International Journal of Research in Advent Technology, Vol.3, No.8, August 2015
E-ISSN: 2321-9637

Application of a Hybrid MCDM Method

Bobin Cherian Jos[1] ,Nisha Markose[2] , Shinu S Kurian[3] and Beena Jacob[4]
Department of Mechanical Engineering[1], Department of Computer Applications[2,3,4]
Mar Athanasius College of Engineering, Kothamangalam, Kerala
Email: bobincherian@gmail.com, nishamark@yahoo.com[2], ssusank@rediffmail.com[3], beena_ jhoni@rediffmail.com[4]

Abstract—Multiple-criteria decision making **(**MCDM)explicitly considers multiple criteria in decision-making environments. Extended Enterprise (EE) is one of the latest organizational strategies in manufacturing. Partner selection is one of the crucial problems in the formation and operation of an extended enterprise. The objective of this paper is to introduce the application of TOPSIS combined with Analytical hierarchy process for the selection of partners in Extended Enterprise. This paper briefly reviews the concepts of extended enterprise, AHP-TOPSIS implementation process and demonstrates the application of this hybrid model in the partner selection problem of an extended enterprise.

Index Terms—AHP, Extended Enterprise,MCDM,TOPSIS.

1. INTRODUCTION

Multiple-criteria decision-making (MCDM) or Multiple-criteria decision analysis (MCDA) is a sub-discipline of operations research that explicitly considers multiple criteria in decision-making environments. In our daily lives there are typically multiple conflicting criteria that need to be evaluated in making decisions. Usually one of the main criteria is cost or price. Measure of quality and cost is another conflict criterion. In a service industry, customer satisfaction and the cost of providing service are two conflicting criteria that would be useful to consider. Similar types of conflicting criteria are evaluated by various MCDM tools. AHP and TOPSIS are the major MCDM tools used by industries.

Enterprises are characterized by dramatic and unanticipated changes and must develop and implement new and innovative strategies for competitive success. The concept of Extended Enterprise (EE) is one among the most interesting competitive strategies being explored by manufacturing firms. It differs from existing inter-organizational models by the degree of shared accountability and responsibility of the participants and the structure by which companies contribute their competencies.

One of the key problems of extended enterprise's success is how the dominant enterprise selects the proper cooperative partner. Partners' selection is not a simple optimization problem. Various qualitative and quantitative factors depend on the selection of partners. Although the partnership selection problem is considered as critical in the formation of EE, only few formalized decision making methods have been proposed in the literatures. Many studies have been done on vendor selection in supply chain but modeling of extended enterprise is a new area for the researchers and practitioners. Hence we propose a hybrid model, AHP-TOPSIS, for the selection of partner companies in EE.

The rest of this paper is organized as follows: section 2 provides a brief description about extended enterprises. Section 3 gives a literature review on the partner selection problems. Section 4 describes the advantages of MADM techniques which are adopted for the research. The detailed procedure of the proposed hybrid model, AHP-TOPSIS, is given in Section 5. In section 6 one case example is used to explain the application of the proposed model. Finally conclusions are given in section 7.

2. EXTENDED ENTERPRISE

The concept of the Extended enterprise (EE) is one of the latest organizational strategies in manufacturing. Extended enterprise is the formation of closer co-ordination in the design, development, costing and the co-ordination of the respective manufacturing schedules of co-operating independent manufacturing enterprises and related suppliers. Extensive use of information technology within the respective enterprises and electronic communications among them are the additional features of these extended enterprises.[1].

Extended enterprise is a temporary coalition of independent companies that come together to share resources, costs and skills in order to achieve specific business goals that they could not undertake individually within a given time period and at a cost lower than any of the cooperating partners would be able to achieve by themselves.

New market requirements arise very quickly and the individual organizations often do not have all necessary skills and competencies to deal with these requirements. However, by combining their areas of particular expertise with the complementary expertise of other partner companies, it is possible to create an EE, capable of prospering and responding to the new requirements [2].The participating members share costs, skills and core competencies that enable them to access a specific market niche with solutions that could not be provided individually. Each member of the EE brings to the co-operation of his core competencies relevant to the mission and concentrates on those areas where it may have a unique competitive advantage [1].

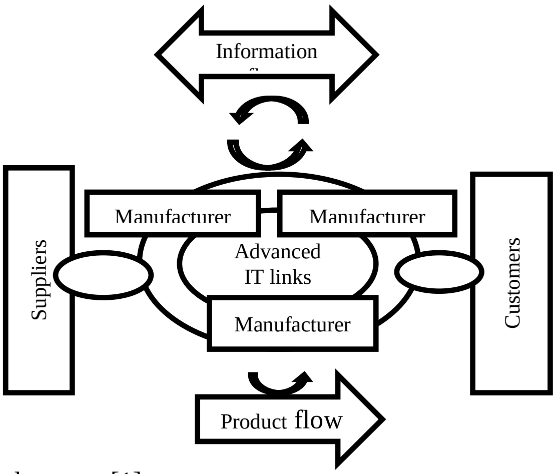

Fig 1 The Extended Enterprise

The success of the mission depends on all organizations cooperating as a synergetic unit, because each partner brings his strengths or core competence to the EE. It means that the competitive advantage that can be achieved by the EE depends on how well the individual organizations complement each other and their ability to integrate with one another [3]. Extended enterprise is responsible for the whole product life cycle from material procurement and supply, management to production and manufacturing, further to product distribution and customer service, and finally to the recycling and disposal of end of life products. [4].

3. RELATED RESEARCH STUDIES

Selection of best partners plays a key role to form a quality organization. Henceforth recently partner selection process in supply chain has attracted much research attention. Kasilingam and Lee(6) propose a mixed integer programming model for selecting vendors and determining order quantities. Talluri(7) formulate the selection process as a multiple criteria decision-making problem and apply a mathematical modeling approach, based on a linear goal programming method. Babic and Plazibat (8) employ multiple criteria analysis for ranking of enterprises, according to the achieved level of business efficiency. X.N.Chu, S.K.Tso, W.J.Zhang and Q.Li [9], applied Group technology (GT) for retrieving and selecting potential partners.ToniJarimo and AhtiSalo (10) proposed a MILP model ,which focuses on the minimization of total fixed and variable costs, capacity risk and account for the inter-organizational dependencies due to an earlier collaboration history. W.H. Ipa, Min Huangb (11) considered the selection of partners in virtual enterprise as a multi-objective optimization model and proposed genetic algorithm for minimizing the objective function.

NaiqiWu ,Ping Su [13] modeled partner selction problem by an integer programming formulation to minimize cost. Camarinha-Matos and Cardoso [14] present a framework for partner selection and describe the functionalities in detail, but no techniques to make the tradeoff based on the cost and time are proposed. Under AM and supply chain management,the partner selection problem is studied by Gunasekaran [15] and Maloni [16], and they point out that the mathematical models and optimization methods are still a challenge. The partner selection problem is also studied under project management in the cooperation relationship of subprojects contracted by partners [17-19]. In the study of Brucker et al.[17], the partner selection is embedded in the project scheduling problem.

BurakSari ,Tayyarsen ,EnginKilie [20], proposed a classical AHP model for the selection of partners in virtual enterprise and considered caution cost and performance variability as the factors . Narasimahn [21], Nydick and Hill [22], Partovi et al. [23] also did suggest the use of the AHP for vendor selection problems, because of its inherent capability to handle qualitative and quantitative criteria, its simple and understandable decision procedure and the effective evaluation and selection process. The vendor selection problem is further discussed in Tam [24], who proposes the application of the AHP in a group-decision making process. Zhang Xiangying [25] applied AHP-TOPSIS forthe selection of knowledge share partners in the logistics enterprises.

From the above literature review it can be concluded that the partnership selection process should be considered as a multiple criteria decision-making problem, rather than a pure mathematical modeling problem. The suitability of the classical

AHP method which is widely used for problems having multiple criteria and alternatives is recognized by many researchers, working on the partnership selection problem. In this paper, other than the previous works, in the process of evaluating and selecting partners based on AHP method, we import the TOPSIS method to standardize the evaluation result so that we can get more objective and effective evaluation result and get the final appropriate partner. Although several effective techniques and models have been utilized for evaluating partners, there is little work for the selection of partners in extended enterprise integrating core competence and level of commitment into the decision making process, which are the fundamental characteristics of an extended enterprise.

Different from other researchers we propose unit price, level of commitment (for the long term trust worthy relation), reaction time (representing task completion probability) and core competence (partners' performance as a combination of quality, progress and market value) as the criteria to be considered in the partner selection process. Because these are the major factors which differentiate extended enterprise from other collaborations in supply chain [1-3]. On the basis of the proposed foundation, we will establish a generalized AHP-TOPSIS model in a group decision environment.

4. MULTIPLE CRITERIA DECISION-MAKING

Multiple criteria decision-making (MCDM) refers to an approach of problem solving that addresses problems where the selection is made from a finite number of alternatives. In this paper, two important multiple attribute decision-making methods, namely technique for order preference by similarity to the ideal solution (TOPSIS) and analytic hierarchy process (AHP), are used concurrently for decision-making. Both TOPSIS and AHP are logical decision-making approaches and deal with the problem of choosing a solution from a set of candidate alternatives

The AHP was developed first by Saaty, 1980[31]. It is a powerful and flexible multi – criteria decision-making tool by structuring a complicated decision problem hierarchically at several different levels where both qualitative and quantitative aspects need to be considered. The AHP combines both subjective and objective assessments into an integrative framework based on ratio scales from simple pair wise comparisons and helps the analyst to organize the critical aspects of a problem in to a hierarchical structure [32]. The AHP can efficiently deal with tangible and non-tangible attributes, especially where the subjective judgments of different individuals constitute an important part of the decision-making process. It has the following advantages

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), developed by Hwang and Yoon (1981), is a multi-attribute decision-making (MCDM) method.TOPSIS is based on a simple and intuitive concept; it enables consistent and systematic criteria, which is based on choosing the best alternative having the shortest distance from the ideal solution and the farthest distance from the negative ideal solution. TOPSIS assumes that each attribute has a tendency toward monotonically increasing or decreasing utility. Therefore, it is easy to locate the ideal and negative ideal solutions [29].The ideal solution is regarded as the maximal benefits solution, consists of taking the best value of alternative .The negative ideal solution is treated as the minimal benefits solution, and is composed of all worst value of alternatives. Subsequently the alternatives are ranked with respect to the relative closeness to the ideal solutions.

TOPSIS is more efficient in dealing with the tangible attributes and the number of alternatives to be assessed[30].However, the TOPSIS method needs an efficient procedure to determine the relative importance of different attributes with respect to the objective; AHP provides such a procedure. Hence, to take the advantages of both the methods, a combined MADM (using TOPSIS and AHP) is developed in this paper for the partner company selection in an extended enterprise from a set of interested partners given bid to the EE initiator

5. AHP-TOPSIS MODEL

The main procedure of the combined TOPSIS and AHP method is as follows.

5.1 Establishment of a structural hierarchy

This step allows a complex decision to be structured into a hierarchy descending from an overall objective to various 'criteria', 'sub-criteria', and so on until the lowest level. The objective or the overall goal of the decision is represented at the top level of the hierarchy. The criteria and sub-criteria contributing to the decision are represented at the intermediate levels. Finally, the decision alternatives or selection choices are laid down at the last level of the hierarchy. According to Saaty [31] , a hierarchy can be constructed by creative thinking, recollection, and using people's perspectives. He further notes that there is no set of procedures for generating the levels to be included in the hierarchy. Yoon [33] comments that the structure of the hierarchy depends upon the nature or type of managerial decision. Also, the number of the levels in a hierarchy depends on the complexity of the problem being analyzed and the degree of detail of the problem that an analyst requires to solve . As such, the hierarchical representation of a system may vary from one person to another.

5.2 Establishment of Comparative Judgments

Once the hierarchy has been structured, the next step is to determine the priorities of elements at each level (*'element'* here means every member of the hierarchy). A set of comparison matrices of all elements in a level of the hierarchy with respect to an element of the immediately higher level are constructed so as to prioritize and convert individual comparative judgments into ratio scale measurements. The preferences are quantified by using a nine-point scale[31]. The pair-wise comparisons are given in terms of how much more element A is important than element B. As the AHP approach is a subjective methodology [34], information and the priority weights of elements may be obtained from a decision maker of the company using direct questioning or a questionnaire method.

5.3 Synthesis of priorities and measurement of consistency

The pair-wise comparisons generate a matrix of relative rankings for each level of the hierarchy. The number of matrices depends on the number elements at each level. The order of the matrix at each level depends on the number of elements at the lower level that it links to. After all matrices are developed and all pair-wise comparisons are obtained, eigenvectors or the relative weights (the degree of relative importance amongst the elements), global weights, and the maximum eigenvalue (λmax) for each matrix are then calculated.

The λmax value is an important validating parameter in AHP. It is used as a reference index to screen information by calculating the consistency ratio CR [31] of the estimated vector in order to validate whether the pair-wise comparison matrix provides a completely consistent evaluation. The consistency ratio is calculated as per the following steps:

1. Calculate the eigenvector or the relative weights and λmax for each matrix of order *n*
2. Compute the consistency index for each matrix of order *n* by the formulae:

$$CI = (\lambda max - n)/(n-1) \quad (1)$$

3. The consistency ratio is then calculated using the formulae:

$$CR = CI / RI \quad (2)$$

where*RI* is a known random consistency index obtained from a large number of simulation runs and varies depending upon the order of matrix. The acceptable *CR* range varies according to the size of matrix. i.e., 0.05 for a 3 by 3 matrix, 0.08 for a 4 by 4 matrix and 0.1 for all larger matrices, $n \geq 5$ [31-35].

5.4 Construct the weighted normalized decision matrix

Obtain the weighted normalized matrix Vij . This is obtained by the multiplication of each element of the column of the matrix R_{ij} with its associated weightWj . Hence, the elements of the weighted normalized matrix Vij are expressed as:

$$Vij = WjR_{ij} \quad (3)$$

5.5 Determination of the Ideal and Negative Ideal Solutions

The ideal solution ($A*$) is defined as the best performance score result all alternatives on a criterion, on the contrary, the negative ideal solution is (A') is determined as the as the worst performance score result across all alternatives on a criterion.

Ideal solution:

$$A* = \{V1*,....,Vn*\}, \quad (4)$$
$$Vj* = \{max(Vij)\, if \ldots j \in J; min(Vij)\, if \ldots j \in J'\}$$

Negative ideal solution:

$$A' = \{V1',....,Vn'\}, \quad (5)$$
$$Vj' = \{min(Vij)\, if \ldots j \in J; max(Vij)\, if \ldots j \in J'\}$$

5.6 Separation of Each Alternative from the Ideal and Negative Ideal Solution

After determining the ideal solution and negative ideal solution, the distance between the two solutions for each alternative are calculated. The separation from the ideal alternative is:

$$Si* = \left[\sum (Vj* - Vij)^2\right]^{1/2} \quad i = 1,..m \quad (6)$$

Similarly, the separation from the negative ideal alternative is:

$$S'i = \left[\sum (Vj' - Vij)^2\right]^{1/2} \quad i = 1, ..m \quad (7)$$

5.7 *Calculation of Relative Closeness to the Ideal Solution*

Calculate the relative closeness to the ideal solution Ci* as shown below.

$$Ci^* = \frac{S'i}{(Si^* + S'i)}, 0 < Ci^* < 1 \quad (8)$$

Select the option with Ci^* closest to 1.Rank the alternatives according to Ci^*.Finally, higher the score from TOPSIS, higher the priority of the alternative.

6. CASE EXAMPLE

To demonstrate the application of the developed model, a case study entitled as "An extended enterprise for Car Manufacturing" is presented in this section. Interested partner can be defined as a member of network willing to join a specific EE. The EE Initiator decomposes the product into the four tasks (T1, T2, T3, and T4) and looking for the four partners with the relevant skills to execute these tasks. The proposed AHP model is applied to the first task, T1 to illustrate the key activities related in selecting required EE partners. The various alternatives in this problem are the companies interested in the formation of this extended enterprise, who have given bid to the initiator. In this case example P1, P2, and P3 are the interested partners for the first task T1.

The fundamental factors need to be considered in the selection of partner companies in extended enterprise are described below

Unit cost: This is the cost of completing the required task by the interested partner. Cost is a major factor which influences the partner selection. A partner bid involving higher cost is liable to be rejected on economic ground. The total task quantity also influences the overall price. Thus, the lower this value is, the more preferable for the Extended enterprise

Level of commitment: Level of commitment is measured in terms of a caution cost, which is the cost that the partner must pay to the EE if the partner decides to give up the assigned task and is secured in the form of letter of credit. Thus, the higher this value is, the more preferable for the Extended enterprise.

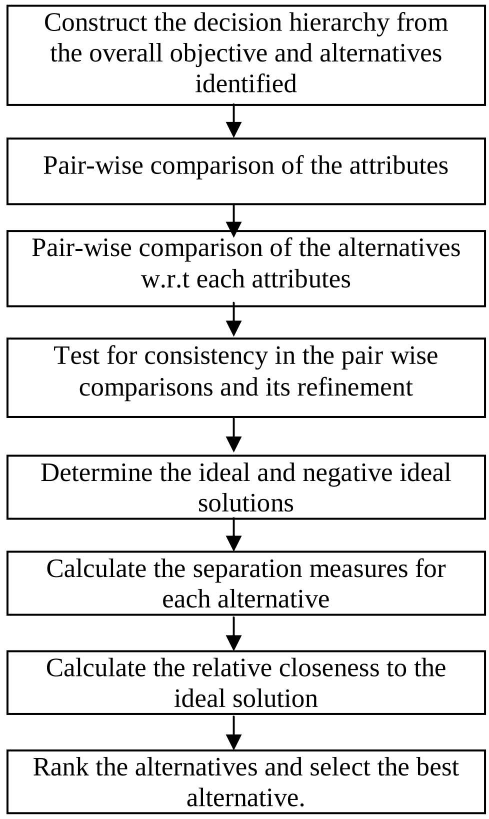

Fig 2 Overview of the selection process using AHP-TOPSIS

Reaction time: Reaction time is defined as the time required to complete the task under the given specifications. Completing the task by the given time period is calculated using program evaluation review technique (PERT).

*Core competence:*Core competencies are the most significant value creating skills within the corporation and key areas of expertise which are distinctive to the company and critical to the company's long term growth. Company's core competencies are the things that it can do better than its competitors in the critical or central areas of production, where the most value is added to products. This can be estimated from the product quality and past performance of the partner. Considering the goal, the attributes and the alternatives, decision hierarchy for the partner selection is developed as shown in Fig. 3

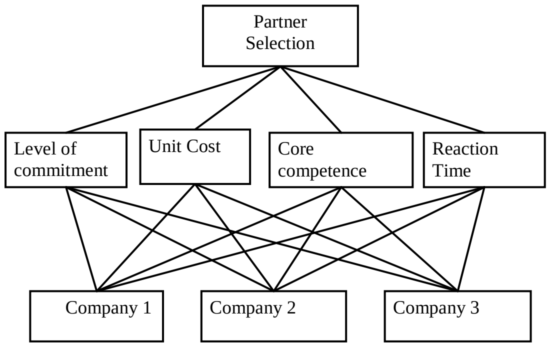

Fig.3 Decision hierarchy

In this problem, we have four objectives for the selection of partners. These are unit cost of the task (UC), level of commitment (LC), Reaction time (RT) and Core competence of the partner (CC). In the next step, we begin writing down a 4×4 matrix 'A' as shown in table I (known as the pair wise comparison matrix). The entry in row i and column j of this matrix A (calling it aij) indicates how much more important objective i is than objective j. "Importance" is to be measured on satys integer-valued 1–9 scale, [31]

Table I: Pair wise comparison matrix of the criteria

	UC	LC	RT	CC
UC	1.00	1/3	2.00	1/6
LC	3.00	1.00	4.00	0.50
RT	1/2	1/4	1.00	1/8
CC	6.00	2.00	8.00	1.00

λmax =4.020 CI=0.0069 RI=0.89
CR=0.0077<0.08

As the value of CR is less than 0.08, the judgments are acceptable. Relative weights of each attribute is calculated using the AHP [31] and given in table IV.

Next step is the pair-wise comparisons of the interested partners on the basis of each criterion. In these comparison matrices we are representing, the relative importance of the different partners on each alternative-Core competence, level of commitment, reaction time and unit cost. The entry (aij) in row i and column j of the matrix indicates how much more important partner i is than partner j against that particular criterion. Importance is measured on an integer valued 1-9 scale [31]. The comparison matrix of the alternatives on core competence is given below.

Table II: Pair-wise comparison matrix-Core competence

CC	P1	P2	P3
P1	1.00	½	1/3
P2	2.00	1.00	½
P3	3.00	2.00	1.00

λmax = 3.0183 CI= 0.009194 CR= 0.0158<0.05

Priority weights of the interested partners for each criterion are calculated from the pair-wise matrix using the AHP method. The calculated weights have been summarized in table III.

Table III:Priority weights of Partners for each

	UC	LC	RT	CC
P1	0.21	0.08	0.12	0.16
P2	0.65	0.76	0.32	0.29
P3	0.13	0.14	0.55	0.53

criteria

We get the normalized weighted decision matrix Vijusing the equation (3);the calculated values are shown in table V. Determine the ideal (A*) and negative ideal (A') solutions using the equations (4) & (5). Table VI gives the values of ideal and negative ideal solutions.

Table IV: Priority weights of the objectives

Criteria	Weights
Unit Cost	0.10365
Level of commitment	0.27763
Reaction Time	0.06345
Core competence	0.55526

Table V: Normalized weighted decisionmatrix

P1	0.30	0.10	0.18	0.25
P2	0.93	0.97	0.48	0.46
P3	0.19	0.18	0.85	0.84

Table VI: ideal and negative ideal solutions

A*	0.93	0.97	0.85	0.84
A'	0.19	0.10	0.18	0.25

Calculate the separation measures for each alternative using equation (6) & (7).The obtained values are given in table VII .The relative closeness of each alternative to the ideal solution Ci* is given in table VIII; which calculated using the equation (8).Rank the alternatives according to the relative Closeness to the ideal solution.A large value of index Ci* indicates a good performance of the alternative Pi.The best alternative is the one with greatest relative closeness to the ideal solution.The result shows that the second alternative P2 is the preferred partner compared with P1 and P3.

Table VII: Separation from ideal and non ideal solution

	P1	P2	P3
Si*	1.3943	0.52498	1.08355
S'i	0.1110	1.20123	0.89230

Table VIII: Relative closeness of each alternative to the ideal solution

	P1	P2	P3
Ci*	0.07378	0.69587	0.45160

This simplified example is chosen for illustrative purposes and for better understanding of the main principles of the proposed approach. In real situations the number of criteria and alternatives could be greater, and the decision hierarchy might include intermediate levels of sub-criteria. In real situations, the number of alternative partners could be reduced during the initial phase of the analysis, by the filtering techniques.

7. CONCLUSIONS

A hybrid MCDM method is used for the selection of partners in an extended enterprise. One of the key issues that affect the extended enterprise's success is how the dominant enterprise selects proper cooperative partners. In this paper, partnership selection process of an extended enterprise is formulated as a multiple attributedecision-making problem and an AHP based model is proposed to derive global priorities of all possible alternatives. The rank has been calculatedusing TOPSIS based on these global priority weights. This hybrid model is a powerful decision-support tool within a multi-criteria analysis framework. This feature makes the proposed approach a suitable alternative for resolving certain partnership selection problems and for developing an appropriate decision-making tool.

REFERENCES

[1] H.S Jagdev; J Browne (1998) The extended enterprise –a context for manufacturing Production planning and control, Vol 9,no 3 216-229

[2] J. Browne; P.J.Sackett; J.C.Wortmann (1995),Future manufacturing systems- Towards the extended enterprise, Computers in Industry 25 235-254

[3] Jim Browne;Jiang Zhang (1999) Extended enterprise and virtual enterprise –similarities and differences, International journal of agile management systems 1/1

[4] Meade L; Liles D; Sarkis J. (1997) Justifying strategic alliances and partnering: a prerequisite for virtual enterprising. Omega; 25:29–42.

[5] Introduction to the extended enterprise; (2006) Pearson education

[6] Kaslingam R; Lee C. (1996) Selection of vendors—a mixed integer programming approach. Computers and Industrial Engineering;31:347–50

[7] Talluri S; Baker R; Sarkis J. (1999) A framework for designing efficient value chain networks. International Journal on Production Economics;62:133–44.

[8] Babic Z; Plazibat N. (1998) Ranking of enterprises based on multi-criteria analysis. International Journal on Production Economics; 56–57:29–35.

[9] X N. Chu;S. K. Tso; W. J. Zhang and Q. Li(2002) Partnership Synthesis for Virtual Enterprises International Journal of Advanced Manufacturing Technology 19:384–391

[10] Toni Jarimo (2006) An Optimisation Model for Partner Selection in Virtual Organisations Annual Reviews in Control 27 221–228

[11] W.H. Ipa; Min Huangb; K.L. Yung; Dingwei Wang (2003) Genetic algorithm solution for a risk-based partner selection problem in a virtual enterprise Computers & Operations Research 30 213–231

[12] HendrikJahna; Marco Fischera Tobias Teichb (2004) Optimizing the selection of partners in production networks, Robotics and Computer-Integrated Manufacturing 20 593–601
[13] Naiqi Wu; Ping S (2005) Selection of partners in virtual enterprise paradigm, Robotics and Computer-Integrated Manufacturing 21 119–131
[14] Camarinha-Matos LM; Cardoso T. (1999) Selection of partners for a virtual enterprise . Pro-VE'99 book, infrastructure for virtual enterprises: networking industrial enterprises. Boston Dordrecht London:Kluwer Academic Publishers;. p. 259–78.
[15] Kumanan, S., and BobinCherian Jos. Selection of partners in virtual enterprise using sheepflocks heredityalgorithm.SCMIS 2008.
[16] Maloni MJ; Benton WC(1997). Supply chain partnership: opportunities for operations research. European Journal of Operation Research;101:419–29.
[17] Brucker P; et al. (1999) Resource-constrained project scheduling: notation, classification, models, and methods. European Journal of Operations Research;112:3–41.
[18] Elmaghraby SE. (1977) .Activity networks-project planning and control by network models. New York: Wiley;
[19] Wang D; Yung KL; Ip WH. (1998) A heuristic genetic algorithm for subcontractor selection in a global manufacturing environment. IEEE Trans Syst Man Cybern C 2001;31(2):189
[20] Burak Sari; TayyarSen& S. EnginKilic (2007) Ahp model for the selection of partner companies in virtual enterprises,International Journal of Advanced Manufacturing Technology DOI 10.1007/s00170-2007-1097-6
[21] Narasimahn R. An analytical approach to supplier selection. Journal of Purchasing and Materials Management 1983;19: 27–32.
[22] Nydick R; Hill R.(1992) Using the AHP to structure the supplier selection procedure. Journal of Purchasing and Materials Management ;25(2):31–6.
[23] Partovi F; Burton J; Banerjee A. (1989) Application of the AHP in operations management. International Journal of Operations and Production Management ;10:5–19.
[24] Tam M; RaoTummala VM.(2001) An application of the AHP in vendor selection of a telecommunications system. Omega 2001;29:171–82.
[25] WANG Ying; LIU (2007) Yan-ping Research on the Evaluation and Selection of Partner in Logistics Strategic Alliance Based on AHP-TOPSIS International Conference on Management Science & Engineering (14th) August 20-22, 2007 Harbin, P.R.China
[26] Min Wu (2007)Topsis-AHP simulation model and its application to supply chain management. World Journal of Modelling and Simulation Vol. 3 No. 3, pp. 196-201
[27] Hsu-Shih Shiha; Huan-JyhShyurb, (2007),An extension of TOPSIS for group decision making. Mathematical and Computer Modelling 45 801–813
[28] Jos, BobinCherian, Sunil Natesan, and Bos Mathew Jos. "ANP Model for the Raw Material Procurement in a Paper and Wood Industry-A BOCR Analysis."Automation and Autonomous System 2.8 (2010): 60-66.
[29] Tien-Chin Wang; Tsung-Han Chang (2007) , Application of TOPSIS in evaluating initial training aircraft under a fuzzy environment; Expert Systems with Applications 33 870–880
[30] R. VenkataRao, (2006) Machinability evaluation of work materials using a combined multiple attribute decision-making method ,International Journal of Advanced Manufactruing Technology 28: 221–227
[31] Saaty TL (1980) Analytic hierarchy process. McGraw-Hill, New York
[32] Hwang CL; Yoon K (1982) Multiple attribute decision-making –methods and applications – a state of art survey. Springer, Berlin Heidelberg New York
[33] Jos, BobinCherian, and S. Kumanan. "Selection of partner companies in extended enterprise using fuzzy AHP." International Journal of Services, Economics and Management 2.3-4 (2010): 322-331.
[34] Jos, BobinCherian, Sunil Natesan, and Bos Mathew Jos. "A Decision Support Model for the Raw Material Procurement in a Paper and Wood Industry." IISM-2010 (2010).
[35] John, Anu, Aby K. Abraham, and Jacob Kurian. "AHP Approach for Vendor Evaluation and Selection in a FMCG Company."