International Journal of Soft Computing 3 (1): 24-32, 2008
ISSN: 1816-9503

A Fuzzy ANP-Based Approach for Selecting ERP Vendors

Prabjot Kaur and N.C. Mahanti
Department of Applied Mathematics, Birla Institute of Technology,
Mesra-835215, Ranchi, India

Abstract: In Vendor Selection Process the most important issue is to determine a suitable decision-making method for selecting the best Vendor. Essentially the Vendor Selection Problem (VSP) is a multi-criteria decision making problem involving tangible as well as intangible criterion. Analytical Hierarchy Process (AHP) can best handle these criterions. But AHP fails to address the issue of interdependencies among and between different levels of attributes. ANP provides a holistic framework for selection of best Enterprise Resource Planning (ERP) vendor alternative by using a dynamic multi-directional relationship among the decision attributes. Also ANP equipped with fuzzy logic helps in overcoming the impreciseness or vagueness in the preferences. The method adopted here uses triangular fuzzy numbers for pair-wise comparison of attributes and weights are calculated using entropy concept. A practical example explains our concept and also a comparison is made with crisp ANP.

Key words: Vendor selection, Analytical Network Process (ANP), Analytical Hierarchy Process (AHP), Triangular Fuzzy Number (TFN), Entropy

INTRODUCTION

ERP is an acronym for Enterprise Resource Planning and signifies the techniques and concepts employed for integrated management of businesses as a whole from the viewpoint of the effective use of management resources to improve efficiency of an enterprise (Alexis Leon, 2000). ERP concepts are supported by ERP packages that are integrated software packages designed to model and automate many of the basic processes of a company. To implement ERP systems, companies often seek the help of an ERP vendor or of third-party consulting companies.

Vendor Selection is an ongoing process to define the procurement capabilities needed to support the company's business plan and its operating model. The value of these capabilities has to be considered in addition to simply the price of a vendor's product. The value of product quality, service levels, just in time delivery and technical support can only be estimated in the light of what is called for by the business plan and company's operating model. Once there is an understanding of the current purchasing situation and an appreciation of what a company needs to support its business plan and operating model, a search can be made for Vendors who have both the products and service capabilities needed. These firms typically provide 3 areas of professional services as Consulting, Custo-misation and Support.

The main players in ERP systems are SAP AG, People Soft, Oracle, Baan and JD Edwards etc. These Vendors are offering new applications such as supply chain management, sales force automation, customer support and human resources. ERP vendors have a 10-20% penetration. This will grow to 40-60% with the next five years. The Indian scenario is slightly different, with the Indian ERP package-Ramco's Marshal accounting for 9% of the market share. According to the Dataquest survey, in India also, SAP is the market leader with a 20% market share. While, SAP R/3 and 'QAD' S MFG/PRO continue to dominate the Indian market scene, there is also undeniable presence of lesser-known breeds like J.D.Edwards and SSA's BPCS.

Existing ERP commercial packages cannot provide at once for all business models for every process of all industry. Thus no single ERP packaged software can meet all company functionalities or all special business requirements. So to choose a flexible ERP system they need co-operative Vendor that is responsive to customer needs. The objectives of selecting best ERP Vendor were those related to Vendor features or criteria including excellent reputation, technical capability and ongoing

Corresponding Author: Prabjot Kaur, Department of Applied Mathematics, Birla Institute of Technology, Mesra-835215, Ranchi, India

service etc. Vendor Selection Process (VSP) of identifying and prioritising relevant criteria Dickson (1966) and Weber *et al.* (1991) and evaluating the trade-off between different criteria is becoming the need of corporate. VSP is flooded with several decision models from simple weighted techniques to advanced mathematical programming. The oldest methodology for VSP being categorical method proposed by Timmerman (1986) and Weighted Point Plan used by Wind and Robinson (1968) and Gregory (1986). Literature survey reveals the use of Linear Programming (LP), Mixed Integer Programming (MIP), Interval Programming (IP) and Goal Programming (GP). A multicriteria approach to allocating order quantity among Vendor by Chaudhary *et al.* (1991). Also Weber and Ellram (1993) proposed a Multiobjective programming. IP approach was proposed by Kumar (2004). Some other methods like interpretative structural modelling by Mandal and Deshmukh (1994), Discrete choice analysis experiment by Verma and Pullman (1998) and Talluri *et al.* (2004) used a chanced constrained data envelopment analysis for evaluating the vendors. To generate weights for Vendor Selection problem Ghodsypour and O'Brien (1998) developed a DSS by integrating the AHP with LP. Zhang *et al.* (2004) and Tam and Tummala (2001) used AHP model for Vendor selection problem. Built on AHP is the technique of ANP. ANP allows for interdependency and goes beyond AHP. So far ANP in Vendor Selection problem has been used by Sarkis and Talluri (2002) and Ozden Bayaziz 2006 but fuzzy logic using ANP has not been used so far in this VSP.

Approaches employing only exact numerical values cannot support decision-making procedure for such evaluation problem. Fuzzy set theory proposed by Zadeh (1965) is a classical two-valued logic for reasoning under uncertainty. It provides a mechanism to utilize subjective or imprecise determination of preferences, constraints and goals. In our problem of Vendor Selection conflicting criteria used for evaluating Vendor are best represented by fuzzy sets. A number of studies have been devoted to examining fuzzy approach to Vendor Selection methods. A multicriteria fuzzy AHP has been used by Kahraman *et al.* (2006) for selecting Vendors. Albino *et al.* (1998) and Nassimbeig (2003) has used fuzzy logic in Vendor rating by comparing fuzzy logic system and a neural network. Kumar *et al.* (2004, 2006) have used a couple of fuzzy programming approach for Vendor selection in a supply chain. Taskin and Bayrak (2004) has used a fuzzy approach for Vendor selection by ranking the technically efficient Vendors according to predetermined performance criteria and additional product related performance criteria. Chou *et al.* (2006) has used Vendor Selection in a modified re-buy situation using a strategy-aligned fuzzy approach.

Some examples of fuzzy ANP in other application as by Mohanty *et al.* (2005) in R&D project selection, Kahraman *et al.* (2004) in QFD planning process. The main aim of using fuzzy ANP is because of its simplicity, easier approach for calculating weights.

In this study of fuzzy ANP based approach for Vendor selection problem we propose an ANP model to choose the best Vendor.

MATERIALS AND MEHTODS

The analytical network process: ANP (Salty, 1980) a comprehensive decision making technique built on the widely used AHP (Pan, 1989) technique. It is a special case of AHP except for the fact that it allows for interdependencies i.e. dependency within a set of elements (inner dependency i.e. interdependency among the various enablers) and among different sets of elements (outer dependence, e.g. determinants are dependent on dimensions). The interdependency among factors and levels of factors is defined as a system with feedback approach. The ANP allows for more complex interrelationships among the decision levels and attributes. The looser network structure of the ANP makes possible the representation of any decision problem without concern for what comes first and what comes next in a hierarchy. Once the hierarchy is established pair-wise comparisons are made systematically including all the combination of elements /cluster relationships. ANP uses the same fundamental comparison scale (1-9) as the AHP. Except in case of fuzzy representation triangular fuzzy numbers are used.

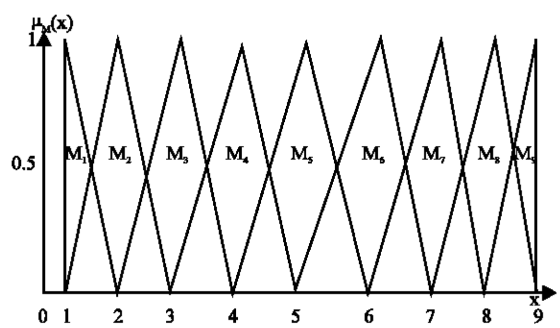

Fig. 1: Fuzzy sets

Fuzzy representation of criteria assessments within the framework of fuzzy set theory, instead of assigning definite ratings of 1-9 to represent the assessments of criterion from, we express them as special fuzzy sets from M1 ='approximately 1' to M9 = 'approximately 9' in order to take the imprecision of people's qualitative assessments into consideration. Following the work of Chen and Hwang (1992), these fuzzy sets can be specified as suitable triangular fuzzy numbers (Appendix A), shown in Fig. 1. For operations on TFN's (Appendix B).

APPENDIX A

Fuzzy set theory: Fuzzy set theory, first introduced by Zadeh (1965), was developed for solving problems in which descriptions of activities, observations and judgments are subjective, vague and imprecise. The term 'fuzzy' generally refers to the situation in which no boundary for the activity or judgment can be well defined. For example, which we can easily put a person aged 22 into the class of 'young' men, it is not so easy to decide whether or not a man aged 35 belongs to that class, because the term 'young' has no well-defined boundary. The notion of fuzziness is common in our everyday life, such as the class of 'important' customer needs, the class of 'nice' cars, etc. These classes of objects are either in a set or are not and cannot partially belong to a set, but they can be well represented using fuzzy set theory.

Membership function: Let U be the universe of discourse $U = \{u_1, u_2, \ldots, u_n\}$. A fuzzy set $\tilde{A}$ of U is a set of ordered pairs

$$\{(u_1, f_{\tilde{A}}(u_1)), ((u_2, f_{\tilde{A}}(u_2)), \ldots\ldots, (u_n, f_{\tilde{A}}(u_n))\}$$

Where $f_{\tilde{A}}$, $f_{\tilde{A}}$: U ->[0,1], is the membership of $\tilde{A}$ and $f_{\tilde{A}}(u_i)$ indicates the grade of membership of u_i in $\tilde{A}$.

Triangular fuzzy numbers: A fuzzy number is a special fuzzy set $F = \{(x, \mu_F(x)), x \in R^1\}$ where x takes its value on the real line R_1: $-\infty < x < +\infty$ and $\mu_F(x)$ is a continuous mappings from R^1 to the closed interval [0,1] Dubois and Prade (1980). Fuzzy numbers are used to handle imprecise numerical concepts, such as 'close to 7',' about 8 to 9','approximately 5', etc.

A triangular fuzzy number, denoted as M = (a, b, c), where $a \le b \le c$, is a special fuzzy number, which, representing a fuzzy set or concept M='approximately b' Kaufmann and Gupta (1985) and Laarhoven and Pedryzy (1983), has the following triangular-type membership function:

$$\mu_M = \begin{cases} 0 & x \le a \text{ or } x \ge c \\ (x-a)/(b-a) & a \le x \le b \\ (c-x)/(c-b) & b \le x \le c \end{cases}$$

For example, if a customer gives customer need W_j a rating of 7, which implies that W_j is 'important ', then we may assign it a triangular fuzzy number M_7 ='approximately 7'=(6,7,8) which is represented by the following membership function:

$$\mu_{M7}(x) = \begin{cases} 0 & x \le 6 \text{ or } x \ge 8 \\ x-6 & 6 \le x \le 7 \\ 8-x & 7 \le x \le 8 \end{cases}$$

This means that, for example, the membership value or possibility that W_j is assigned a rating of 7 is $\mu_{M7}(7) = 1$, the possibility that W_j is assigned a lower rating of 6.5 or a higher rating of 7.5 is $\mu_{M7}(6.5) = 0.5$ $\mu_{M7}(7.5) = 0.5$.So assigning W_j a rating of 6.5 or 7.5 is acceptable or 'possible ' to the degree of 50% (Fig. 1).

APPENDIX B

Fuzzy Arithmetic: Fuzzy arithmetic, mainly used on fuzzy numbers is a direct application of the extension principle Dubois and Prade (1980) and Zadeh (1965). Some fuzzy number operations are quite intuitive and consistent with traditional ones, but there are a number of operations that result in properties valid for fuzzy numbers only.

For triangular fuzzy numbers (TFNs), addition and subtraction are closed operations i.e. the sum and difference of two TFNs are still TFNs. But multiplication and division of TFNs only produce approximate TFNs. We briefly summarize the basic arithmetic for TFNs, $M_1=(a_1, b_1, c_1)$ and $M2=(a_2, b_2, c_2)$, based on Dubois and Prade (1980) and Cheng and Hwang (1992).

1. Addition: $M_1+M_2 = (a_1+a_2, b_1+b_2, c_1+c_2)$
2. Subtraction: $M_1 - M_2 = (a_1-c_2, b_1-b_2, c_1-a_2)$
3. Scalar Multiplication: $k M_1=(ka_1,kb_1,kc_1)$, k>0
4. Multiplication: $M_1 x M_2 = (a_1a_2, b_1b_2, c_1c_2)$,$a_1 \ge 0$, $a_2 \ge 0$.
5. Division: $M_1/M_2 = (a_1/c_2, b_1/b_2, c_1/a_2)$.

MODEL DEVELOPMENT

The relevant criteria, sub criteria and alternatives are chosen and structured in the form of a control hierarchy (Fig. 2) where the criteria at the top level in the model have the highest strategic value. These criteria or determinants

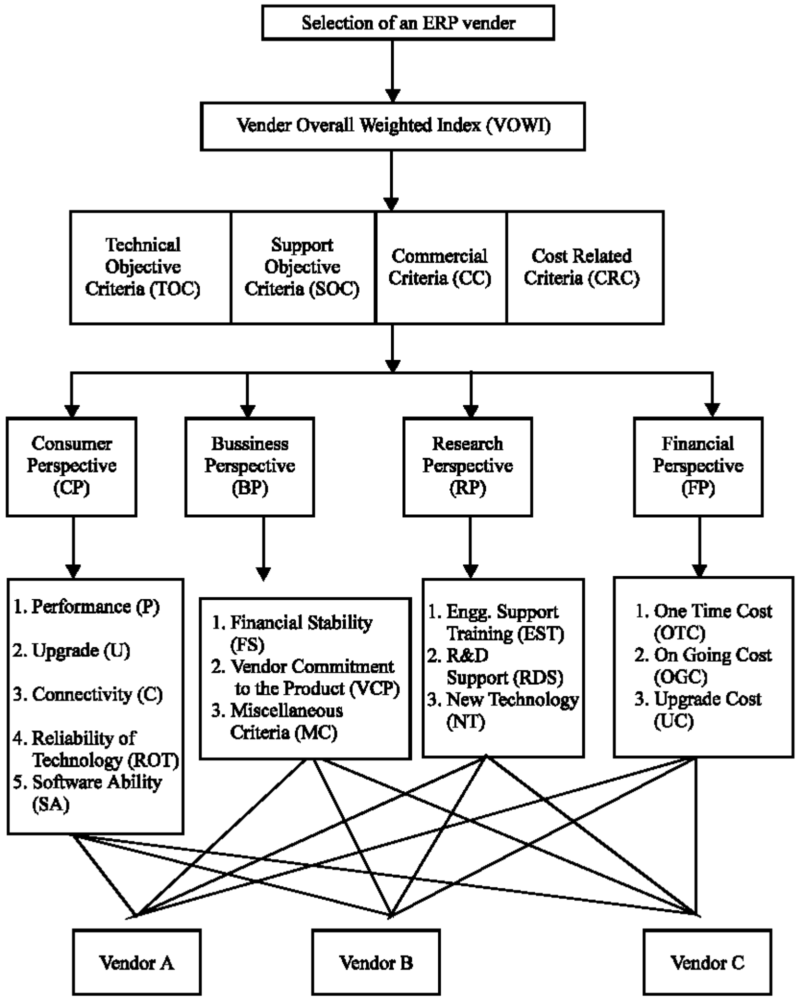

Fig. 2: Dicision making problem in form of a hierachy

are Technical Objective Criteria (TOC), Support Objective Criteria (SOC), Commercial Criteria (CC) and Cost Related Criteria (CRC). In the second level of hierarchy four sub-criteria or dimension are placed they are Customer Perspective (CP), Business Perspective (BP), Research Perspective (RP) and Financial Perspective (FP). Each of these four dimensions supports all the four determinants at the top level of hierarchy. For example good research perspective helps in achieving the four determinants of TOC, SOC, CC and CRC. Similar relationships are valid for CP, BP and FP.In the model each of the dimension have enablers, which help achieve that dimension. For example dimension Research Perspective (RP) is supported by enablers EST, RDS and NT. These enablers have some interdependency on one another. The feedback and network structure of the ANP makes possible the representation of the decision problem without much concern for what comes first and what comes next in a hierarchy. The alternatives that the DM wishes to evaluate are shown at the bottom of the model.

SOLUTION OF THE MODEL

Calculation of the weights for each of the attributes

Step 1: Once a pair-wise comparison matrix using triangular fuzzy numbers (l_i, m_i, n_i) are formed, weighted vectors for all the matrices are calculated. To select the best vendor weight vectors have to be calculated for the individual level of the hierarchy.

Step 2: We defuzzify the above fuzzy matrices representing attributes using the equation

$$w_i = \frac{l_i + 2\,m_i + n_i}{4} \quad (1)$$

Step 3: We calculate weights now by using Shannon entropy. Basically Shannon entropy is originally derived from thermodynamics studies (Dubios and Pradw, 1980). Shannon entropy gives a measure of information and the information gain from an event is inversely related to its probability of occurrences. Shannon defines the n-state entropy function with base two logarithms as:

$$H = -\sum_{i=1}^{n} p_i \log(p_i) \tag{2}$$

where p_i is the relative frequency.

The entropy weight (Dubios and Pradw, 1980) is shown as follows:

- Let V be a crisp judgment matrix where V is nxn matrix.

$$V = \begin{bmatrix} v_{11} & v_{12} \ldots v_{in} \\ v_{21} & v_{22} \ldots v_{2n} \\ \ldots\ldots & \ldots\ldots \\ v_{n1} & v_{n2} \quad v_{nn} \end{bmatrix} \tag{3}$$

- The normalized matrix with elements represent the relative frequency is illustrated as follows:

$$V = \begin{bmatrix} \frac{v_{11}}{r_1} & \frac{v_{12}}{r_1} \ldots \frac{v_{in}}{r_1} \\ \frac{v_{21}}{r_2} & \frac{v_{22}}{r_2} \ldots \frac{v_{2n}}{r_2} \\ \ldots\ldots & \\ \frac{v_{n1}}{r_k} & \frac{v_{n2}}{r_k} \ldots \frac{v_{nn}}{r_k} \end{bmatrix} = \begin{bmatrix} f_{11} f_{12} f_{13} \ldots f_{1k} \\ f_{21} f_{22} f_{23} \ldots f_{2k} \\ \ldots\ldots \\ \ldots\ldots \\ \ldots\ldots \\ f_{k1} f_{k2} f_{3k} \ldots f_{kk} \end{bmatrix} \tag{3a}$$

where r_i , i=1,...k be the sum of the i-th row.f_{ij} be the relative frequency $f_{ij} = \frac{v_{ij}}{r_i}$, $r_i = \sum_{j=1}^{k} a_{ij}$

- From Eq. 1, the entropy is determined as

$$\begin{aligned} H_1 &= -\sum_{j=1}^{k} p_{1j} \log_2(p_{1j}) \\ H_2 &= -\sum_{j=1}^{k} p_{2j} \log_2(p_{2j}) \\ &\ldots\ldots\ldots\ldots \\ H_k &= -\sum_{j=1}^{k} p_{kj} \log_2(p_{kj}) \end{aligned} \tag{4}$$

The entropy weight is obtained by normalizing each element of entropy values in Eq. 4.

Calculation of desirability index: Interdependencies occur when the direction of influence of the components between two levels of the hierarchy is not unidirectional. When considering the impact of interdependency, the components of two interdependent levels are viewed as controlling components for one another. To determine the composite weights of two interdependent levels, ANP proposes the formation of a super matrix. This allows a resolution of the effects of interdependencies that exist in the hierarchy. Then the weight vectors for each of the matrices are calculated and placed in the super matrix. In order to obtain a long-term stable set of weights, the resulting matrix needs to be column stochastic. For convergence of the matrix to occur, the super matrix is arbitrarily raised to large powers until the entries are stable.

After calculating the weights for all the attributes using the above formulation, the desirability index D_{ia} , for alternative i and determinant as defined as Meade and Sarkis (1999):

$$D_{ia} = \sum_{j=1}^{J} \sum_{k=1}^{Kja} P_{ja} A^{D}_{kja} A^{I}_{kja} S_{ikja} \tag{5}$$

In this equation, P_{ja} is the relative importance weight of dimension j on the determinant 'a'; A^{D}_{kja} is the relative importance weight for attribute enabler k, dimension j and determinant 'a' for the Dependency (D) relationships. A^{I}_{kja} is the stabilized relative importance weight for attribute enabler k of 'j' dimension in the determinant 'a' for Interdependency (I) relationships within the attribute enablers' component level. These values are taken from the converged supermatrix. S_{ikja} is the relative impact of alternative I on enabler k of dimension j for determinant a, K_{ja} is the index set of attribute enablers for dimension j of determinant a, J is the index set for the dimension j.

Calculation of Vendor Overall Weighted Index (VOWI): The VOWI for the alternative i (OWI_i) is the summation of the products of the desirability indices D_{ia} and the relative importance weights of the determinants (C_a) of the overall weighted index.

$$OWI_i = \sum D_{ia} * C_a \tag{6}$$

PRACTICAL EXAMPLE

MEC is a leading freight forwarding company in Taiwan. The company needed to standardize and streamline its accounting and human resource processes, throughout all its operations worldwide, in order to achieve cutting edge business flexibility, customer perspective etc. At that time, the MEC group of

Table 1: The fundamental scale

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favour one activity over another.
5	Strong importance	Experience and judgment very strongly over another, its dominance demonstrated in practice.
7	Very strong importance	An activity is favoured very strongly over another; its dominance demonstrated in practice.
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation.
2,4,6,8	For compromise between the above values	Sometimes one needs to interpolate a compromise judgment numerically because there is no good word to describe it.

Table 2: Pairwise comparison matrix of determinants

	TOC	SOC	CC	CRC	Weights
TOC	(1,1,2)	(2,3,4)	(5,6,7)	(6,7,8)	0.2979
SOC	(1/4,1/3,1/2)	(1,1,2)	(2,3,4)	(5,6,7)	0.3282
CC	(1/7,1/6,1/5)	(1/4,1/3,1/2)	(1,1,2)	(2,3,4)	0.2279
CRC	(1/8,1/7,1/6)	(1/7,1/6,1/5)	(1/4,1/3,1/2)	(1,1,2)	0.1460

Table 3: Pairwise comparison matrix for CP under TOC

CP	P	U	C	ROT	SA	Priority vector
P	(1,1,2)	(.2,.25,.33)	(.25,.33,.5)	(.33,.5,1)	(1,2,3)	0.1512
U	(3,4,5)	(1,1,2)	(2,3,4)	(1,2,3)	(6,7,8)	0.2680
C	(2,3,4)	(.25,.33,.5)	(1,1,2)	(.25,.33,.5)	(1,2,3)	0.1864
ROT	(1,2,3)	(4,5,6)	(2,3,4)	(1,1,2)	(3,4,5)	0.2417
SA	(4,5,6)	(.125,.143,.167)	(.33,.5,1)	(.2,.25,.33)	(1,1,2)	0.1527

Table 4: Super matrix M for TOC before convergence

	P	U	C	ROT	SA	EST	RDS	NT	FS	VCP	MC	OTC	OGC	UCP
P	0	0.291	0.324	0.300	0.302	0	0	0	0	0	0	0	0	0
U	0.25	0	0.307	0.291	0.259	0	0	0	0	0	0	0	0	0
C	0.25	0.301	0	0.239	0.129	0	0	0	0	0	0	0	0	0
ROT	0.25	0.231	0.207	0	0.310	0	0	0	0	0	0	0	0	0
SA	0.25	0.177	0.162	0.170	0	0	0	0	0	0	0	0	0	0
EST	0	0	0	0	0	0	0.296	0.5	0	0	0	0	0	0
RDS	0	0	0	0	0	0.303	0	0.5	0	0	0	0	0	0
NT	0	0	0	0	0	0.697	0.704	0	0	0	0	0	0	0
FS	0	0	0	0	0	0	0	0	0	0.325	0.687	0	0	0
VCP	0	0	0	0	0	0	0	0	0.341	0	0.313	0	0	0
MC	0	0	0	0	0	0	0	0	0.659	0.675	0	0	0	0
OTC	0	0	0	0	0	0	0	0	0	0	0	0	0.388	0.433
OGC	0	0	0	0	0	0	0	0	0	0	0	0.360	0	0.567
UCP	0	0	0	0	0	0	0	0	0	0	0	0.640	0.612	0

companies was using fragmented human resource, production and accounting systems, including manual bookkeeping. Before selecting their chosen solutions MEC selection team meticulously documented their existing process, objective and requirements. They carefully reviewed over eight applications selected for selecting the software. After selecting the software, MEC sent invitations to three Vendors (Vendor A, Vendor B and Vendor C) for ERP system selection. In this empirical study we illustrate the process of selecting ERP Vendor. The various criteria, sub-criteria and alternatives affecting the decision-making problem in form of a hierarchy are depicted in Fig. 2. The aim of decision maker is to select best Vendor that meets the requirements of the organisation. Table 2 lists the opinions of the decision maker in terms of TFNs and shows the weights of different attributes (i.e. C_a). Using the Eq. 1 for defuzzification and then using Eq. 2-4 for calculating the weights for different level of the hierarchy. We then calculate the relative importance of each of the dimensions on the determinants. One such matrix for Customer Perspective (CP) is shown in Table 3. After the weights are determined for all levels of the hierarchy, an analysis is performed to obtain the interdependencies among and between different levels of the hierarchy. In this case interdependence occurs between the enablers. Table 4 shows the supermatrix M for TOC before convergence. Table 5 Shows the supermatrix M for TOC after convergence. In this case study convergence occurs at the 29th power of the original matrix. These values are imported as A^{I}_{kja} in Table 6. Similarly S_{ikja} is the relative impact of alternative i on enabler k of dimension j for determinant a. Here the final set of pair-wise comparisons is made for the relative impact of each of the alternatives (Vendor A, Vendor B, Vendor C) on the enablers in influencing the determinants. In the present case there

Table 5: Super matrix M for TOC after convergence

	P	U	C	ROT	SA	EST	RDS	NT	FS	VCP	MC	OTC	OGC	UCP
P	0.233	0.233	0.233	0.233	0.233	0	0	0	0	0	0	0	0	0
U	0.216	0.216	0.216	0.216	0.216	0	0	0	0	0	0	0	0	0
C	0.192	0.192	0.192	0.192	0.1912	0	0	0	0	0	0	0	0	0
ROT	0.198	0.198	0.198	0.198	0.198	0	0	0	0	0	0	0	0	0
SA	0.161	0.161	0.161	0.161	0.161	0	0	0	0	0	0	0	0	0
EST	0	0	0	0	0	0.293	0.293	0.293	0	0	0	0	0	0
RDS	0	0	0	0	0	0.295	0.295	0.295	0	0	0	0	0	0
NT	0	0	0	0	0	0.412	0.412	0.412	0	0	0	0	0	0
FS	0	0	0	0	0	0	0	0	0.355	0.355	0.355	0	0	0
VCP	0	0	0	0	0	0	0	0	0.246	0.246	0.246	0	0	0
MC	0	0	0	0	0	0	0	0	0.400	0.400	0.400	0	0	0
OTC	0	0	0	0	0	0	0	0	0	0	0	0.292	0.292	0.292
OGC	0	0	0	0	0	0	0	0	0	0	0	0.323	0.323	0.323
UCP	0	0	0	0	0	0	0	0	0	0	0	0.385	0.385	0.385

Table 6: Pairwise comparison matrix for alternatives impact on enabler in influencing determinant

SA	Vendor A	Vendor B	Vendor C	Priority vector
Vendor A	(1,1,2)	(.2,.25,.33)	(1,1,2)	0.3424
Vendor B	(3,4,5)	(1,1,2)	(3,4,5)	0.3151
Vendor C	(1,1,2)	(.2,.25,.33)	(1,1,2)	0.3424

Table 7: Desirability indices for Technical objective Criteria (TOC)

Dimension	P_{JA}	Enablers	A^{D}_{KJA}	A^{L}_{KJA}	S_{1kja}	S_{2kja}	S_{3kja}	A	B	C
CP	0.2996	P	0.1512	0.2330	0.3145	0.2472	0.4383	0.003614	0.003326	0.0036
CP	0.2996	U	0.2680	0.2163	0.2726	0.3309	0.3965	0.005076	0.00645	0.0058
CP	0.2996	C	0.1864	0.1915	0.3110	0.2902	0.3987	0.003326	0.003105	0.0042
CP	0.2996	ROT	0.2417	0.1979	0.2923	0.3714	0.3363	0.003907	0.004742	0.0057
CP	0.2996	SA	0.1527	0.1612	0.3424	0.3151	0.3424	0.002319	0.001823	0.0032
BP	0.2742	EST	0.2476	0.2933	0.3198	0.2740	0.4063	0.006368	0.005454	0.0081
BP	0.2742	RDS	0.3986	0.2948	0.2318	0.3426	0.4257	0.007469	0.011039	0.0137
BP	0.2742	NT	0.3538	0.4119	0.3965	0.3309	0.2726	0.015844	0.013223	0.0109
RP	0.1342	FSV	0.3166	0.3545	0.2726	0.3309	0.3965	0.004051	0.004917	0.0059
RP	0.1342	VCP	0.4310	0.2459	0.4257	0.3426	0.2318	0.005973	0.004807	0.0033
RP	0.1342	MC	0.2524	0.3996	0.4131	0.3105	0.2764	0.005516	0.004146	0.0369
FP	0.2937	OTC	0.4257	0.2921	0.3012	0.3613	0.3375	0.011	0.013195	0.0123
FP	0.2937	OGC	0.3426	0.3232	0.3511	0.2971	0.3511	0.011418	0.009681	0.0114
FP	0.2937	UCP	0.2318	0.3847	0.3632	0.2736	0.3632	0.00951	0.007166	0.0095
Total desirability indices								.0954	0.0931	0.1014

Table 8: Comparing the results of the two methods

	Fuzzy ANP	Crisp ANP	Average
Vendor A	0.09581(III)	0.06753(III)	0.0817(II)
Vendor B	0.10127(II)	0.12857(I)	0.0115(III)
Vendor C	0.10277(I)	0.07916(II)	0.0910(I)

are 14 enablers for each determinant, which lead to 56 such pairwise matrices. One such pairwise comparison matrix is shown in Table 6 where the impacts of three alternatives are evaluated on the enabler SA for TOC. These priority vectors from this matrix are imported to columns 6-8 of Table 7. The final three columns represent the weighted values of the alternatives (P_{ja}*A^{D}_{kja}* A^{I}_{kja}*S_{ikja}) for each enabler. For example in Table 7, value of A for P is .003614 (i.e. .2996*. 1512*. 2330*. 3145). The summation of these results is shown at the end of Table 7. Using Eq. 5, the desirability index is determined for the entire alternative. Finally the overall weighted index is determined for each Vendor using Eq. 6.

FUZZY-ANP RESULTS

We observe that in Fuzzy ANP convergence of the super matrix takes place at a lesser power i.e. in our example convergence takes place at the 29th power. But in case of crisp ANP convergence takes place at 87th power. Now coming to the main result from Table 8 for Fuzzy ANP the value of VOWI in case of Vendor C is highest (.1028), followed by Vendor B (.1013) and then Vendor A (.0958). In Crisp ANP Vendor B comes out to be the best followed by Vendor C and Vendor A. From Table 8 it is also observed that while taking the average of both the cases Vendor C (.0910) is the best. This explains the consistency of the result with Fuzzy ANP and also Vendor C is selected the best Vendor.

CONCLUSION

ANP methodology has proven to be useful in considering both quantitative as well as qualitative characteristics, which needs to be considered. From an application perspective this may require some time from the managers and the decision makers in filling the pair-wise comparison matrices. From an investment point of view this model will help reduce the risk of poor investment decisions. It has also proven to be useful for structuring the decision in decision makers mind from a macro level point of view. The case study provides an example of the application of the methodology to a real life situation. But it would be good to show that the proposed model can be implemented in real world problems.

Eliciting information from the DM for large number of pair-wise comparison (133 pair-wise comparison matrices were required for the problem) can become tedious and time consuming. Also the inconsistency may occur in the pair-wise comparison of matrices. Therefore the technique should be targeted for the strategic decisions only. The use of matlab for super matrix approach and excel spreadsheet analysis makes calculations easier.

Also the use of fuzzy logic makes fuzzy ANP a better choice as a methodology because of its less performance time. Also fuzzy logic addresses the ambiguities associated with the preferences of the decision maker in best possible way.

The ANP method is realistic, easy, flexible and inexpensive to use. It provides transparency and accountability in reaching decisions. The model presented here does not consider all the possible factors and criteria associated with VSP. However, more factors may be considered according to organization specification.

REFERENCES

Albino, V., A.C. Garavell and M. Gorgoglione, 1998. Fuzzy logic in Vendor Rating: A comparison between a fuzzy logic system and a neural network. Fuzzy Econ. Rev., 3: 25-47.

Alexis Leon, E.R.P., 2000. Demystified. Tata Mc Graw Hill Publishing Company Limited.

Anthony, T.F. and F.P. Buffa, 1977. Strategic purchase scheduling. J. Purchasing and Materials Manag., pp: 27-31.

Chaudhary, S.S., F.G., Forst and J.L. Zydak, 1981. A multicriteria approach to allocating order quantity among Vendors. Prod. Inventory Manag. J. 3rd Quart., pp: 82-85.

Chen, S.J. and C.L. Hwang, 1992. Fuzzy Multiple Attribute Decision Making. New York: Springer-Verlag.

Chou, S.Y., C.Y. Shen and Y.H. Chang, 2006. Vendor selection in a modified re-buy situation using a strategy-aligned fuzzy approach. Int. J. Prod. Res., pp:1-21.

Dickson, G.W., 1966. An analysis of vendor selection systems and decisions. J. Purchasing, 2: 5-17.

Don-Lin Mon, 1995. Evaluating Weapon system using Fuzzy AHP based on entropy weights. Fuzzy systems, 1995, International joint conference of the fourth IEEE International Conference on Fuzzy systems and the second International fuzzy Engineering symposium. Proc. IEEE. Int. Conf., 2: 591-598.

Dubois, D. and H. Prade, 1980. Fuzzy sets and Systems: Theory and Applications. New York: Academic.

Ghodsypour, S.H. and C.O. Brien, 1998. A DSS for supplier selection using an integrated AHP and Linear Programming. Int. J. Prod. Econ., pp: 56-57, 199-212.

Gregory, R.E., 1986. Source Selection: A Matrix Approach. J. Purchasing Materials Manag., pp: 24-29.

Kahraman Cengiz, Tijen Ertay and Gulcin Buyukozkan, 2006. A fuzzy optimisation model for QFD planning process using analytic network approach. European J. Operational Res., 171: 390-411.

Kasilingam Raja, G. and P. Lee Chee, 1996. Selection of Vendors-A mixed integer programming approach. J. Comput. Indus. Engin., 31: 347-389.

Kaufmann, A. and M.M. Gupta, 1985. Introduction to Fuzzy Arithmetic, New York: Van Nostrand.

Kumar Manoj, 2004. Vendor Selection: An interval-programming model. Udyog Pragati, 28: 4.

Kumar Manoj, Vrat Prem and Shankar Ravi, 2004. A fuzzy goal programming approach for Vendor Selection problem in a supply chain. Comput. Indus. Eng., 46: 69-85.

Kumar Manoj, Vrat Prem and Shankar Ravi, 2006. A fuzzy programming approach for Vendor Selection problem in a supply chain. Int. J. Prod. Econ., 101: 273-285.

Laarhoven, P.J.M. and W. Pedryce, 1983. A fuzzy extension of Saaty's priority theory. Fuzzy Sets Sys., 11: 229-241.

Mandal, A. and S.G. Deshmukh, 1994. Vendor Selection using Interpretative Structural Modelling (ISM). Int. J. Operations Prod. Manag., 14: 52-59.

Meade, L.M. and J. Sarkis, 1999. Analysing organizational project alternative for agile manufacturing processes: An Analytical Network Approach. Int. J. Prod. Res., 37: 241-261.

Mohanty, R.P., R. Agarwal, A.K. Choudhry and M.K. Tiwari, 2005. A fuzzy ANP based approach to R&D project selection: A case study. Int. J. Prod. Res., 43: 5199-5216.

Nassimbeig, B. F., 2003. Evaluation of supplier contribution to product development: Fuzzy and neuro-fuzzy based approaches. Int. J. Prod. Res. 41: 2933-2956.

Ozden Bayazit, 2006. Use of analytic network process in vendor selection decisions. Benchmarking: An Int. J., 13: 566-579.

Pan, A.C., 1989. Allocation of order quantities among suppliers. J. Purchasing and Materials Manag., pp: 36-39.

Saaty, T.L., 2001. Decision Making with Dependence and Feedback the Analytical Network Process. 2nd Edn. RWS Publications, Pittsburgh PA.

Saaty, T.L., 1980. The Analytical Hierarchy Process. Mc Graw hill Company, New York.

Sarkis, J. and S. Talluri, 2002. A synergistic framework for evaluating business process improvements. The Int. J. Flexible Manufacturing Sys., 14: 53-71.

Ta kin Harun and M.Y. Bayrak, 2004. A fuzzy approach method for vendor selection. YA/EM'2004-yöNEYLEM Ara tirmas/Endûstri Mûhendislig I-XXIV Ulusal Kongresi, Haziran, Gaziantep-Adana, pp: 15-18.

Talluri, S., N. Ram and N. Anand, 2004. Vendor performance with supply risk: A chance-constrained DEA approach. Int. J. Prod. Econ., pp: 1-10.

Tam Maggie, C.Y. and V.M. Rao Tummala, 2001. An Application of the AHP in vendor selection of a telecommunications system. Omega, 29: 171-182.

Timmerman, E., 1986. An approach to vendor performance evaluation. J. Purchasing Materials Manag., pp: 2-8.

Verma, R. And E. M. Pullman, 1998. An analysis of the supplier selection process. Omega, 26: 739-750.

Weber, C.A. and L.M. Ellram, 1993. Supplier selection using multiobjective programming: A decision support systems approach. Int. J. Physical Distribution Logistics Manag., 23: 3-14.

Weber, C.A., J.R. Current and R. Benton, 1991. Vendor selection criteria and methods. Eur. J. Operational Res., 50: 2-18.

Wind, Y. and P.J. Robinson, 1968. The determinants of vendor selection: the evaluation function approach. J. Purchasing Materials Manag., pp: 29-41.

Zadeh, L.A., 1965. The concept of a linguistic variable and its application to approximate reasoning –I. Infor. Sci., 8: 199-249.

Zhang He , Xiu Li, Wenhuang Liu, Bing Li and Zhihong Zhang, 2004. An application of the AHP in 3PL vendor Selection of a 4PL system. IEEE Conference on systems, Man and Cybernetics, pp: 1255-1260.