GRBER Global Review of Business and Economic Research
Vol. 10 • No. 2 • Autumn 2014 : 153-162

SUPPLIER PERFORMANCE EVALUATION BY USING FUZZY TOPSIS METHODOLOGY

Murat Taha Bilişik, Özge Nalan Bilişik

Abstract: *In supply chains suppliers have important role and for this reason suppliers' performance evaluation and supplier selection are critical decisions for companies. Fuzzy TOPSIS allows to take in to account multiple criteria and linguistic expressions of decision makers. In this study, fuzzy TOPSIS (fuzzy technique for order preference by similarity to ideal solution) technique is applied to evaluate supplier performance. This study helps companies to implement strategies, realize their weaknesses and increase their own and suppliers' benefit and productivity.*

Keywords: *Supplier Performance Evaluation, Supply Chain Management, Fuzzy TOPSIS*

1. INTRODUCTION

Supply chain management (SCM) is denned as the set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and stores, so that merchandize is produced in the right quantities, distributed to the right locations, and at the right time, in order to minimize system-wide costs (or maximize profits) while satisfying service level requirements [1]. For this reason, the firms that provides supply chain support service processes is called as supplier, has an important role in the supply chain management. In addition, selection and evaluation of suppliers are the critical decision problems for efficient supply chain management.

Supplier selection is sometimes highly complex, since it incorporates a great variety of uncontrollable and unpredictable factors that affect the decisions involved. This should prompt careful attention to the way in which such decisions are reached and justified, and would consequently suggest (among other things) the use of decisional models to support procurement decision making. Moreover, supplier assessments or ratings should be done routinely to ensure that incoming materials meet relevant quality standards [2].

* Department of Business Administration, Istanbul Kultur University, E5 Freeway Bakýrkoy, Istanbul, 34256, Turkey, *E-mail:m.bilisik@iku.edu.tr*

** Department of Industrial Engineering, Yildiz Technical University, Yildiz Besiktas, Istanbul, 34349, Turkey, *E-mail: oznalan@yildiz.edu.tr*

In this paper, a new methodology is proposed to evaluate suppliers' performances and to select and classify the most appropriate suppliers to get service and fuzzy TOPSIS method is applied to validate the results of proposed methodology. The structure of this paper is as follows: In section 2, the literature review is shown. In section 3, fuzzy TOPSIS steps are given. In section 4, the application is performed. In the last section the conclusions and discussions are presented.

2. LITERATURE REVIEW

There are many studies in literature about supplier evaluation and selection. Some of these studies are summarized here. Lee *et al.* (2009) evaluate green suppliers by using the Delphi method to differentiate the criteria for evaluating traditional suppliers and green suppliers and fuzzy extended analytic hierarchy process [3]. Yücel and Güneri (2010) study supplier selection problem and they propose a model based neural network and Adaptive Neuro Fuzzy Inference System (ANFIS) based model [4]. Zeydan *et al.* (2011) propose a new methodology that increases the supplier selection and evaluation quality by using fuzzy AHP (Analytical Hierarchical Process) to find criteria weights and fuzzy TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) to rank suppliers. Secondly, Qualitative variables are transformed into a quantitative variable for using in DEA (Data Envelopment Analysis) methodology [5]. Chen *et al.* (2006) aim to present a hierarchical multiple criteria decision-making (MCDM) model based on fuzzy-sets theory to deal with the supplier selection problems in the supply chain system [6]. Vahdani *et al.* (2012) present an effective artificial intelligence (AI) approach called locally linear neuro-fuzzy (LLNF) to predict the performance rating of suppliers and the proposed model is trained by a locally linear model tree (LOLIMOT) learning algorithm [7]. Xiao *et al.* (2012) integrate the fuzzy cognitive map (FCM) and fuzzy soft set model for solving the supplier selection problem. This method considers both the dependent and feedback effect among criteria and the uncertainties on decision making process [8]. Çelebi and Bayraktar (2008) aim to explore a novel integration of neural networks (NN) and data envelopment analysis for evaluation of suppliers under incomplete information of evaluation criteria [9]. Erdem and Göçen (2012) develop models and generate a decision support system (DSS) for the improvement of supplier evaluation and order allocation decisions in a supply chain [10]. Chang *et al.* (2011) use the fuzzy decision-making trial and evaluation laboratory (DEMATEL) method to find influential factors in selecting SCM suppliers [11]. Chen (2011) propose a structured methodology for supplier selection and evaluation based on the supply chain integration architecture. Firstly, the enterprise competitive strategy is identified using strengths weaknesses opportunities threats (SWOT) analysis. Secondly, the criteria and indicators of supplier selection are chosen to establish the supplier selection framework according to the strategy. Thirdly, potential suppliers are screened through DEA. Potential suppliers are ranked by TOPSIS methodology Finally, the Taiwanese textile industry is used to illustrate the application and feasibility of the proposed methodology [12]. Keskin *et al.* (2010) propose a new tool for supplier selection. Fuzzy Adaptive Resonance Theory (ART)'s classification ability to the supplier evaluation and selection area is used. The proposed selection method is selecting the most appropriate suppliers and clusters the vendors according to chosen criteria [13]. Bruno *et al.* (2012) aim to contribute to understand the dichotomy between theoretical approaches and empirical applications by implementing a model for supplier evaluation based on AHP in a corporate environment [14].

3. FUZZY TOPSIS

The steps of fuzzy TOPSIS are presented as follows [15]:

Step 1. Determine the weights of evaluation criteria.

Step 2. Construct the fuzzy performance/decision matrix and choose the appropriate linguistic variables for the alternatives with respect to criteria.

$$\tilde{D} = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \\ \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{array} \quad i = 1,2,\ldots, m;\ j = 1,2,\ldots,n \tag{2}$$

$$\tilde{x}_{ij} = \frac{1}{K}(\tilde{x}_{ij}^{1} \oplus \ldots \oplus \tilde{x}_{ij}^{k} \ldots \oplus \tilde{x}_{ij}^{K})$$

where $\tilde{x}_{ij}^{k}$ is the performance rating of alternative A_i with respect to criterion C_j evaluated by kth expert and $\tilde{x}_{ij}^{k}=(l_{ij}^{k}, m_{ij}^{k}, u_{ij}^{k})$.

Step 3. Normalize the fuzzy-decision matrix. The normalized fuzzy-decision matrix denoted by $\tilde{R}$ is shown as following formula:

$$\tilde{R} = [\tilde{r}_{ij}]_{m\times n}, \quad i = 1,2,\ldots,m;\ j = 1,2,\ldots,n \tag{3}$$

Then, the normalization process can be performed by following formula:

$$\tilde{r}_{ij} = \left(\frac{l_{il}}{u_j^{+}}, \frac{m_{il}}{u_j^{+}}, \frac{u_{il}}{u_j^{+}}\right), u_j^{+} = \max_i \{u_{ij} \mid i = 1,2,\ldots,n\}$$

or we can set the best aspired level u_i^{+} and j = 1,2,. . . ,n is equal one; otherwise, the worst is zero.

The normalized $\tilde{r}_{ij}$ is still triangular fuzzy numbers. For trapezoidal fuzzy numbers, the normalization process can be conducted in the same way. The weighted fuzzy normalized decision matrix is shown as following matrix $\tilde{V}$:

$$\tilde{V}=\left[\tilde{v}_{ij}\right]_{nxn}, i=1,2,\ldots,m;\ j=1,2,\ldots,n \tag{4}$$

Where $\tilde{v}_{ij}=\tilde{r}_{ij}\otimes\tilde{w}_j$

Step 4. Determine the fuzzy positive-ideal solution (FPIS) and fuzzy negative-ideal solution (FNIS). According to the weighted normalized fuzzy-decision matrix, we know that the elements $\tilde{v}_{ij}$ are normalized positive TFN and their ranges belong to the closed interval [0, 1]. Then, we can define the FPIS A^+ (aspiration levels) and FNIS A^- (the worst levels) as following formula:

$$A^+=(\tilde{v}_1^*,\ldots,\tilde{v}_j^*,\ldots,\tilde{v}_n^*) \tag{5}$$

$$A^-=(\tilde{v}_1^-,\ldots,\tilde{v}_j^-,\ldots,\tilde{v}_n^-) \tag{6}$$

where $\tilde{v}_j^*=(1,1,1)\otimes\tilde{w}_j=(lw_j,mw_j,uw_j)$ and $\tilde{v}=(0,0,0)$, $j = 1,2,\ldots,n$.

Step 5. Calculate the distance of each alternative from FPIS and FNIS. The distances $\tilde{d}_i^+$ and $\tilde{d}_i^-$ of each alternative from A^+ and A^- can be currently calculated by the area compensation method

$$\tilde{d}_i^+=\sum_{j=1}^{n} d(\tilde{v}_{ij},\tilde{v}_j^*), i=1,2,\ldots,m;\ j=1,2,\ldots,n \tag{7}$$

$$\tilde{d}_i^-=\sum_{j=1}^{n} d(\tilde{v}_{ij},\tilde{v}_j^-), i=1,2,\ldots,m;\ j=1,2,\ldots,n \tag{8}$$

Step 6. Obtain the closeness coefficients (relative gaps-degree) and improve alternatives for achieving aspiration levels in each criterion. Therefore, we propose the CC_i is defined to determine the fuzzy gaps-degree based on fuzzy closeness coefficients for improving alternatives; once the $\tilde{d}_i^+$ and $\tilde{d}_i^-$ of each alternative have been calculated. Calculate similarities to ideal solution. This step solves the similarities to an ideal solution by formula:

$$\tilde{CC}=\frac{\tilde{d}_i^-}{\tilde{d}_i^+ + \tilde{d}_i^-}=1-\frac{\tilde{d}_i^+}{\tilde{d}_i^+ + \tilde{d}_i^-},\quad i=1,2,\ldots,m \tag{9}$$

4. APPLICATION

In this study, a company which gives service about survey and research subjects is investigated. The suppliers that the company is working together are giving two different services: One of the services is software support. These suppliers are constructing the required software and interfaces. Other suppliers give ground and interviewer support by making surveys in several points. In addition, they give service in entering the data from the completed surveys in several computer file types. Apart from these services, in the ground services computer aided telephone interview (CATI), online panel studies etc. are implemented and while giving these services, several techniques and technologies are used.

The evaluation criteria are as in Table 1 and evaluated by experts from logistics sector [16]. Table 1. The evaluation criteria and their descriptions

Criteria	*Definition*
To keep up with critical situations (Q1)	The responsiveness and agility when an unusual situation occurs.
Meeting the demand (Q2)	To satisfy the companies' product requirements
Meeting the cost requirements (Q3)	To find the most appropriate cost level for supplier and company
Process capability and quality (Q4)	The quality of processes and services of suppliers
Personnel capability (Q5)	The capability of suppliers' personnel when company required or asked anything
To match the lead times (Q6)	The suppliers' punctuality to deliver the service to company
To be solution-oriented (Q7)	To find solutions quickly and efficiently
Accessibility and Communicating (Q8)	To be easily accessible and have efficient communication ways.
To keep up with technological developments (Q9)	To follow new technologies to integrate with their processes

The application steps are as follows:

Step 1. The fuzzy decision matrix is constructed by using the evaluation of logistics experts for suppliers. Fuzzy decision matrix is shown in Table 5.

Step 2. In this step, we normalize the fuzzy-decision matrix by using Eq (3).

In this step, the weights of each criteria has determined by using the evaluations of experts. The average values of company are calculated. Then they are shown as fuzzy numbers.

The linguistic variables that are used in evaluating the decision criteria's importance degrees are shown in Table 2 and the linguistic variables that are used by the experts are shown in Table 3.

The fuzzy weights of each criterion are calculated as in the example that is done for determining the fuzzy value of the first criterion below:

The crisp value of the first criteria is 4,29, this value is between the crisp values 4 and 5. Then we determine the lower (l_1), medium (m_1) and upper (u_1) values of fuzzy value of criterion as follow:

$$\frac{(5-4,29)}{(5-4)}=\frac{(7-1_1)}{(7-5)}$$

The crisp and fuzzy values of each criterion for company and suppliers are shown in Table 4.

The normalized fuzzy decision matrix is shown in Table 6 and weighted normalized fuzzy decision matrix is shown in Table 7.

Table 2
The linguistic variables that are used to determine importance degrees

Linguistic values	*Fuzzy Numbers*
Very poor	(0,1,0,1,0,3)
Poor	(0,1,0,3,0,5)
Medium	(0,3,0,5,0,7)
Good	(0,5,0,7,0,9)
Very good	(0,9,0,9,1)

Table 3
The linguistic variables that are used by the experts

Linguistic values	*Fuzzy Numbers*
Very poor	(1,1,3)
Poor	(1,3,5)
Medium	(3,5,7)
Good	(5,7,9)
Very good	(7,9,9)

Table 4
The crisp value and fuzzy number of each criterion

	Supplier 1		*Supplier 2*		*Supplier 3*		*Supplier 4*		*Supplier 5*	
Criteria	*Crisp Value*	*Fuzzy Number*	*Crisp Value*	*Fuzzy Number*	*Crisp Value*	*Fuzzy Number*	*Crisp Value*	*Fuzzy Number*	*Crisp Value*	*Fuzzy Number*
Q1	2,71	(2,4,6)	3,43	(4,6,8)	2,95	(3,5,7)	2,76	(3,5,7)	3,10	(3,5,7)
Q2	3,19	(3,5,7)	3,52	(4,6,8)	3,00	(3,5,7)	3,67	(4,6,8)	3,38	(4,6,8)
Q3	3,67	(4,6,8)	3,86	(5,7,9)	3,33	(4,6,8)	3,24	(3,5,7)	3,95	(5,7,9)
Q4	3,14	(3,5,7)	3,14	(3,5,7)	3,19	(3,5,7)	2,57	(2,4,6)	3,86	(5,7,9)
Q5	2,81	(3,5,7)	3,62	(4,6,8)	3,38	(4,6,8)	2,95	(3,5,7)	3,52	(4,6,8)
Q6	2,71	(2,4,6)	3,14	(3,5,7)	2,52	(2,4,6)	2,86	(3,5,7)	3,43	(4,6,8)
Q7	3,48	(4,6,8)	3,05	(3,5,7)	2,81	(3,5,7)	3,19	(3,5,7)	3,67	(4,6,8)
Q8	3,43	(4,6,8)	2,81	(3,5,7)	3,71	(4,6,8)	3,19	(3,5,7)	3,38	(4,6,8)
Q9	3,05	(4,6,8)	3,76	(5,7,9)	2,90	(3,5,7)	3,00	(3,5,7)	3,52	(4,6,8)

Table 5
Fuzzy decision matrix

	Q1	*Q2*	*Q3*	*Q4*	*Q5*	*Q6*	*Q7*	*Q8*	*Q9*
Supplier_1	(2,4,6)	(3,5,7)	(4,6,8)	(3,5,7)	(3,5,7)	(2,4,6)	(4,6,8)	(4,6,8)	(4,6,8)
Supplier_2	(4,6,8)	(4,6,8)	(5,7,9)	(3,5,7)	(4,6,8)	(3,5,7)	(3,5,7)	(3,5,7)	(5,7,9)
Supplier_3	(3,5,7)	(3,5,7)	(4,6,8)	(3,5,7)	(4,6,8)	(2,4,6)	(3,5,7)	(4,6,8)	(3,5,7)
Supplier_4	(3,5,7)	(4,6,8)	(3,5,7)	(2,4,6)	(3,5,7)	(3,5,7)	(3,5,7)	(3,5,7)	(3,5,7)
Supplier_5	(3,5,7)	(4,6,8)	(5,7,9)	(5,7,9)	(4,6,8)	(4,6,8)	(4,6,8)	(4,6,8)	(4,6,8)

Table 6
Normalized fuzzy decision matrix

	Q1	*Q2*	*Q3*	*Q4*	*Q5*	*Q6*	*Q7*	*Q8*	*Q9*
Supplier_1	(0,3,0, 6,0,9)	(0,6,0, 9,0,4)	(0,9,0, 4,0,7)	(0,4,0, 7,1)	(0,7,1, 0,5)	(1,0,5, 0,7)	(0,5,0, 7,0,9)	(0,7,0, 9,0,4)	(0,9,0, 4,0,6)
Supplier_2	(0,5,0, 8,1,1)	(0,8,1, 1,0,5)	(1,1,0, 5,0,8)	(0,5,0, 8,1)	(0,8,1, 0,5)	(1,0,5, 0,8)	(0,5,0, 8,1)	(0,8,1, 0,4)	(1,0,4, 0,6)
Supplier_3	(0,4,0, 7,1)	(0,7,1, 0,4)	(1,0,4, 0,6)	(0,4,0, 6,0,9)	(0,6,0, 9,0,4)	(0,9,0, 4,0,6)	(0,4,0, 6,0,9)	(0,6,0, 9,0,4)	(0,9,0, 4,0,6)
Supplier_4	(0,4,0, 6,0,9)	(0,6,0, 9,0,6)	(0,9,0, 6,0,8)	(0,6,0, 8,1,1)	(0,8,1, 1,0,4)	(1,1,0, 4,0,6)	(0,4,0, 6,0,8)	(0,6,0, 8,0,2)	(0,8,0, 2,0,5)
Supplier_5	(0,4,0, 7,1)	(0,7,1, 0,5)	(1,0,5, 0,7)	(0,5,0, 7,1)	(0,7,1, 0,6)	(1,0,6, 0,8)	(0,6,0, 8,1)	(0,8,1, 0,5)	(1,0,5, 0,8)

Table 7
Weighted fuzzy normalized matrix

	Q1	*Q2*	*Q3*	*Q4*	*Q5*	*Q6*	*Q7*	*Q8*	*Q9*
Supplier_1	(0,2,0, 4,0,8)	(0,3,0, 5,0,9)	(0,2,0, 4,0,8)	(0,2,0, 4,0,7)	(0,1,0, 3,0,6)	(0,2,0, 5,0,8)	(0,2,0, 4,0,8)	(0,2,0, 5,0,8)	(0,2,0, 4,0,8)
Supplier_2	(0,3,0, 6,0,9)	(0,3,0, 6,1)	(0,2,0, 5,0,8)	(0,2,0, 4,0,7)	(0,2,0, 5,0,8)	(0,3,0, 5,0,9)	(0,2,0, 4,0,7)	(0,1,0, 4,0,7)	(0,2,0, 5,0,8)
Supplier_3	(0,2,0, 5,0,8)	(0,2,0, 5,0,8)	(0,2,0, 4,0,7)	(0,2,0, 4,0,7)	(0,2,0, 4,0,8)	(0,2,0, 4,0,7)	(0,1,0, 3,0,7)	(0,2,0, 5,0,9)	(0,1,0, 3,0,7)
Supplier_4	(0,2,0, 4,0,8)	(0,3, 0,6,1)	(0,2,0, 4,0,7)	(0,1,0, 3,0,6)	(0,1,0, 4,0,7)	(0,3,0, 5,0,8)	(0,2,0, 4,0,7)	(0,2,0, 4,0,8)	(0,1,0, 4,0,7)
Supplier_5	(0,2,0, 5,0,8)	(0,3,0, 6,0,9)	(0,2,0, 5,0,8)	(0,2,0, 5,0,9)	(0,2,0, 4,0,8)	(0,4,0, 6,1)	(0,2,0, 5,0,8)	(0,2,0, 5,0,8)	(0,2,0, 4,0,8)

Step 3. The fuzzy positive-ideal solution (FPIS) and fuzzy negative-ideal solution (FNIS) are determined by using Eq (5) and (6) and they are shown in Table 8.

Step 4. Calculate the distance of each alternative from FPIS and FNIS by using Eq (7) and (8). The distances are shown in Table 9 and 10.

Step 5. Determine the closeness coefficient by using Eq (9). The closeness coefficients are shown in Table 11.

Table 8
Positive and negative ideal solutions

Criteria	*Positive Ideal Solution*	*Negative Ideal Solution*
Q1	0,93	0,19
Q2	1,00	0,24
Q3	0,82	0,17
Q4	0,86	0,11
Q5	0,80	0,13
Q6	0,96	0,19
Q7	0,82	0,13
Q8	0,88	0,14
Q9	**0,81**	**0,14**

Table 9
Distance from positive ideal solution

	Q1	*Q2*	*Q3*	*Q4*	*Q5*	*Q6*	*Q7*	*Q8*	*Q9*	*Total*
Supplier_1	0,5	0,5	0,4	0,5	0,5	0,5	0,4	0,5	0,4	4
Supplier_2	0,4	0,5	0,4	0,5	0,4	0,4	0,5	0,5	0,4	4
Supplier_3	0,5	0,5	0,5	0,5	0,4	0,6	0,5	0,4	0,5	4
Supplier_4	0,5	0,4	0,5	0,6	0,5	0,5	0,4	0,5	0,5	4
Supplier_5	0,5	0,5	0,4	0,4	0,4	0,4	0,4	0,5	0,4	4

Table 10
Distance from negative ideal solution

	Q1	*Q2*	*Q3*	*Q4*	*Q5*	*Q6*	*Q7*	*Q8*	*Q9*	*Total*
Supplier_1	0,36	0,41	0,38	0,39	0,32	0,38	0,42	0,44	0,40	3
Supplier_2	0,48	0,47	0,41	0,39	0,43	0,46	0,36	0,35	0,44	4
Supplier_3	0,40	0,37	0,34	0,40	0,40	0,34	0,33	0,48	0,32	3
Supplier_4	0,36	0,49	0,33	0,31	0,34	0,40	0,38	0,40	0,33	3
Supplier_5	0,42	0,44	0,42	0,50	0,42	0,51	0,45	0,43	0,40	4

Table 11
The closeness coefficients

	d_i^+	d_i^-	CC_i
Supplier_1	4	3	0,452
Supplier_2	4	4	0,486
Supplier_3	4	3	0,438
Supplier_4	4	3	0,436
Supplier_5	4	4	0,511

When the closeness coefficients of five suppliers are compared according to the Table 11, the ranking of suppliers' is determined as follows:

Supplier_5 > Supplier_2 > Supplier_1 > Supplier_3 > Supplier_4.

5. CONCLUSION

Suppliers have an important role in the supply chain management. In addition, selection and evaluation of suppliers are the critical decision problems for efficient supply chain management. Supplier selection is a complex decision because it incorporates a great variety of uncontrollable and unpredictable factors that affect the decisions.

In this study, fuzzy TOPSIS methodology is applied to evaluate suppliers' performance. Supplier_5 is the most efficientsupplier. When the Supplier_5's services are analyzed in detail, the above features are realized: The supplierpresents the most appropriate cost level to their customers, it gives qualified services, it delivers services in due time and when a problem occurs it finds appropriate solutions quickly and efficiently.

References

H.Y. Mak, Integrated Supply Chain Design Under Uncertainty (University of California, Berkeley, 2009).

A.S. Erdem and E. Göçen, Development of a decision support system for supplier evaluation and order allocation, *Expert Syst Appl* 39 (2012) 4927–4937.

A.H.I. Lee, H.Y. Kang, C.F. Hsu, H.C. Hung, A green supplier selection model for high-tech industry, *Expert Syst Appl* 36 (2009) 7917–7927.

A. Yücel and A.F. Güneri, Application of adaptive neuro fuzzy inference system to supplier selection problem, *Journal of Engineering and Natural Sciences*, Sigma 28 (2010) 224-234.

M. Zeydan, C. Çolpan and C. Çobanoğlu, A combined methodology for supplier selection and performance evaluation, *Expert Syst Appl*, 38 (2011) 2741–2751.

C.T. Chen, C.T. Lin, S.F. Huang, A fuzzy approach for supplier evaluation and selection in supply chain management, *Int J Prod Res* 102 (2006) 289–301.

B. Vahdani, S.H. Iranmanesh, S. Meysam Mousavi, M. Abdollahzade, A locally linear neuro-fuzzy model for supplier selection in cosmetics industry, *Applied Mathematical Modelling,* 36 (2012) 4714–4727.

Z. Xiao, W. Chen, L. Li, An integrated FCM and fuzzy soft set for supplier selection problem based on risk evaluation, *Applied Mathematical Modelling* 36 (2012) 1444–1454.

Çelebi and D. Bayraktar, An integrated neural network and data envelopment analysis for supplier evaluation under incomplete information, *Expert Syst Appl* 35 (2008) 1698–1710.

A.S. Erdem and E. Göçen, Development of a decision support system for supplier evaluation and order allocation, *Expert Syst Appl* 39 (2012) 4927–4937.

Chang, C.W. Chang, C.H. Wu, Fuzzy DEMATEL method for developing supplier selection criteria, *Expert Syst Appl* 38 (2011) 1850–1858.

Y.J. Chen, Structured methodology for supplier selection and evaluation in a supply chain, Inform Sciences 181 (2011) 1651–1670.

G.A. Keskin, S. Ilhan, C. Özkan, The Fuzzy ART algorithm: A categorization method for supplier evaluation and selection, *Expert Syst Appl* 37 (2010) 1235–1240.

G. Bruno, E. Esposito, A. Genovese, R. Passaro, AHP-based approaches for supplier evaluation: Problems and perspectives. *Journal of Purchasing & Supply Management*, 18 (2012) 159–172.

C.C. Sun, A performance evaluation model by integrating fuzzy AHP and fuzzy TOPSIS methods, *Expert Syst Appl*, 37 (2010) 7745–7754.

M.E. Biliþik, A comparative performance analyze model and supplier positioning in performance maps for supplier selection and evaluation, Istanbul Kultur University, Institute of Social Sciences, Department of Business Administration, Quality and Product Management, 2012, İstanbul.