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Full Length Research Paper

Application of multi criteria decision making technique to evaluation suppliers in supply chain management

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Supplier selection, the process of determining the suitable suppliers who are able to provide the buyer with the right quality products and/or services at the right price, at the right time and in the right quantities, is one of the most critical activities for establishing an effective supply chain. In other words, supplier selection is a multi-criteria decision making problem which includes both qualitative and quantitative factors. In order to choose the best suppliers, it is essential to make a trade-off between these tangible and intangible factors, some of which may conflict. The aim of this study is developing a methodology to evaluate suppliers in supply chain cycle based on Technique for Order Preference by Similarity to Ideal Solution method (TOPSIS). The authors, with the help of going over expertise of experts and their relevant specialized literature, could recognize variables and effective criteria in supplier selection. After, the weights for a number of criteria are calculated based on the opinions of experts; these weights are inputted to the TOPSIS method to rank suppliers. Finally, this methodology is done by a numerical example, then, the rank of each supplier is determined according to its results.

Key words: Supplier selection problem, technique for order preference by similarity to ideal solution method (TOPSIS Method), supplier management, multi criteria decision making, outsourcing, supply chain management.

INTRODUCTION

Increases and varieties of customer demands, advances of recent technologies in communication and information systems, competition in global environment, decreases in governmental regulations, and increases in environmental consciousness have forced companies to focus on supply chain management (Tracey and Tan, 2001). The "supply chain management" term has been used for almost 20 years and is defined as the integration of activities to procure materials, transforms them into intermediate goods and final products, and delivers to customers (Heizer and Render, 2001). In supply chains, coordination between a manufacturer and suppliers is typically a difficult and important link in the channel of distribution. Once a supplier becomes part of a well-managed and established supply chain, this relationship will have a lasting effect on the competitiveness of the entire supply chain. Because of this, supplier selection problem has become one of the most important issues for establishing an effective supply chain system. Besides, selection of suppliers is a complicated process by the facts that numerous criteria must be considered in the decision making process (Tarofder and Haque, 2007). Research results indicated that supplier selection process is one of the most significant variables, which has a direct impact on the performance of an organization (Ho et al., 2010). As the organization becomes more and more dependent on their suppliers, the direct and indirect consequences of poor decision making will become more critical. The nature of this decision is usually complex and

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unstructured. On the other hand, supplier selection decision-making problem involves trade-offs among multiple criteria that involve both quantitative and qualitative factors, which may also be conflicting (Ghodsypour and O'Brien, 1998).

In this article, with the help of going over expertise of experts and their relevant specialized literature, we can recognize variables and effective criteria in supplier selection, with regards to this point that, considering all criteria for supplier selection is impossible, the main and important criteria have been extracted by expert judgment. Thereafter, we will evaluate and determine weight of each supplier and finally, by implementing TOPSIS method, the rank of each supplier is determined. The main advantages of using TOPSIS Methods are "simple to use"; "take into account all types of criteria (subjective and objective)"; "TOPSIS logic is rational and understandable"; "The computation processes are straightforward"; "The concept permits the pursuit of best alternatives criterion depicted in a simple mathematical"; and "The importance weights are incorporated comparison procedures" (Wang, 2008).

Literature review

The objective of supplier selection is to identify suppliers with the highest potential for meeting a firm's needs consistently. Weber et al. (1991) assessed 74 supplier selection papers from 1966 to 1991, and illustrated that nearly 63% of them were in a multi-criteria decision making situation. In the past, several methodologies have been proposed for supplier selection problem. Weber and Ellram (1993) developed the use of a multi-objective programming approach as a method for supplier selection in just in time (JIT) setting. Weber and Current (1993) used multi-objective linear programming for supplier selection to systematically analyze the trade-off between conflicting criteria. In this model, aggregate price, quality and late delivery are considered as goals. Ghodsypour and O'Brien (1998) proposed integration of an AHP and linear programming to consider both tangible and intangible factors in choosing the best suppliers and placing optimum order quantities among them. They also (Ghodsypour and O'Brien, 2001) presented a mixed integer non-linear programming model to solve the multiple sourcing problem, with multiple criteria and with supplier's capacity. Chaudhry et al. (1991) have used integer goal programming to solve the problem of allocating order quantities among suppliers. Karpak and Kasuganti (1999) have used visual interactive goal programming for supplier selection process. Liu et al. (2000) used data envelopment analysis (DEA) to compare the performance evaluation of different supplier for best selection. Kumar et al. (2002) have used fuzzy mixed integer goal programming for supplier selection problem. Wang et al. (2004) used the advantages of AHP and preemptive goal programming to incorporate both quantitative and qualitative factor in supplier selection problem. Bhutta and Huq (2002) have illustrated and compared the technique of total cost of ownership and AHP in supplier selection process. Chan et al. (2007) applied an AHP to determine the optimal supplier. His model evaluated the suppliers based on 14 criteria. Wadhwa and Ravindran (2007) proposed a supplier selection methodology that consists of 3 objectives, such as price, lead time and rejects. All of these objective functions are minimization. Vahdani et al. (2008) also presented a three step methodology based on balancing and ranking methods in supplier evaluation.

Hong et al. (2005) formulated a mixed integer linear programming model for the suppliers' assessment. The model provides jointly, 'optimal order quantity' and 'optimal number of suppliers'. Narasimhan et al (2006) developed a multi objective programming model to indicate the best supplier and the optimal order quantity. Mendoza and Venture (2008) utilized a two step method to solve supplier selection problem. At the first step, AHP was used to rank and decrease number of supplier. At the second step, the mix integer non linear programming model was applied to determine the optimal order quantity. Ng (2008) presented a weighted linear programming model for supplier evaluation. His proposed model is based on maximizing the suppliers' score.

Chang (1996) introduced a new extent analysis approach for the synthetic extent values of the pair wise comparison for handling fuzzy AHP (FAHP). The proposed FAHP with extent analysis is simple and easy for implementation to prioritize decision variables as compared with the conventional AHP (Kwong and Bai, 2003). Chen (2001) presented a multiple-criteria decision-making model based on fuzzy-set theory for supplier selection. Kahraman et al. (2003) used the fuzzy AHP for domestic supplier selection with only 3 criteria and 11 attributes and neglected the many important criteria which create the uncertainty in supplying the products, that is, the risk factors involved in global supplier selection. Chiou et al. (2005) used a fuzzy hierarchical analytic process to determine the weights of criteria from subjective judgments and a non-additive integral technique to evaluate the performance of sustainable development strategies for aquatic products processors. Beside these approaches, Amiri et al. (2008) presented a multivariate approach for solving supplier selection problem. His approach is based on principal component analysis that used information obtained from Eigenvector to combine different ratio measures defined by every input and output.

SUPPLIER SELECTION CRITERIA

Supplier selection is a multi-criteria decision making problem which includes both qualitative and quantitative criteria. In order to select the best suppliers, it is necessary to make a trade-off between these tangible and intangible factors, some of which may conflict. Dickson (1966) presented 23 supplier selection criteria that were taken into consideration during the decision making process in his study. Later, Wind and Robinson (1968) reported that most supplier selection decisions involved multiple criteria and since then, several articles have been published for supplier selection (Weber et al., 2000). Weber et al. (1991, 2000) reviewed and classified various articles related to supplier selection and discussed the impact of just-in-time (JIT) manufacturing strategy on supplier selection. They used Dickson's 23 criteria and indicated that net price, delivery, and quality were discussed in 80, 59, and 54% of the 74 articles, respectively. Different companies have different specific requirements concerning supplier evaluation. Stamm and Golhar (1993), and Ellram (1990) identified 13 and 18 criteria for supplier selection respectively. Price, quality, lead-time, technical service and delivery reliability are the five primary criteria used in the supplier selection problem. Mummalaneni et al. (1996) have identified six attributes on time delivery, quality, price/cost targets, profess-sionalism, responsiveness to customer needs, and long term relationship with the purchasing company as the performance criteria of suppliers for Chinese purchasing managers. Verma and Pullman (1998) studied the perceived importance of supplier selection criteria and identified the relative weights of the attributes in actual selection of suppliers. Ho et al. (2010) repre-sented many criteria that is the most popular in supplier evaluation. Based on his research, it was revealed that price/cost is not the most widely adopted criterion. The traditional single criterion approach based on lowest cost bidding is no longer supportive and robust enough in contemporary supply management. A firm uses supplier criteria to evaluate whether the supplier fits its supply and technology strategy. These considerations are largely independent of the product or service sought. For instance, in the automotive industry, functions of supplier logistics performance measurement include strategy formulation and clarification, management information, communication, motivation of suppliers, coordination and alignment, decision making and priority, and learning (Schmitz and Platts, 2004). Due to this, each firm/industry should extract specific criteria to assess their suppliers. Studying related articles to supplier selection and also using expertise of experts, we have recognized key and crucial criteria for supplier selection. Recognized criteria are as follows: Six sigma program; support ability; management knowledge; urgent delivery; net rejection; remedy for quality problem; compliance with international standards; technical and R&D support; supplier's expertise; Interoperability with other systems; process time; fault diagnosis capabilities; conformance quality; testability; on time delivery; ordering cost; cost of support service; warranty period; product availability; production capacity; verify satisfaction; maintainability; geographical location; political stability; handling; packaging; guarantee period; performance monitoring capability; product price; responsiveness to customer needs; cost of network management system; past performance; financial stability; average time needed for solving problem; quality of support services; delivery lead time; future technology development; accessibility; financial status; length of time in business; capital investment; operation cost; management attitude; quality assess-ment; reliability; system redundancy; transportation cost; taxes; flexibility; repair turnaround; duration of relation-ship with supplier; compatibility; manufacturability; accountability health; accountability safety; supplier's experience in related products; supplier's reputation; technical level; economic situation; quality of relationship; management organization; rejection of defective product; fault diagnosis in processing; system performance; technical ability.

In order to take a suitable and accurate decision that satisfies organization's requirements, paying attention to afore mentioned criteria is crucial and vital.

MATERIAL AND METHODS

TOPSIS method was introduced for the first time by Yoon and Hwang and was appraised by surveyors and different operators (Benitez et al., 2007) In this method, options are graded based on ideal solution similarity. If an option is more similar to an ideal solution, it has a higher grade (Wang, 2008). Ideal solution is a solution that is the best from any aspect that does not exist practically and we try to approximate it. Basically, for measuring similarity of a design (or option) to ideal level and non- ideal, we consider distance of that design from ideal and non-ideal solution.

General TOPSIS process with six steps is listed below (Wang and Elhag, 2006):

Step 1) Establish a decision matrix for the ranking. The structure of the matrix can be expressed as follows:

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{cccc} F_1 & F_2 & \cdots & F_n \end{array} \\ \begin{bmatrix} f_{11} & f_{12} & \cdots & f_{1n} \\ f_{21} & f_{22} & \cdots & f_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ f_{m1} & f_{m2} & \cdots & f_{mn} \end{bmatrix} \end{array} \quad (1)$$

Where Ai denotes the alternatives i, i = 1, . . . ,m; Fj represents jth attribute or criterion, j = 1, . . . , n, related to ith alternative; fij is a crisp value indicating the performance rating of each lternative Ai with respect to each criterion Fj .

Step 2) Calculate the normalized decision matrix R(=[rij

]). The normalized value rij is calculated as:

$$r_{ij} = \frac{f_{ij}}{\sqrt{\sum_{j=1}^{n} f_{ij}^2}} \quad i = 1,...,n;\ j = 1,...,m \qquad (2)$$

Step 3) Calculate the weighted normalized decision matrix by multiplying the normalized decision matrix by its associated weights. The weighted normalized value vi j is calculated as:

$$v_{ij} = w_{ij} r_{ij}, \quad j = 1,...,n;\ i = 1,...,m \qquad (3)$$

Where wj represents the weight of the jth attribute or criterion.

Step 4) Determine the PIS and NIS, respectively:

$$V^{+} = \{v_1^{+}, ..., v_n^{+}\} = \{(Max\, v_{ij} \mid j \in J), (Min\, v_{ij} \mid j \in J')\} \qquad (4)$$

$$V^{+} = \{v_1^{-}, ..., v_n^{-}\} = \{(Min\, v_{ij} \mid j \in J), (Max\, v_{ij} \mid j \in J')\} \qquad (5)$$

Where J is associated with the positive criteria and J` is associated with the negative criteria.

Step 5) Calculate the separation measures, using the m-dimensional Euclidean distance. The separation measure D_i^{+} of each alternative from the PIS is given as:

$$D_i^{+} = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^{+}\right)^2}\ ,\ i = 1, ..., m \qquad (6)$$

Similarly, the separation measure D_i^{-} of each alternative from the NIS is as follows:

$$D_i^{-} = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^{-}\right)^2}\ ,\ i = 1, ..., m \qquad (7)$$

Step 6) Calculate the relative closeness to the idea solution and rank the alternatives in descending order.
The relative closeness of the alternative Ai with respect to

PIS V+ can be expressed as:

$$\overline{C}_i = \frac{D_i^{-}}{D_i^{+} + D_i^{-}} \qquad (8)$$

where the index value of $\overline{C}_i$ lies between 0 and 1. The larger the index value, the better the performance of the alternatives. In this paper, TOPSIS method is used for determining the final ranking of the cement firms.

Proposed methodology

The proposed methodology for supplier selection problem, composed of TOPSIS method, consists of three Steps: (1) Identify the criteria to be used in the model; (2) weigh the criteria by using expert views; (3) evaluation of alternatives with TOPSIS and determination of the final rank.

In the first Step, with the help of going over expertise of experts and their relevant specialized literature, we try to recognize variables and effective criteria in supplier selection and the criteria which will be used in their evaluation is extracted. Thereafter, list of qualified suppliers are determined and. In the last stage of the first step, the decision criteria are approved by decision-making team. After the approval of decision criteria, we assigned weights on them by organizing experts' sessions in the second step. In the last stage of this step, calculated weights of the criteria are approved by decision making team. Finally, ranks are determined, using TOPSIS method in the third step. Schematic diagram of the proposed model for weapon selection is provided in Figure 1.

NUMERICAL EXAMPLE AND RESULTS

In this section, to implement the methodology, the authors have solved simulated numerical example. Assume that the management of a manufacture wants to choose their best suppliers. Based on proposed methodology, 3 steps are applied for assessment and selection of suppliers. In this part we deal with application of these steps.

After forming decision making team, step 1 starts developing an updated pool of supplier selection criteria for the given industry, using those accepted criteria given in the literature, as well as those criteria recommended by the experts. In this numerical example, the criteria are selected as shown in Table 1. Although, the criteria considered in supplier evaluation are condition-industry-specific, and each firm will build up its own selection criteria when facing with defining suitable suppliers. The authors are utilizing these criteria in the accomplishment of our methodology; however, a decision maker can simply modify the criteria to fit his/her state.

Selection of criteria is totally industry specific and based on each case and the criteria are changed and replaced. Opinions of decision makers on criteria were aggregated and weights of all criteria have been calculated by organizing the expert meeting. Its results have

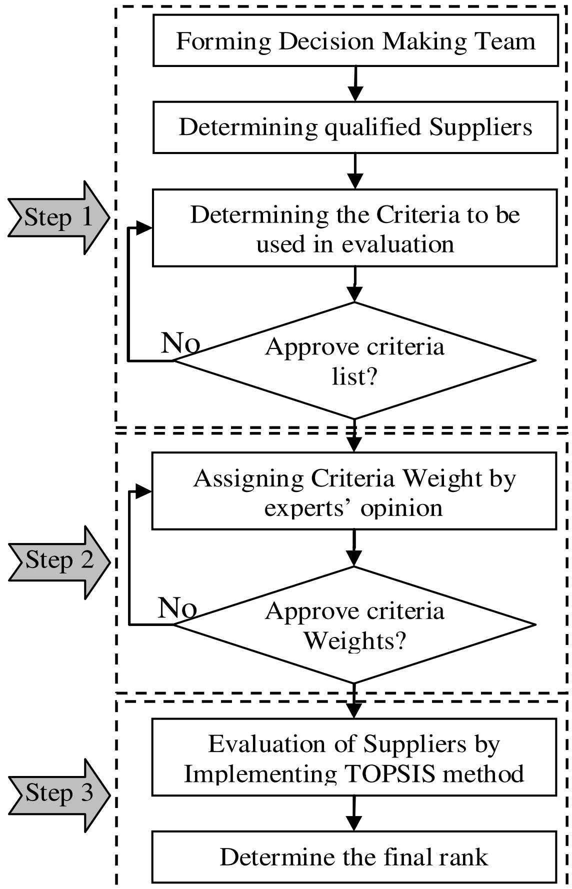

Figure 1. Schematic diagram of the proposed methodology.

Table 1. Selected criteria for supplier evaluation.

Abbreviation	Criteria
UD	Urgent delivery
OD	On time delivery
OC	Ordering cost
WP	Warranty period
PP	Product price
FS	Financial stability
DL	Delivery lead time
AC	Accessibility
RI	Reliability
TC	Transportation cost
RD	Rejection of defective product
CS	Cost of support service
TS	Testability

been mentioned in Table 2.

Assuming 5 suppliers are included in the evaluation process, information of each of suppliers has been mentioned in Table 3. After normalizing information and considering weight of criteria in them, negative and positive separation measures, based on normalized Euclidean distance for each alternative were calculated and then final weight of each supplier is calculated.

Table 2. Weight of criteria.

Criteria	Weight (%)
Urgent delivery (UD)	0.04
On time delivery (OD)	0.09
Ordering cost (OC)	0.06
Warranty period (WP)	0.07
Product price (PP)	0.16
Financial stability (FS)	0.04
Delivery lead time (DL)	0.11
Accessibility (AC)	0.04
Reliability (RL)	0.11
Transportation cost (TC)	0.07
Rejection of defective product (RD)	0.09
Cost of support service (CS)	0.05
Testability (TS)	0.07

Table 3. Supplier's information.

Criteria	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5
UD (Yes/No)	No	Yes	Yes	No	No
OD (%)	88	82	92	80	95
OC ($)	35	42	40	10	35
WP (Month)	12	10	12	12	10
PP ($)	850	820	800	820	840
FS (Grad)	3	2	4	3	4
DL (Day)	15	12	10	15	14
AC (Rate)	98	95	95	95	96
RL (%)	92	90	90	92	95
TC ($)	50	45	40	40	45
RD (%)	0.01	0.02	0.01	0.01	0.03
CS ($)	50	45	0	20	20
TS (%)	50	60	50	55	50

Table 4. Separation measures and the relative closeness coefficient.

Suppliers	D_i^+	D_i^-	$\overline{C}_i$	Rank
Supplier 1	0.0028	0.0021	0.4286	3
Supplier 2	0.0023	0.0015	0.3896	4
Supplier 3	0.0006	0.0046	0.8858	1
Supplier 4	0.0014	0.0032	0.6926	2
Supplier 5	0.0037	0.0007	0.1499	5

Thereafter, the relative closeness coefficients were determined, and five alternatives were ranked. Obtained results have been mentioned in Table 4. As it is seen, supplier 3 has the biggest weight amongst 5 suppliers and can gain the best score among all projects

Conclusion

In supply chains, coordination between a manufacturer and suppliers is typically a difficult and important link in the channel of distribution. This study presents a multi-criteria decision making for evaluation of supplier by implementing TOPSIS method. The main advantages of using TOPSIS method are “TOPSIS logic is rational and understandable”, “The computation processes are straightforward”, “The concept permits the pursuit of best alternatives criterion depicted in a simple mathematical” and “The importance weights are incorporated comparison procedures”.

Due to this, decision making for selection of suitable supplier is of special importance. Acquired results from numerical example determine that this model could be used for decision making optimization in supplier selection.

REFERENCES

Amiri M, Hadadi B, Amirkhani AH, Izadbakhsh H (2008). Supplier selection via principal component analysis: an empirical examination. J. Applied Sci., 8(20): 3715-3720.DOI: 10.3923/jas.2008.3715.3720

Benitez JM, Martin JC, Roman C (2007). Using fuzzy number for measuring quality of service in the hotel industry. Tourism Manag., 28: 544-555.

Bhutta KS, Huq F (2002). Supplier selection problem: A comparison of the total cost of ownership and analytical hierarchy process. Supply Chain Manage., 7: 126-135.

Chan FTS, Kumar N (2007). Global supplier development considering risk factors using fuzzy extended AHP-based approach. OMEGA – Int. J. Manag. Sci., 35: 417-431.

Chang DY (1996) . Applications of the extent analysis method on fuzzy AHP. Eur. J. Operat. Res., 95: 649-55. http://ideas.repec.org/a/eee/ejores/v95y1996i3p649-655.html.

Chaudhry SS, Forst FG, Zydiak JL (1991). Multi criteria approach to allocating order quantities among suppliers. Prod. Invent. Manag. J., 3: 82-5.

Chen CT (2001). Supplier selection method for supply chain system. Proceedings of 16th International Conference on Production Research : ICPR – 16, July 29-Aug. 3, Prague, Czech Republic, pp:75-89.

Chiou HK, Tzeng GH, Cheng DC (2005). Evaluating sustainable fishing development strategies

Dickson GW (1966). An analysis of vendor selection systems and decisions. J. Purch.,2 5-17. DOI:10.1002/(SICI)1099-1360(199903)8:2<93::AID MCDA235>3.0.CO;2-#

Ellram LM (1990). The supplier selection decision in strategic partnerships. J. Purch. Mater. Manag., 26, 8-14. http://www.accessmylibrary.com/article-1G1-9117162/supplier-selection-decision-strategic.html

Ghodsypour SH, O’Brien C (1998). A decision support system for supplier selection using an integrated analytic hierarchy process and linear programming. Int. J. Prod. Econ., 56-57: 199-212. http://ideas.repec.org/a/eee/proeco/v56-57y1998i1p199-212.html.

Ghodsypour SH, O’Brien C. (2001). The total cost of logistics in supplier selection, under conditions of multiple sourcing, multiple criteria and capacity constraints. Int. J. Prod. Econ., 73: 15-27.

Heizer J, Render B (2001). Operations Management. 6th Edn., Prentice-Hall, Englewood Cliffs, NJ.

Hong GH, Park SC, Jang DS, Rho HM (2005). An effective supplier selection method for constructing a competitive supply relationship. Expert Syst. Appl., 28: 629-639.

Ho W, Xu X, Dey KP (2010). Multi criteria decision making approaches for supplier evaluation and selection: A literature review. Eur. J. Oper. Res., doi: 10.1016/j.ejor.2009.05.00

Kahraman C, Cebeci U, Ulukan Z (2003). Multi criteria supplier selection using fuzzy AHP. Logistics Inform. Manage., 16: 382-94.

Karpak K, Kasuganti RR (1999). An application of visual interactive goal programming: A case in supplier selection decisions. J. Multi Criterion Decis. Making, 8: 93-105.

Kumar M, Vrat P, Shankar R (2002). A multi-objective interval programming approach for supplier selection problem in a supply chain. Proceedings of International Conference on Manufacturing: An Emerging Need for 21st Century World Class Enterprises, Nov. 17-19.

Kwong CK, Bai H (2003). Determining the importance weights for the customer requirements in QFD using a fuzzy AHP with an extent analysis approach. IIE Trans., 35: 619-26. Doi:10.1080/07408170304355

Liu J, Ding FY, Lall V (2000). Using data envelopment analysis to compare suppliers for supplier selection and performance improvement. Supply Chain Manag. Int. J., 5: 143-150.doi: 10.1108/13598540010338893 .

Mendoza A, Ventura JA (2008). An effective method to supplier selection and order quantity allocation. Int. J. Bus. Syst. Res., 2: 1-15. doi: 10.1504/IJBSR.2008.018117.

Mummalaneni V, Dubas KM, Chao C (1996). Chinese purchasing managers preferences and tradeoffs in supplier selection and performance evaluation. Ind. Mark. Manag., 25: 115-124. doi: 10.1016/0019-8501(95)00070-4

Narasimhan R, Talluri S. Mahapatra SK (2006). Multi product, multi criteria model for supplier selection with product life-cycle considerations. Decis. Sci., 37: 577-603. http://www.allbusiness.com/management/benchmarking/4110577-1.html

Ng WL (2008). An efficient and simple model for multiple criteria supplier selection problem. Eur. J. Operat. Res., 186: 1059-1067.

Schmitz, J, Platts KW (2004). Supplier logistics performance measurement: Indication from a study in the automotive industry. Int. J. Prod. Econ., 89: 231-243.

Stamm CL, Golhar DY (1993). JIT purchasing: Attribute classification and literature review. Prod. Plan. Control, 4: 273-82. Doi: 10.1080/09537289308919445.

Tarofder AK, Haque A (2007). Exploring critical factors for supplier selection in telecommunication industry in Malaysia. Asian J. Mark., 1: 1-13.

Tracey M, Tan CL (2001). Empirical analysis of supplier selection and involvement, customer satisfaction, and firm performance. Supply Chain Manage. Int. J., 6 : 174-88. using fuzzy MCDM approach. Omega Int. J. Manag. Sci., 33: 223-34.

Vahdani B, Zandieh M, Alem-Tabriz A (2008). Supplier selection by balancing and ranking method. J. Applied Sci., 8: 3467-3472.

Verma R, Pullman ME (1998). An analysis of the supplier selection Process.omega, Int J. Manag. Sci., 26: 739-50.doi;10.1016/S0305 0483(98)00023-1.

Wadhwa V, Ravindran AR (2007). Vendor selection in outsourcing. Comput. Operat. Res., 34: 3725-3737. doi: 10.1016/j.cor.2006.01.009

Wang G, Samuel HH, Dismukes JP (2004). Product-driven supply chain selection using integrated multi-criteria decision-making methodology. Int. J. Prod. Econ., 91: 1-15. doi: 10.1016/S0925-5273(03)00221-4

Wang YJ (2008). Applying FMCDM to evaluate financial performance of domestic airlines in Taiwan. Expert Syst. Appl., 34: 1837–1845.

Wang YM, Elhag TMS (2006). Fuzzy TOPSIS method based on alpha level sets with an application to bridge risk assessment. Expert Syst. Appl., 31: 309-319.

Weber CA, Current JR (1993). A multi objective approach to supplier selection. Eur. J. Operat. Res., 68, 173-184.doi: 10.1016/0377-2217(93)90301-3

Weber CA, Ellram LM (1993). Supplier selection using multi objective programming: A decision support system approach. Int. J. Phys. Distrib. Logistics Manag., 23: 3-14.

Weber CA, Current J, Desai A (2000). An optimization approach to determining the number of vendors to employ. Supply Chain Manage. Int. J., 5: 90-98. DOI: 10.1108/13598540010320009.

Weber CA, Current JR, Benton WC (1991). Vendor selection criteria and methods. Eur. J. Operat. Res., 50: 2-18. DOI: 10.1016/0377-2217(91)90033-R

Wind Y, Robinson PJ (1968). The determinants of vendor selection: The evaluation function approach. J. Purch. Mater. Manag., 29-41.