Application of Fuzzy-ANP Model for Performance Measurement of Supply Chain Management

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Abstract
In the present era, Supplier selection is crucial and good cause to minimize the lead time and maximize the profit. Selection of proper suppliers not only helps to manufacture quality products but also helps in reducing the wastage along with unnecessary storing cost. A qualified supplier is a key element & good resource for buyer in reducing cost, evaluation & selection of potential suppliers. An important problem in decision analysis is the evaluation of the difference between two or more different rankings for a set of alternatives. This work makes use of ANP & Fuzzy for the analysis of the proper selection. The Fuzzy-ANP is a mathematical technique for multi criteria decision making. This methodology tolerates the vagueness and uncertainty of human judgments.

Keywords
ANP, FUZZY, Supply Chain management (SCM),) Multi Criteria Decision Making, Supplier Selection

I. Introduction
A supply chain is a system of organizations, people, activities information, and resources involved in moving a product or service from supplier to customer. Supply chain activities transform natural resources, raw materials, and components into a finished product that is delivered to the end customer. In sophisticated supply chain systems, used products may re-enter the supply chain at any point where residual value is recyclable. Supply chains link value chains. Supplier selection is the process by which firm's identify, evaluate, and contract with suppliers. The supplier selection process deploys a tremendous amount of a firm's financial resources. In return, firms expect significant benefits from contracting with suppliers offering high value. This article describes the typical steps of supplier selection processes: identifying suppliers, soliciting information from suppliers, setting contract terms, negotiating with suppliers, and evaluating suppliers. It highlights why each step is important, how the steps are interrelated, and how the resulting complexity provides fertile ground for ORMS research.
The different criteria for selecting a supplier is shown in the fig. 1.

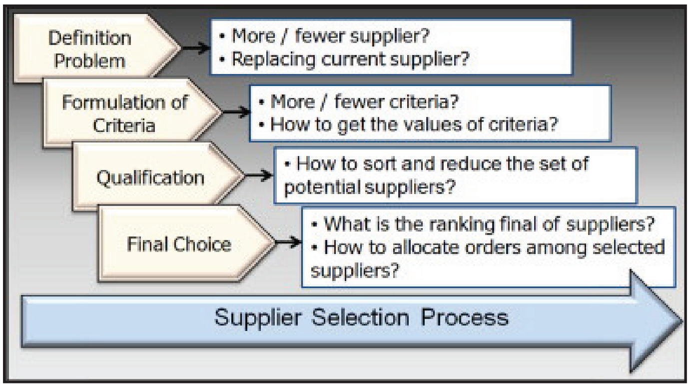

Fig. 1: Supplier Selection Framework

The development of analytical approaches for global supplier selection has been limited, although many attempts have been made to develop analytical approaches for evaluating various domestic suppliers. For the review of supplier selection one can refer to Weber et al.[1991]. There are basically two stages in the global supplier selection process. In first stage the decision variables, critical for the selection process should be identified and in the second stage a specific decision making technique should be analyzed to discuss the preferences of alternative suppliers based on these criteria. Most of the researchers identified a number of decision criteria for the selection of suppliers confined in small area, but not much attention has been paid for the global suppliers. A quick review of supplier selection models in outsourcing literature shows that many researches proposed methods based on AHP and ANP to solve the supplier selection problems. In this section, a brief review of these works is presented. A. Gunashekharan et al. [2004] deals with strategies and technologies for effectively managing a supply chain is quite vast. Aref A. Hervani and Marilyn M.Helms [2005] stated that in supply chains with multiple vendors, manufacturers, distributors and retailers, whether regionally or globally dispersed, performance measurement is challenging because it is difficult to attribute performance results to one particular entity within the chain. Bohui Pang [2009] demonstrates this paper develops a supplier evaluation approach based on the analytic network process (ANP) and fuzzy synthetic evaluation under a fuzzy environment. Elanchezhian, C. [2010] used a versatile technique namely multi criteria decision making (MCDM) technique which involves the analytical network process (ANP) and technique for order performance. Lin,Chen [2011] explained the increasing pressures and challenges to improve economic and environmental performance have caused developing countries in general and automobile manufacturing firms in particular to consider and start implementing green supply chain management. Olungo,Wong [2012] states about Closed-loop supply chain management has been identified as an efficient, effective and economical strategy towards environmental sustainable practices in manufacturing companies. Sadeghi eta al [2012] demonstrates most required products and services of companies are provided through other organizations. Pal,Gupta [2013] states that an effective supplier selection process is very important to the success of any manufacturing organization. Bhattacharya, M.K.Tiwari, P.Mohapatra [2014] states ANP fuzzy based green balanced scorecard has been used within CDM approach to assist in arriving at a consistent, accurate & timely data flow across all cross functional areas of business . The purpose of the paper was to delineate green supply chain performance . Onder etal [2015] explains Strategic supply chain management has gained more importance with the effect of globalization.

B. Problem Statement
Performances of ten suppliers are to be evaluated and compared. The candidate-suppliers can be identified as S_1, S_2, S_3, ..., and S_{10} representing a total of ten candidate-suppliers. There are thirteen criteria are provided. In the present, there is a relationship among the criteria for supplier selection decision-making. Both cardinal and ordinal preferences have been considered for evaluation of candidate suppliers. In a supply-chain framework such decision-making involves cost factors. Thus, cost factor components have

been included and a trade off among all the criteria has been established integrating the quality function deployment (QFD) technique[Bhattacharya et al. 2010] suitably with fuzzy (Triangular fuzzy numbers, Tiwari et al, 2008. Supplier selection is viewed as a combination of both customer requirements and engineering requirements. Customers are the companies that purchase the technical expertise of the suppliers. Therefore, such a company–supplier relation can be viewed as a 'house of quality' model. The outcome of the integrated methodology presented in this paper is determined with indices trading off all the types of information available within the supply-chain framework.

III. Methodology

The ANP model is described as follows:

Step 1: Criteria definition

The criteria which affect the decision being made must be defined. In order to define the criteria, a group of managers who make the decision or consultants (e.g., an expert group) can be an appropriate choice. As per definition of criteria, we have considered the criteria shown in the Table 1.

Table 1. Criteria Dataset

Cluster	Criteria
Customer requirement	Deliver (C1)
	Factory audit (C2)
	Customer rejection (C3)
	On urgent delivery(C4)
	On quality problem (C5)
	Business skill(C6)
	Attitude (C7)
	Honesty (C8)
	Procedural compliance (C9)
	Financial position (C10)
Technical requirement	Machinery (C11)
	Layout (C12)
	Infrastructure (C13)
	Product range (C14)
	Ability to solve technical problem (C15)

Step 2: Connecting Networks

Network formation comprises two steps described as follows: Clustering. Some clusters are formed with respect to the criteria. Then, the criteria are assigned to the clusters to which are mostly related. Finally, alternatives make a separate cluster. In this step, the related clusters are connected with respect to the dependencies between their corresponding criteria. The connections which reflect interrelationships and feedback structure can be either inner (between two criteria within the same cluster) or outer (between two different clusters). The connecting network is shown in fig. 2.

Step 3: Pair Wise Comparison Matrix

Pair-wise comparisons are performed between each pair of criteria with respect to a control criterion. Criterion to which some other criteria are dependent. In other words, the group of criteria connected to a specific (control) criterion is compared pair-wisely. In addition to the comparisons of criteria, clusters of the network must be compared pair-wisely with respect to the control cluster.

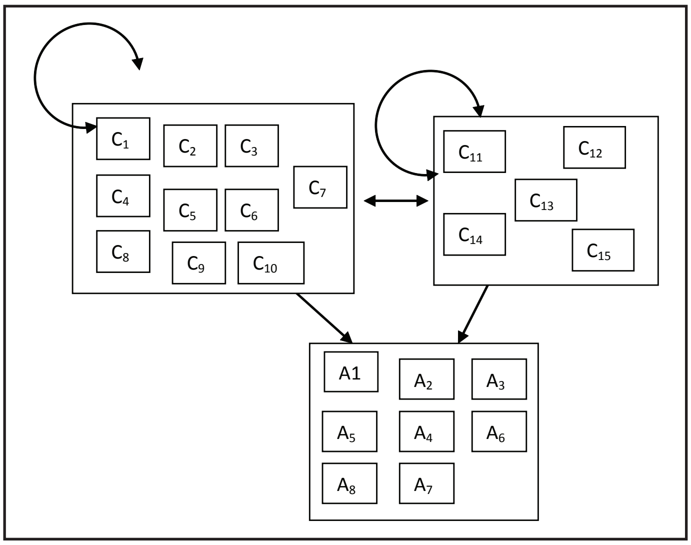

Fig. 2: Framework of the Model

Step 4: Supper Matrix Calculation

(i). Unweighted Super Matrix

Unweighted super matrix is constructed by putting the eigenvectors together (please refer to the super matrix in Statement) This super-matrix consists of blocks wij which are the matrices of eigenvectors corresponding to the comparison of elements of cluster i with respect to the control elements of cluster j.

$$w = \begin{bmatrix} w_{11} & w_{12} \dots w_{1n} \\ w_{21} & w_{22} \dots w_{2n} \\ \dots & \\ w_{n1} & w_{n2} \dots w_{nn} \end{bmatrix}$$

(ii). Weighted Super Matrix

The unweighted super-matrix is not necessarily column stochastic, i.e., all columns do not sum to one. To normalize the columns, each eigenvector in a column is multiplied by the clusters' relative priorities obtained using comparison matrix of the clusters. The resulted column stochastic matrix is the weighted super-matrix.

(iii). Limit Matrix

In the network model, the direct dependencies are signed by connections and the indirect ones are neglected. To cope with this problem, weighted super-matrix is powered until it converges, i.e., its rows stabilize to a unique value. The resulted matrix is limit super-matrix.

(iv). Selection

Final priorities or weights of alternatives are the values in rows corresponding to the alternatives based upon which final decision is made.

B. FUZZY

In this paper fuzzy methodology has been discussed for the global supplier selection. It has the ability to extract the merits of both approaches to efficiently and effectively tackle the multi-attribute decision making problems like supplier selection. In this approach triangular fuzzy numbers are used for the preferences of one criterion over another and then by using the extent analysis method, thesynthetic extent value of the pairwise comparison is calculated.

If the object set is represented as P={p_1, p_2, . . . , p_n} and the goal set as,Q¼{q_1, q_2, . . . , q_m}, then according to the concept of extent analysis (Chang 1991, 1996), each object is taken and extent analysis for each goal Qi is performed respectively. The algebraic operations on triangular fuzzy numbers follow the same mathematical rule. The m extent analysis values for each object are denoted as:

N^1_{oi}, N^2_{oi},...... N^m_{oi}, where i = 1,2,...,.n.

where all the N^j_{oi}(j=1,2,....m) are triangular fuzzy numbers. N^m_{oi} represents the value of the extent analysis of the ith object for mth goal. The value of fuzzy synthetic extent with respect to the ith object is defined as:

$$K_i = \sum_{j=1}^{m} N_{oi}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} N_{oi}^{j} \right]^{-1} \qquad (1)$$

The value of $\sum_{j=1}^{m} N_{oi}^{j}$ can be found by performing the fuzzy addition operation of m extent analysis values from a particular matrix such that:

$$\sum_{j=1}^{m} N_{oi}^{j} = \left(\sum_{j=1}^{m} n1j, \sum_{j=1}^{m} n2j, \sum_{j=1}^{m} n3j \right) \qquad (2)$$

and the value of $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} N_{oi}^{j} \right]$ can be obtained by performing the fuzzy addition operation of Njoi(j=1,2,....m) such that

$$\sum_{i=1}^{n} \sum_{j=1}^{m} N_{oi}^{j} = \left(\sum_{j=1}^{m} n1j, \sum_{j=1}^{m} n2j, \sum_{j=1}^{m} n3j \right) \qquad (3)$$

and $[\sum_{i=1}^{n} \sum_{j=1}^{n} N^j_{oi}]^{-1}$ can be calculated by the inverse of the previous equation as follows:

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} N_{oi}^{j} \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} n_{3i}}, \frac{1}{\sum_{i=1}^{n} n_{2i}}, \frac{1}{\sum_{i=1}^{n} n_{1i}} \right) \qquad (4)$$

The degree of possibility of N_1=(n_{11}, n_{12}, n_{13})≥ N_2 =(n_{21}, n_{22}, n_{23}) is defined as

V ($N_1 \geq N_2$) = 1. Since N_1 and N_2 are convex fuzzy numbers so,

$$V(N_1 \geq N_2) = 1 \quad if\ n_{11} \geq n_{21}$$

and

$$V(N_1 \geq N_2) = hgt(N_1 \cap N_2) = \mu N_1(d)$$

where d is the ordinate of the highest intersection point D between μN_1 and μN_2

When N_1=(n_{11}, n_{12}, n_{13}) and N_2 =(n_{21}, n_{22}, n_{23}) then ordinate of D is computed by

$$V(N_1 \geq N_2) = hgt(N_1 \cap N_2) = \frac{n_{11} - n_{23}}{(n_{22} - n_{23}) - (n_{12} - n_{11})} \qquad (5)$$

For the comparison of N_1 and N_2, both the values of V($N_1 \geq N_2$) and V($N_2 \geq N_1$) are required.

The degree possibility for a convex fuzzy number to be greater than k convex fuzzy numbers N_i(i=1, 2, . . . , k) can be defined by

$$V(N \geq N_1, N_2, \ldots, N_k) = V[(N \geq N_1) and (N \geq N_2) and \ldots and (N \geq N_k)]$$

$$= \min V(N \geq N_1), i = 1, 2, \ldots, k$$

$$if\ m(P_i) = \min V(K_i \geq K_k)$$

for k=1, 2, . . . , n; k≠i. then the weight vector is given by

$$W_P = (m(P_1), m(P_1), \ldots, m(P_n))^T \ where\ P_i (i = 1, 2, 3, .., n)$$

are n elements

After normalizing Wp, we get the normalized weight vectors

$$W = (w(P_1), w(P_2), \ldots, w(P_n))^T$$

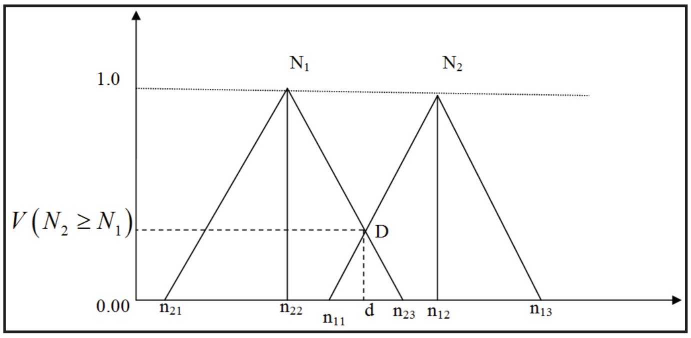

Fig. 3: Intersection Between N_1 and N_2.

where W is a non fuzzy number and this gives the priority weights of one alternative over other.

IV. Calculations for the Criteria

Table 2: Pair Wise Matrix for Delivery

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	**Weight**
S1	1,1,1	1.5,2,2.5	2,2.5,3	.33,.5,1	2.5,3,3.5	.25,.28,.33	.33,.4,.5	3.5,4,4.5	.2,.22,.25	4.5,5,5.5	**0.1328**
S2	.4,.5,.67	1,1,1	.28,.33,.4	2,3,4	1,2,3	2,3,4	2.5,3,3.5	.33,.4,.5	3,4,5	.16,.2,.25	**0.1046**
S3	.33,.4,.5	2.5,3,3.5	1,1,1	2,2.5,3	.33,.4,.5	.5,1,1.5	.5,.66,1	.33,.5,1	.4,.5,.66	3,4,5	**0.0764**
S4	1,2,3	.25,.33,.5	.33,.4,.5	1,1,1	.25,.33,.5	.4,.5,.67	4,4.5,5	2,3,4	.22,.25,.28	2,2.5,3	**0.0829**
S5	.28,.33,.4	.33,.5,1	2,2.5,3	2,3,4	1,1,1	.33,.4,.5	.25,.33,.5	.33,.5,1	.5,1,1.5	.22,.25,.28	**0.0389**
S6	3,3.5,4	.25,.33,.5	.66,1,2	1.5,2,2.5	2,2.5,3	1,1,1	.33,.4,.5	.5,.57,1	2,3,4	.5,1,1.5	**0.0897**
S7	2,2.5,3	.28,.33,.4	1,1.5,2	.2,.22,.25	2,3,4	2,2.5,3	1,1,1	2,2.5,3	.28,.33,.4	1,1.5,2	**0.0873**
S8	.22,.25,.28	2,2.5,3	1,2,3	.25,.33,.5	1,2,3	1,1.5,2	.33,.4,.5	1,1,1	3.5,4,4.5	.2,.22,.25	**.0788**
S9	4,4.5,5	.2,.25,.33	1.5,2,2.5	3.5,4,4.5	.66,1,2	.25,.33,.5	2.5,3,3.5	.22,.25,.28	1,1,1	1.5,2,2.5	**.1328**
S10	.18,.2,.22	4,5,6	.2,.25,.33	.33,.4,.5	3.5,4,4.5	.66,1,2	.5,.66,1	4,4.5,5	.4,5,.66	1,1,1	**.1757**

Using fuzzy mapping function(Tiwari et al, 2008) , the weights are calculated as follows:
F_1=(1+1.5+2+.33+2.5+.25+.33+3.5+.2+4.5,
1+2+2.5+.5+3+.28+.4+4+.22+5,
1+2.5+3+1+3.5+.33+.5+4.5+.25+5.5)
= (16.110, 18.900, 22.080)

F_2= (12.670, 17.430, 22.320),
F_3= (10.890, 13.960, 17.660),
F_4= (11.450, 14.810, 18.450)
F_5= (7.240, 9.810, 13.180),
F_6= (11.740, 15.300, 20.000),
F_7= (11.760, 15.380, 19.050),
F_8= (10.500, 14.200, 18.030),
F_9 = (15.330, 18.330, 22.110),
F_{10} =(14.770, 22.010, 21.210),
122.46 = 16.110 + 12.670 +10.890 + 11.450 + 7.240 + 11.740 +11.760 +10.500+15.330+14.770

K_1 = (16.110, 18.900, 22.080) (194.090, 160.130, 122.460)$^{-1}$ = (0.0830, 0.118, 0.180)
K_2= (0.0652, 0.1088, 0.1822),
K_3 = (0.0561, 0.0871, 0.1442,),
K_4 = (0.0589, 0.0924, 0.1506)
K_5 = (0.0373, 0.0612, 0.1076),
K_6 = (0.0604, 0.0955, 0.1633),
K_7 = (0.06059, 0.0960, 0.155)
K_8 = (0.05409, 0.0886, 0.1472),
K_9 =(0.07898, 0.1144, 0.1805),
K_{10} = (0.0760, 0.1374, 0.1731)

Now $V(K2 \geq K1)$=1 if n11> n22
Normalizing these value we get the final result are
(0.1328, 0.1046, 0.076, 0.0829, 0.0389, 0.0873, 0.0788, 0.1328, 0.1757)

V. Conclusion

The FUZZY-ANP technique is adopted and the weights were found out for each 15 criteria. Based on the criteria ,data adopted was applied into the technique and it was found out that Alternative A3 had the highest weight which was 0.139034 and S3 was selected as the best supplier. The result is shown in Table 3 and figure 4.

Table 3: Priorty Weights of Alternatives

Name	W_o
A1	0.124213
A2	0.134192
A3	0.139034
A4	0.11865
A5	0.10829
A6	0.126229
A7	0.12838
A8	0.121012

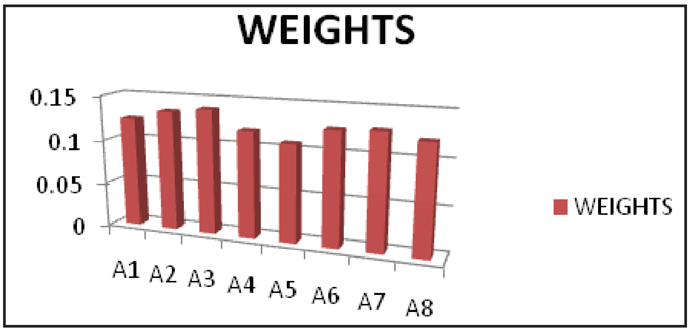

Fig. 4: Graph Depicting the Best Supplier

Regarding future observation, TOPSIS can be calculated & necessary comparisons to be made to find most optimum result. Several authors have pointed out importance of supplier selection by emphasizing the impact that decisions throughout the entire supply chain from procuring raw materials to delivering finished products to final customers.

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