IOSR Journal of Engineering
Mar. 2012, Vol. 2(3) pp: 461-467

Application of Fuzzy AHP for Evaluation of Green Supply Chain Management Strategies

P Muralidhar[1], Dr K Ravindranath[2], Dr V Srihari[3]
[1, 3](NICMAR's -CISC, NAC Campus, Kondapur post Hyderabad-500084)
[2] (Professor, Dept of mechanical Engineering, SVUniversity, TIRUPATI.)

ABSTRACT

This study deals with the application of Fuzzy AHP method for evaluating Green supply chain management strategies for cement manufacturing company. The strategies are calculated by the model of Fuzzy AHP, the main attributes, sub attributes and measurement indicators are defined based on the cement manufacturing process. The weights are calculated based on the pair-wise comparison of matrices of attributes and indicators. The results of the study revealed that "green manufacturing" share is the most significant attribute in the present Green supply chain management strategy.

Key Words: *Sustainability, Measurement Indicators, Green Supply Chain Management (GSM), Fuzzy Analytical Hierarchy Process (FAHP), Green Manufacturing.*

1. INTRODUCTION

Many Researchers have investigated to evaluate Green supply chain management with respect to Environment cost, Green manufacturing and management. The literature survey shows gap in the procurement aspects and customer service aspects [1]. Hence an attempt has been made to make the entire supply chain process greener, by taking the case study of cement manufacturing process in this paper.

Green Supply chain management is the basic tool for integration of raw materials procurement, production handling and material distribution. The added benefits of this process is effective management capacity, accuracy in demand forecasting and enhanced delivery performance by making the supply chain more sustainable and effective [2]. The organizations should adopt ecological balance, eco-friendly strategies for the establishment of harmonic supply chain management [3].

The various investigators have been studied and developed theoretical and empirical models in field of supply chain management. The supply evaluation has been established with sixteen criteria's by Dickson (1966), initiated to develop numerous quantitative models in the area of procurement, logistics, and operations management [4],[5],[9] and Thomas L. Saaty [6] was developed the Analytic Hierarchy Process (AHP). It is a formulated technique to analyze complex criteria structure in different levels. Fuzzy AHP is an extension of synthesized AHP method where the fuzziness of the decision making is considered [7].

This paper is organized in such a way that initially AHP and FAHP scales are defined for pair wise comparison matrices and then measurement Indicators are defined, Level I, level II pair wise comparison matrices are established for obtaining the priority weights. The table 4 indicates the global weights of Green procurement, green manufacture, Customer service and Environment management.

2. The fuzzy Analytic Hierarchy Process

The comparison matrix defined by T.L Saaty employs 1-9 scales. The 1-9 scales are illustrated with the following comparison matrix and table 1.

$$A = \begin{bmatrix} \frac{W1}{w1} & \frac{w1}{w2}\cdots & \frac{w1}{wn} \\ \frac{w2}{w1} & \frac{w2}{w2}\cdots. & \frac{w2}{wn} \\ . & . & . \\ . & . & . \\ \frac{wn}{w1} & \frac{wn}{w2}\cdots. & \frac{wn}{wn} \end{bmatrix} = \begin{bmatrix} a11 & a12\cdots & . & a1n \\ a21 & a22\,\ldots. & . & a2n \\ . & . & . & . \\ . & . & . & . \\ an1 & an2\,..\,.. & . & ann \end{bmatrix} \text{\_\_\_(1)}$$

Table 1. Saaty's scale for pair wise comparison.

S.No	Saaty's scale	The relative importance of the two sub-elements
1	**1**	Equally important
2	**3**	Moderately important with one over another
3	**5**	Strongly important
4	**7**	Very strongly important
5	**9**	Extremely important
6	**2,4,6,8**	Intermediate values

In this new fuzzy comparison matrix we use membership scales, instead of the 1-9 scales, as the values of the elements.

$$A = \begin{bmatrix} \frac{w1}{w1+w1} & \frac{w1}{w1+w2} & \cdots & \frac{w1}{w1+wn} \\ \frac{w2}{w2+w1} & \frac{w2}{w2+w2} & \cdots & \frac{w2}{w2+wn} \\ . & . & & . \\ . & . & & . \\ \frac{wn}{wn+w1} & \frac{wn}{wn+w2} & \cdots & \frac{wn}{wn+wn} \end{bmatrix} = \begin{bmatrix} r11 & r12 & \cdots & r1n \\ r21 & r22 & \ldots. & r2n \\ . & . & & . \\ . & . & & . \\ \vdots & . & & \vdots \\ rn1 & rn2 & & rnn \end{bmatrix} \text{\_\_\_(2)}$$

If this comparison matrix is consistent, it should satisfy:

$$r_{ij} = 0.5,\ r_{ij} + r_{ji} = 1,\ \frac{1}{rij} - 1 = \left(\frac{1}{rik} - -1\right)\text{x}\left(\frac{1}{rki} - -1\right) \text{\_\_\_(3)}$$

This method compares weights in pairs and is more straightforward and easier to use for the decision-makers. The meanings of our membership scales can also be expressed in the same way as Saaty's scale as shown in table 2.

Table 2. Scale for fuzzy pair-wise comparison.

S.No	Scale values	The relative importance of the two sub-elements
1	0:5	Equally important
2	0:55(*or*0:5 0:6)	Slightly important
3	0:65(*or*0:6 0:7)	Important
4	0:75(*or*0:7 0:8)	Strongly important
5	0:85(*or*0:8 0:9)	Very strongly important
6	0:95(*or*0:9 1:0)	Extremely important

Normally, the membership scales submitted here should satisfy Saaty's scales .

$r_{ij} = \frac{aij}{aij+1}$ ___(4)

Calculation of the priority weights.

Let $(W = w1;w2; \ldots ;wn);w_i = \frac{bi}{\sum_{i=1}^{n} bi}$ __(5)

Where $b_i = \frac{1}{[\sum_{j=1}^{n}\frac{1}{rji}]-n}$ ___ (6)

Consistency test of the comparison matrix.

We can use the following equation to calculate the consistency index (CI)

$CI = \frac{[\sum_{i=1}^{n}\frac{(AW)i}{nwi}]}{n-1}$ ___(7)

Where the values of the elements in matrix A could be derived by applying equation to matrix R.The comparison matrix will be considered to be consistent if there exists Consistency Ratio
CR = [CI / RI] < 0.1. The various values of Relative Index (RI) are presented in table 3.

Table 3. Values of Relative Index (RI)

Size of matrix	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

2.1. Case study
The present case study is mainly focusing on XYZ Cement manufacturing company. The cement manufacturing company is focused on producing fly-ash based cement. The fly ash used is waste product from thermal power plant which reduces carbon footprints, energy efficient and environment friendly cement. For this purpose the company wants to give highest priority to green procurement, green manufacturing practices, Good customer service and Environment compliance. The hierchay structure is shown in Figure 1 with three levels.

2.1.2 Model development for Attribute measurement
Companies, which are aware of the fact that doing business with respect to sustainability, gain competitive advantage over other companies in the market. Because of the fact that environmental sustainability has many different aspects to one and other, managers in the supply chain, struggle where to begin to differentiate their way of doing business. Thus, by implementing fuzzy AHP, this paper suggests prioritization of measurement indicators related to sustainable supply chain[8]. The hierarchical structure is formed, as in Figure 1, in order to prioritize the indicators regarding to enhancing sustainability in supply chain. Sixteen indicators were chosen and are explained below.

C1: Logistics cost: In the green procurement process the cost of procurement of inward logistics is minimum and environment friendly method. So the value of the supply chain will be optimized. If the logistics cost is minimum and environment friendly will contribute to green logistics. The transportation of materials should be done completely in safe and environment friendly manner

C2:Lead time: In the process of Green supply chain management the lead time is almost constant through out the year, leads to reduce in cost of warehousing the materials. For this purpose more localization in the supply chain will be preferred.

C3: Cost of materials: The localization in the supply chain plays important role in reducing the cost of material and the same strategy is followed for present cement plant for procurement. A small percentage change in reducing the cost of material leads to large proportion of savings will contribute to increase in the value of the supply chain.

	Green procurement (B1)	Green Logistics (C1) Lead Time (C2) Cost of material (C3) Fulfillment of order (C4)
	Green production (B2)	SC Information Sharing (C5) Production Schedule (C6) Back up systems (C7) Quality level (C8)
Evaluation of Green Supply chain management (A)		
	Customer service (B3)	Technical support (C9) Re- Design (C10) Complaint response time (C11) Shortage Frequency (C12)
	Environment management (B4)	Green Material (C13) Resource Recovery (C14) Recycle of Waste (C15) Emissions (C16)

Fig 1. The hierarchic structure of Green Supply chain management

C4: Order fulfillment: Higher the order fulfillment rate by the supplier leads to maintain the uniformity in product quality .lower the order fulfillment rate leads loss of quality, uniformity in the product, loss of sales, disturbance in the production schedules and loss of reputation in the market due shortage. In the green procurement process priority will be given to vendors who can meet more than 80% of the order fulfillment rate.

C5: SC Info sharing: It is the important driver in enhancing the supply chain performance. When ever the new order arises then information should be shared quickly through Company Management Information system (MIS) to all the departments, to serve the customers as quickly as possible. The information sharing is not that effective in old traditional business process.

C6: Production schedule: when the new order comes from the customer how quickly we can respond to them with delivery dates, will increase the value of the chain. Shorter production schedules helps in meeting the requirements of the customer as quickly as possible. For this purpose how quickly we re-organize the production schedule is important. Slippage of schedules leads to lost of huge orders.

C7: Back up systems: The back up systems is essential for any production process. Any vendor may fails to supply specific quantity/specific requirements of customer then the back up for that material is essential and alternative vendors also to be kept in pipe line to minimize/ prevent the loss. The value of the chain will improve.

C8: Quality level: This is important in providing the best service to customers dealing with the market share and establishing the leadership in the market. Superior quality product can be provided to customers with competitive price will definitely provide edge over the other similar products available in the market. The quality level can be determined based on the customer survey and market expectations about the product.

C9: Market share: Higher expectations from the customers for those products have higher market share/leader ship Good service to customers and good quality level of the product will definitely contribute to good market share. Small percentage increase in market share leads to good returns to company.

C10: Process design: The process design of cement to be defined thoroughly by Good R& D Practices. Simple and effective process leads higher productivity and complicated process will take more responsive time. This leads low customer service and higher dissatisfaction to customers.

C11: Complaint response time: Minimum complaint response time will help in building the new customers to the product, poor service to customers leads to dissatisfaction . Care has been taken to maintain low response time to customer complains about the product, leads to higher satisfaction level to customers. The response time to complaints to be decided on the priority level of the complaint.

C12: Shortage frequency: Frequent shortage of product availability in the market leads to migration of customer's to other similar products. This results in loss of market share and faith of the product.

C13: Green raw material: The Green raw material is very important for green manufacturing process to reduce carbon foot prints and emissions. The raw material procured should be compliance with environmental measures. By products of any other major products will have highest weight age. Fly ash is used to manufacturing the cement in the present case study.

C14: Resource Recovery: The energy recovery from the utilized resources leads to low energy consumption and contribute effectively to resource recovery. The green principle is followed.

C15: Recycle of waste: As this is the one of the important green business principle contributing greatly to the environment. While using the raw materials they are obtained from re- cycled waste.

C16: Emissions: Low emission to atmosphere leads to contributing to environment management Priority will be given to low emission materials during all the stages of manufacturing process. The emission rate should be below the levels will be accepted is maintained.

Pair wise comparison matrix for Level I

A1 =

	GP	GM	CS	EM
GP	1	2/3	5/9	2/3
GM	3/2	1	1/2	2/3
CS	1(4/5)	2	1	7/9
EM	1(3/7)	1(1/2)	1(2/7)	1

Pair wise comparison matrix Level II

B1 =

	C1	C2	C3	C4
C1	1	2/3	5/9	2/3
C2	3/2	1	1/2	7/9
C3	1(4/5)	2	1	7/9
C4	1(1/2)	1(2/3)	1(2/7)	1

Pair wise comparison matrix Level II

B2 =

	C5	C6	C7	C8
C5	1	2/3	1/2	2/3
C6	1(1/2)	1	1/2	3/5
C7	2	2	1	7/9
C8	1(1/2)	1(2/3)	1(2/7)	1

Pair wise comparison matrix Level II

B3 =

	C9	C10	C11	C12
C9	1	2/3	1/2	2/3
C10	1(1/2)	1	1/2	3/5
C11	2	2	1	2/3
C12	1 (1/2)	1 (2/3)	1 (3/7)	1

Pair wise comparison matrix Level II

B4 =

	C13	C14	C15	C16
C13	1	5/9	3/5	2/3
C14	1(4/5)	1	1/2	3/5
C15	1(2/3)	2	1	2/3
C16	1(1/2)	1(2/3)	1(2/7)	1

Similarly Level III pair wise comparison matrices are developed and weights are tabulated in table 4

3. RESULTS

Overall priority weights of the indicators are calculated by using Fuzzy-AHP methodology. These results are tabulated in the table 4.The weights of the indicators are as follows

Global Green Manufacturing is 34.6%
Global Green Procurement is 28.8%
Global Customer Service is 18.7%
Global Environment Management is 17.9%

Table 4: Global weight matrix

Indicator	Level 1	Level 2	Level 3				Global GP	Global GM	Global CS	Global EM
C1	0.178	0.177	0.295	0.348	0.177	0.180	0.009	0.011	0.006	0.006
C2	0.178	0.192	0.293	0.344	0.196	0.167	0.010	0.012	0.007	0.006
C3	0.178	0.301	0.276	0.348	0.197	0.179	0.015	0.019	0.011	0.010

C4	0.178	0.330	0.281	0.339	0.192	0.188	0.017	0.020	0.011	0.011
C5	0.194	0.172	0.288	0.342	0.188	0.182	0.010	0.011	0.006	0.006
C6	0.194	0.191	0.292	0.346	0.177	0.184	0.011	0.013	0.007	0.007
C7	0.194	0.307	0.289	0.343	0.182	0.186	0.017	0.020	0.011	0.011
C8	0.194	0.331	0.282	0.342	0.19	0.186	0.018	0.022	0.012	0.012
C9	0.305	0.172	0.297	0.348	0.179	0.175	0.016	0.018	0.009	0.009
C10	0.305	0.191	0.290	0.343	0.193	0.175	0.017	0.020	0.011	0.010
C11	0.305	0.296	0.288	0.355	0.190	0.167	0.026	0.032	0.017	0.015
C12	0.305	0.341	0.286	0.341	0.196	0.177	0.030	0.035	0.020	0.018
C13	0.322	0.175	0.283	0.351	0.184	0.182	0.016	0.020	0.010	0.010
C14	0.322	0.201	0.297	0.351	0.169	0.183	0.019	0.023	0.011	0.012
C15	0.322	0.287	0.282	0.344	0.194	0.180	0.026	0.032	0.018	0.017
C16	0.322	0.338	0.291	0.344	0.185	0.180	0.032	0.037	0.020	0.020
SUM	-	-	-	-	-	-	**0.288**	**0.346**	**0.187**	**0.179**

4. CONCLUSION

It can be seen that among main attributes highest weight belongs to Green Manufacturing (34.6%) which is followed by Green procurement (28.8%). Since green manufacturing provides better and more permanent solutions or alternatives for sustainability for long term strategies. In addition to that sub-attribute, Cost of Pollutant Effects has significantly more weight than cost of improvement. The reason for it is probably, long term results of pollutants affect human life more than just monetary cost. Another interesting observation is, establishing Green Image has more importance over Management Competencies. This indicates that brands, which work on establishing its green image, gain more advantage over their competitors by satisfying customers. If a brand can create an effective green image, its recognition among society expands in a positive way.

5. REFERENCES.

[1]. P Muralidhar, K Ravindranath, V Srihari, "Perspective patterns of Environmental Green supply chain management" IJ-ETA-ETS(2010) 3(2), 233-237.
[2]. I J Chen, A Paul raj, Understanding supply chain management: Critical research and a theoretical framework, International Journal of Production Research, 42 (1) (2004)., 131-163.
[3]. P K Humphreys, Y K Wong , F T S Chan, Integrating environmental criteria into the Supplier selection process. Journal of Materials Processing Technology,(2003). 138 (1-3), 349- 356.
[4]. A L Guiffrida, A cost-based model for evaluating vendor delivery Performance, MS thesis, Department of Industrial Engineering, State University of New York at Buffalo. (1990)
[5]. Z Degraeve, E Labro, and F Roodhooft, "An evaluation of vendor selection models from a total cost of ownership perspective", European Journal of Operational Research, 125(1), (2000), 34-58.
[6]. T L. Saaty, The Analytic Hierarchy Process: Planning, Priority Setting, Resource allocation, Tata Mc Graw-Hill, (1980).
[7]. R Venkata Rao,D Singh A hybrid multiple attribute decision making method for Solving Problems of industrial environment, International Journal of Industrial Engineering Computations, (2), (2011) 631–644.
[8]. C Ninlawan, P Seksan , K Tossapol , and W Pilada , The Implementation of Green Supply chain Management Practices in Electronic Industry, Proceedings of International multy conference of Engineers and Computer scientists, vol III, March (2010) 17-19, 2010 Hong Kong.
[9]. C Weber, J Current, and W C Benton, "Vendor selection criteria and methods", European Journal of Operational Research, 50(2), (1991) 2-18.