 \leq c_i^{*} \leq 1 \qquad (H)$$

Step7: Calculation of Total score and to select the alternative closest to 1.

The alternative which is having the highest relative closeness is considered as one of the best alternatives.

Table15: Five criterion of the green supplier selection and their ratings

Green Supplier Selection Criteria / Ratings → ↓	Quality of Product	Cost of Product	Environmental Performance	Delivery Aspect	Service Performance
9	Extremely High				
8	Very Much High				
7	High				
6	Low				

Table 16: Parametric values of the criteria

Selection Criteria → / Alternatives Green Suppliers ↓	Quality of Product	Cost of Product	Environmental Performance	Delivery Aspect	Service Performance
Supplier A	8	9	7	8	7
Supplier B	9	7	8	7	8
Supplier C	6	8	9	7	8

Table17: Normalized matrix

Selection Criteria → / Alternatives Green Suppliers ↓	Quality of Product	Cost of Product	Environmental Performance	Delivery Aspect	Service Performance
Supplier A	0.594	0.646	0-502	0.628	0.520
Supplier B	0-669	0.502	0.574	0.550	0.594
Supplier C	0.446	0.574	0.646	0.550	0.594

Table 18: Weighted normalized matrix

Selection Criteria → / Alternatives Green Suppliers ↓	Quality of(QOP) Product	Cost of Product (COP)	Environmental Performance (EP)	Delivery Aspect (DA)	Service Performance (SP)
Supplier A	0.148	0.161	0.125	0.157	0.130
Supplier B	0.167	0.125	0.143	0.137	0.148
Supplier C	0.111	0.143	0.161	0.137	0.148
V_j^+	0.167	0.125	0.161	0.157	0.148

(PIS)					
V_j^- (NIS)	0.111	0.161	0.125	0.137	0.130

Table 19: Relative Closeness Coefficient

Green Suppliers	S_i^*	$S_i^!$	$S_{i+}^*S_i^!$	$C_i=\frac{S_i^!}{S_{i+}^*S_i^!}$	Ranking
Supplier A	0.0572	0.0420	0.0992	0.423	2
Supplier B	0.0269	0.0712	0.0981	0.725	1
Supplier C	0.0621	0.0440	0.1061	0.414	3

5.Results and Discussions

The Fuzzy AHP results which are shown in below table20 indicates that the alternative X1 is the best green supplier with (0.355weight) then followed by the alternative X2 and X3. In the case of TOPSIS technique the results are shown in below table 21. From the table the Green Supplier "B" with (0.725 weight) is the best from among the other two Green Suppliers A & B.

Table20: Ranks of Green Suppliers based on F-AHP Results

Green Supplier	Weight	Rank
Supplier X1	0.355	1
Supplier X2	0.351	2
Supplier X3	0.282	3

Table21: Ranks of Green Suppliers based on TOPSIS Results

Green Supplier	Weight	Rank
Supplier A	0.423	2
Supplier B	0.725	1
Supplier C	0.414	3

6. Conclusion and scope for future studies

Selection and Evaluation of Green Supplier for Small and Medium Enterprises (SME's) is critical as well as the most important decision-making process. The purchasing manager of SMEs can reduce the cost of purchasing the materials drastically by selecting the right kind of Green Supplier. For the purpose of developing Sustainable Development, the organization of SMEs needs to emphasize more on Green Manufacturing with the lesser Environmental Impact. There are many Multi criteria Decision making methods (MCDM) for green supplier selection and evaluation purposes like ANP, DEMATEL, PROMETHE etc. In my research study the hybrid technique of Fuzzy AHP and TOPSIS are used for the best Green Supplier selection for SME's. The decision makers preference depends upon both tangible as well as intangible criteria. By the Fuzzy Set theory, the Vague linguistics variables should be represented clearly. Hence the Fuzzy AHP and TOPSIS techniques are utilized for solving the green supplier selection and evaluation problem of a manufacturing organization of SMEs. The Hybrid techniques determines the best green supplier among the three alternatives X1, X2, X3 and A, B, and C. The green suppliers are selected and evaluated with concerned to five criteria namely, Quality of the Product (QOP), Cost of the Product (COP), Environmental Performance (EP), Delivery Aspect (DA), and Service Performance (SP). As a result of the case study, it is the Sustainable or the Green supplier which is having the highest priority weight and is finally selected as the best green supplier for SMEs of the manufacturing industry.

From the analysis of both the results (Fuzzy AHP- TOPSIS) TOPSIS methodology can be used for final ranking of the green suppliers. The Comprehensive structure of this paper is to address the Green Supplier Selection problem. So here Hybrid Fuzzy AHP- TOPSIS methodology has been utilized to determine the relative importance of the green supplier selection factors by means of using Saaty Scales. There is limited research work on Hybrid MCDM (Fuzzy AHP-TOPSIS) methods for the investigation of green supplier selection problem.

In future studies can be extended to other MCDM techniques for the same type of the problem by applying the techniques like swarm optimization, Fuzzy multi- objective optimization methods, ELECTRE, DEA, and results can be compared. Mathematical Programming methods can be utilized when there will be no supplier for satisfying the buyer needs and requirements as in the case of Multi sourcing Problems.

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