Chapter 27
Application of Alternative Multi-criteria Decision Making Approaches to Supplier Selection Process

Vinod Yadav and Milind Kumar Sharma

Abstract In today's highly competitive and turbulent business environment, selection of reliable and high quality suppliers has become the most important purchasing decision in order to reduce the production cost while maintaining the product quality and customer satisfaction simultaneously. The problem of supplier selection gets complicated further when a company looks for various criteria to evaluate different suppliers that lead it to become a multi-criteria decision making (MCDM) problem. This work reviews supplier selection models based on both individual and hybrid MCDM methodologies. A case study of an automobile company is presented to illustrate and propose three alternative supplier selection models based on analytic hierarchy process (AHP) as an individual MCDM methodology and data envelopment analytic hierarchy process (DEAHP) and fuzzy analytic hierarchy process (FAHP) as hybrid MCDM methodologies.

Keywords Supplier selection process · Multi-Criteria decision making (MCDM) · Analytic hierarchy process (AHP) · Data envelopment analytic hierarchy process (DEAHP) · Fuzzy analytic hierarchy process (FAHP)

27.1 Introduction and Theoretical Background

In today's era of intelligent manufacturing where the application of production technology that can automatically adapt to fast changing business environment and varying process needs, with the capability of producing different products with minimum human intervention has paved the way for competitive manufacturing. Hence, due to global competition, for a manufacturing organization it is challenging

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to produce high quality products whilst offering competitive prices to the customers. Having reliable and competent supplier base has become one of the critical success factors for modern engineering management. The key objective of the purchasing department in any organization is to source the right quality of material in the right size from the right source at the right time and also at reasonable price (Boran et al. 2009). In competitive environment, the manufacturing organizations pay particular attention to the selection of alternative supply sources. Hence, supplier selection process has become the most significant variable in the modern supply chain management (Shaw et al. 2012; Arikan 2013; Pitchipoo et al. 2013; Yu and Wong 2014) as it helps in achieving high quality products and customer satisfaction (Gonzaile et al. 2004; Deng et al. 2014). Effective supplier selection needs robust analytic methods and decision support systems that are able to deal with multiple criteria (Ni et al. 2007; Chen and Chao 2012). Supplier selection assumes very important role in any manufacturing organization as the cost and quality of goods and services sold are directly related to the cost and quality of goods and services purchased. However, it becomes a complex issue to address for manufacturing firms when it considers multiple subjective and objective criteria. Criteria may vary depending on the type of product or industry being considered and include many qualitative factors in addition to the quantitative criteria (Vokurka et al. 1996). An efficient supplier selection process is capable to handle the complexity of the current business scenario.

Supplier selection gets complicated due to consideration of various criteria and sub criteria in decision making. Every buyer has different expectations from the suppliers. Different companies may have different organizational and cultural backgrounds, which may also affect the supplier selection process. The selection criteria may vary from industry to industry. The single criterion approach of the lowest cost supplier is no more accepted in this challenging and continuously changing environment (Agarwal et al. 2011). Quality, delivery performance, services, etc. need to be considered by the manufacturing firms. Dickson (1966) identified 23 criteria for supplier selection based on the survey of 273 purchasing managers. In a survey, Weber et al. (1991) classified all published papers (from 1967 to 1990) according to the studied criteria and they identified quality, cost and on-time delivery as the most important supplier selection criteria in the evaluation of supplier performance. After scanning a plethora of literatures Jain et al. (2009) grouped all criteria into six categories i.e. cost, quality, cycle time, service, relationship and organizational profile. Hence, it is imperative to devise an intelligent system for engineering management of business enterprises that may help decision makers to choose suppliers when it becomes a multi-criteria decision making (MCDM) problem. Multi-criteria decision-making approaches are formal methods to structure the decision problems with multiple and conflicting criteria or goals. MCDM methods have been widely used in many research fields. Supplier selection is basically, a multiple criteria decision-making problem. Broadly, the numerous multi-criteria decision-making approaches suggested in the literature to solve the supplier selection problem may be classified into individual approaches and integrated ones (Ho et al. 2010). The most widespread individual approaches are: the data envelopment analysis (DEA), mathematical programming, the analytic hierarchy process (AHP), the analytic network process (ANP), Neural networks, Structural equation modeling, Multi Attribute Utility Theory (MAUT), Dimensional analysis (DA), fuzzy decision making, genetic algorithms, the simple multi-attribute rating technique (SMART) and many more. The integrated approaches join together different techniques (e.g. integrated AHP and DEA, integrated AHP and goal programming, etc.). Different types of supplier selection approaches reported in the literature are shown in Table 27.1.

Table 27.1 Supplier selection approaches

Approaches	Authors
Data envelopment analysis	• Liu et al. (2000) • Forker and Mendez (2001) • Garfamy (2006) • Seydel (2006) • Wu et al. (2007) • Songhori et al. (2011) • Dotoli and Falagario (2012) • Partovi (2013)
Analytic hierarchy process	• Muralidharan et al. (2002) • Hou and Su (2007) • Chan and Chan (2010) • Kumar and Roy (2011) • Bruno et al. (2012)
Analytic network process	• Gencer and Gurpinar (2007) • Bayazit (2006) • Sarkis and Talluri (2002)
Fuzzy set theory	• Chen et al. (2006) • Florez-Lopez (2007) • Chang et al. (2011) • Jiang and Chan (2011) • Ahmady et al. (2013) • Ghorbani et al. (2013)
Linear programming	• Talluri and Narasimhan (2003) • Talluri and Narasimhan (2005) • Ng (2008)
Integer programming	• Talluri (2002) • Hong et al. (2005)
Goal programming	• Karpak et al. (2001)
Data envelopment analytic hierarchy process	• Sevkli et al. (2007) • Zhang et al. (2011) • Yadav and Sharma (2015a, b)
Integrated AHP-GP	• Cebi and Bayraktar (2003) • Percin (2006) • Kull and Talluri (2008) • Mendoza et al. (2008)
Integrated fuzzy-AHP	• Kahraman et al. (2003) • Kahraman et al. (2004) • Chan and Kumar (2007) • Tas (2012) • Yadav and Sharma (2015a, b)

Data Envelopment Analysis (DEA) is a widely recognized approach (Songhori et al. 2011; Dotoli and Falagario 2012; Partovi 2013) for evaluating the efficiencies of decision making units (suppliers). Because of its easy and successful application and case studies, DEA has gained too much attention and widespread use by business and academy researchers. Many researchers (Hou and Su 2007; Chan and Chan 2010; Kumar and Roy 2011) have concluded that analytic hierarchy process (AHP) is a useful, practical and systematic method for supplier selection. The AHP methodology, which was developed by Saaty (1980), is a powerful tool in solving complex decision problems. Fuzzy set theory has proven advantages within vague, imprecise and uncertain contexts and it resembles human reasoning in its use of approximate information and uncertainty to generate decisions for supplier selection (Jiang and Chan 2011; Chang et al. 2011; Ghorbani et al. 2013; Ahmady et al. 2013). In order to deal with uncertainties of the decision problem and eliminate the disadvantages of AHP, fuzzy AHP is preferred in supplier selection studies (Chan and Kumar 2007; Kilincci and Onal 2011; Tas 2012).

Kahraman et al. (2003) used fuzzy AHP technique to select the best supplier providing the most satisfaction for the three criteria (and 11 sub-criteria) determined in the white good sector. Kahraman et al. (2004) also proposed a fuzzy AHP based model to select a best catering Turkish firm providing the most customer satisfaction. Sevkli et al. (2007) applied an integrated AHP–DEA approach for supplier selection. In the approach, AHP was used to derive local weights from a given pair wise comparison matrix, and aggregate local weights to yield overall weights. Each row and column of the matrix was assumed as a decision making unit (DMU) and an output, respectively. A dummy input that had a value of one for all DMUs was deployed in DEA to calculate the efficiency scores of all suppliers. However, the authors pointed out that the approach was relatively more cumbersome to apply than the individual AHP. Aydin and Kahraman (2010) proposed a fuzzy analytic hierarchy process based methodology in the supplier selection of an air conditioner firm. Chang et al. (2011) proposed fuzzy decision making trial and evaluation laboratory (DEMATEL) method to effectively find evaluation factors for supplier selection. This method was based on practical approach of finding key factors to improve supplier performance through different questionnaire. Jiang and Chan (2011) proposed a methodology with the application of fuzzy set theory (FST), based on twenty criteria to deal with supplier evaluation and selection problem. They used the Dempster Shafer theory (DST) to combine the criterion data to calculate the final scores of the suppliers. Kumar and Roy (2011) proposed a rule based model with the application of AHP to aid the decision makers in vendor evaluation and selection taking a case from a power transmission industry. The article presented a three-step model to calculate the performance scores of various vendors and select the best vendor. The researchers also validated the proposed model taking the data from a multinational transformer company. Songhori et al. (2011) presented a structured framework to help decision makers in selecting the best supplier for a firm using DEA approach. Zhang et al. (2011) developed a hybrid methodology combining the data envelopment analytic hierarchy process (DEAHP) and activity-based costing (ABC). Using this hybrid model, decisions on supplier selection and order quantity could easily be made within an integrated single objective function which was based on consideration of the budget of the buyer and of the capacity of the suppliers. Bruno et al. (2012) proposed a hierarchical model for supplier selection in corporate environment. In this model twelve sub-criteria were considered under four criteria i.e. process and product quality, service level, management and innovation and financial position. The analysis of the implementation process of the methodology allowed the identification of strengths and weaknesses of using formalized supplier selection models to tackle the supplier evaluation problem, also highlighted potential barriers preventing firms to adopt such methods. Dotoli and Falagario (2012) proposed modified DEA approach which was used to evaluate the efficiency of each supplier according to some criteria proposed by the buyer. Ahmady et al. (2013) developed a novel fuzzy DEA approach with double frontiers for supplier selection. Compared with the traditional DEA, the DEA approach with double frontiers can identify the best supplier appropriately and easily without the need to impose any weight restriction or the need to calculate the cross-efficiency matrix, which requires a large number of computations and may also result in inconsistent conclusions. Ghorbani et al. (2013) proposed a three-phase approach for supplier selection based on the Kano model and fuzzy Multi Criteria Decision-Making. Initially, the importance weight of the criteria had been calculated using a fuzzy Kano questionnaire and fuzzy analytic hierarchy process. In the second phase, the Fuzzy TOPSIS technique was used to screen out incapable suppliers. Finally, in the third phase, the filtered suppliers which were qualified, once again evaluated by the same approach for the final ranking. This approach had also been examined in a case study. Partovi (2013) developed a quantitative methodology based on data envelopment analysis (DEA), including the constraint of 'self-efficiency' for supplier selection.

However, after scanning a plethora of literatures, following gaps are observed in it:

- The literature lacks the comparative studies of different MCDM approaches for supplier selection problem.
- Alternative MCDM methodologies for a supplier selection problem do not seem to receive adequate attention of the researchers.
- It is further observed that very less articles have proposed MCDM approach based on DEAHP methodology for supplier selection despite of the fact that this approach offers various benefits over other approaches.
- The literature lacks the case application in developing countries setting such as India.
- Very few researchers reported on flexibility criteria, one of the most crucial factors in today's competitive manufacturing environment, for supplier selection.
- The literature lacks essential elements to recognize some of the elements of long term relationships between buyer and supplier.

On the basis of above, it is felt appropriate to propose supplier selection model based on some alternative MCDM approaches to provide different perspectives. At the same time, a need is also felt to suggest an intelligent system for supplier selection which uses an individual and hybrid MCDM approaches simultaneously to give valuable insights into it. Hence, in this work, an attempt is made to propose supplier selection model based on AHP methodology, an individual MCDM approach and DEAHP and FAHP methodologies as hybrid MCDM approaches. An automobile company from Indian context is chosen for the study.

The rest of the chapter is organized as follow: Sect. 27.2 discusses about the supplier selection problem of the company. The application of analytic hierarchy process (AHP), data envelopment analytic hierarchy process (DEAHP) and fuzzy analytic hierarchy process (FAHP) are reported in Sects. 27.3, 27.4 and 27.5 respectively. Finally last section concludes the chapter and presents the limitation and direction for future research.

27.2 Problem Identification

One of the leading car and truck manufacturing company in India wants to select the best supplier for one of its critical components used in truck. The company providing the context for this application is a manufacturer of automobile, motor vehicles and internal combustion engines founded in 1926 and entered in the Indian market to built medium and heavy duty commercial vehicles in 2008. It is a leading car and truck manufacturing company. Besides, it manufactures buses and provides financial services through its sister concern. It set up a manufacturing plant for trucks in India. Initial production capacity at the plant in 28,000 units per year and expanded to 60,000 units per year by start of next year. The company chosen in the study is new in this market and trying to increase its customer base. The purchasing managers have acknowledged the fact that their suppliers have a major influence on customers' satisfaction level, and it is strongly desired to purchase the right quality of product in the right quantity from the right source at the right time. Therefore, the company decided to develop an effective supplier selection policy for the responsive market. The managers of the company recognized that a wide range of factors must be considered in the supplier selection process and the selection decisions should not be made merely on the basis of price related factors alone. Hence, in order to address this problem, a hierarchy is structured on the basis of identified supplier selection criteria in the literature and evidence found in the company as shown in Fig. 27.1.

In order to maintain the confidentiality of the supplier companies, the suppliers are identified as S1, S2 and S3 in the chapter.

27.3 AHP Model for Supplier Selection

The analytic hierarchy process (AHP) methodology, which was developed by Saaty (1980), is a powerful decision making tool in solving complex multiple criteria problems. In the AHP approach, the problem is structured hierarchically at different

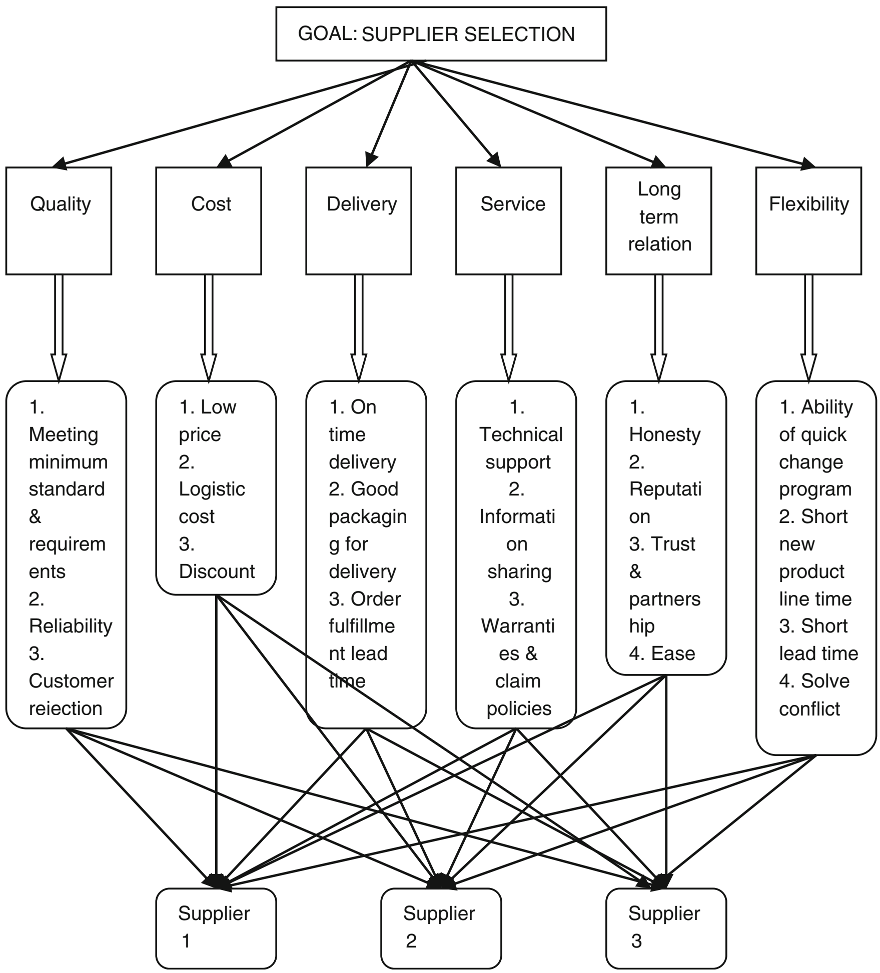


Fig. 27.1 Problem hierarchy

levels with each level consisting of a finite number of decision elements. The upper level of the hierarchy represents the overall goal, while the lower level consists of all possible alternatives. One or more intermediate levels embody the decision criteria and sub-criteria as shown in Fig. 27.1.

Pair wise comparisons are formulated to include all the combinations of criteria, sub-criteria and alternative relationships. The inputs of the pair wise comparison matrix are mangers preferences of the criterion, sub-criteria and alternative over other. The AHP priorities are computed with the help of computer software 'Expert Choice'. These priorities as shown in Table 27.2.

After deriving the priorities of criteria, sub-criteria and alternatives through pair wise comparison, these derived priorities were synthesized to get overall priorities

Table 27.2 AHP priorities for criteria, sub-criteria and alternatives

Goal		S_1	S_2	S_3
Quality (0.420)	MMSR (0.462)	0.218	0.691	0.091
	Reliability (0.103)	0.528	0.333	0.140
	CR (0.134)	0.122	0.320	0.558
	DR (0.301)	0.243	0.088	0.669
Cost (0.243)	LP (0.271)	0.320	0.558	0.122
	LC (0.085)	0.528	0.140	0.333
	Discount (0.644)	0.320	0.558	0.122
Delivery (0.093)	OTD (0.661)	0.493	0.196	0.311
	GP (0.131)	0.333	0.140	0.528
	OFLT (0.208)	0.345	0.547	0.109
Service (0.126)	TS (0.242)	0.320	0.122	0.558
	IS (0.084)	0.309	0.109	0.582
	WCP (0.502)	0.323	0.588	0.089
	Capabilities (0.172)	0.250	0.095	0.655
Long term relationship (0.051)	Honesty (0.556)	0.540	0.297	0.163
	Reputation (0.249)	0.200	0.683	0.117
	TP (0.115)	0.167	0.094	0.740
	EC (0.081)	0.320	0.588	0.122
Flexibility (0.068)	AQCP (0.142)	0.200	0.177	0.683
	SNPLT (0.327)	0.540	0.297	0.163
	SLT (0.095)	0.333	0.097	0.570
	SC (0.436)	0.200	0.683	0.117

of suppliers. Equations (27.1) and (27.2) are used to synthesize the priorities and the overall priorities of suppliers are shown in Table 27.3.

$$\text{Second level priority of supplier } S_i = \sum\left\{\left(\text{local weight of } S_i \text{ w.r.t. sub-criteria } SC_j\right) \times \left(\text{local weight of } SC_j\right)\right\} \tag{27.1}$$

$$\text{First level priority of supplier } S_i = \sum\left\{\left(\text{second level weight of } S_i \text{ w.r.t. criteria } C_j\right) \times \left(\text{local weight of } C_j\right)\right\} \tag{27.2}$$

Table 27.3 Overall AHP priorities

Suppliers	Final priorities
S_1	0.306
S_2	0.421
S_3	0.273

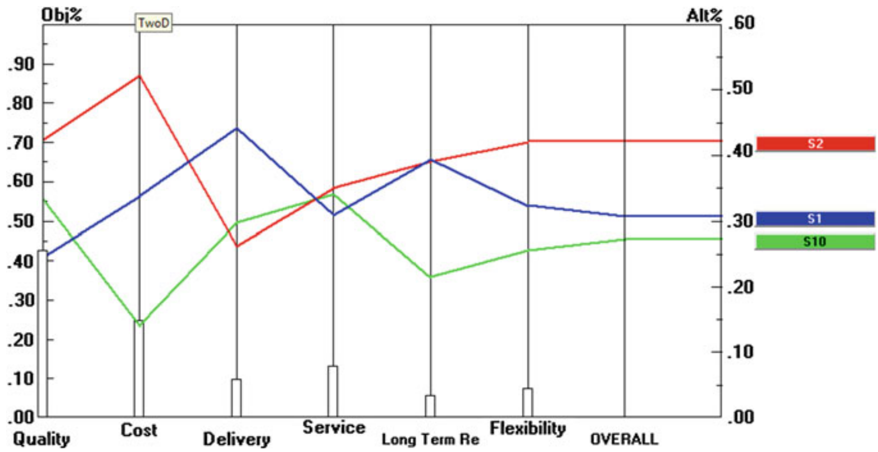


Fig. 27.2 Sensitivity analysis graph for AHP

It may be seen from the Table 27.3 that the supplier 2 (S_2) has got highest priority (0.421) and hence may be selected by the company. Supplier 3 (S_3) has the lowest priority as 0.273 while supplier 1 (S_1) has priority of 0.306. It is worth to notice that the relative score difference between the first and the last supplier in the ranking is quite limited ((0.421 − 0.273)/0.421 = 35.15 %). Therefore, slight variation in managers' judgment can modify the final ranking.

However, the evaluation of supplier based on each criterion is also an important issue to address. Therefore, it is not necessary that overall highest ranked supplier will have highest rank with respect to all individual criterion also. Some interesting insights are obtained in the sensitivity analysis, as shown in Fig. 27.2.

Sensitivity graph with respect to goal is shown in Fig. 27.2. It is clearly seen from the graph that supplier 2 has highest priority with respect to four criteria i.e. quality, cost, service and flexibility while it has lowest priority with respect to delivery criterion. Therefore, in special case where delivery will be a critical criterion, the supplier 2 should be replaced by supplier 1. Supplier 1 has highest priority with respect to delivery and long term relationship while it has lowest priority with respect to the criteria quality and service. Supplier 3 doesn't get highest priority with respect to any criterion so it may be recommended to eliminate it from further analysis.

It is noteworthy to mention here that the local weights of the elements are calculated from the judgment matrices using the eigenvector method (EVM) in AHP. The normalized eigenvector corresponding to the principal eigen value of the judgment matrix provides the weights of the corresponding elements. The ranking of alternatives determined by the traditional AHP may be altered by any addition or deletion of another alternative for consideration. Hence, hybrid use of AHP with another methodology, such as data envelopment analysis (DEA) may overcome this limitation and pave the way for more useful results.

27.4 Hybrid DEAHP Model for Supplier Selection

Ramanathan (2006) first proposed the data envelopment analytic hierarchy process (DEAHP) methodology, in which DEA method is embedded into AHP method. The structure of DEAHP is the same as AHP structure; the upper level of the hierarchy represents the overall goal, while the lower level consists of all possible alternatives. One or more intermediate levels embody the decision criteria and sub-criteria. In this methodology, each row of the pair wise matrix is assumed as Decision Making Unit (DMU) and each column is assumed as output. However, according to DEA method, the efficiency scores of each DMU cannot be calculated entirely with outputs and required at least one input. So, a dummy inputs for all the DMU's is employed, this dummy input has a value of 1. In DEAHP methodology, the efficiency scores are calculated using the DEA method for each pair-wise comparison matrix and could be interpreted as a local weights of the DMUs. Once the local weights of DMUs are calculated the next step is to aggregates the local weights to get overall weights. Again, the DEA method is used to drive the overall weights from the local weights. Ramanathan (2006) proves that DEA method correctly drives the weights for consistent judgment matrix. Sevkli et al. (2007) and Zhang et al. (2011) applied this approach for supplier selection problem. Hence, it is imperative to use an integrated DEAHP approach for the present study also.

Pair wise comparison matrixes are prepared through interviews conducted with the managerial staff employed in the purchase department of the company. In order to derive the local priority for a consistent pair wise matrix DEA methodology is used. For example, to derive the local priority for criterion 'meeting minimum standard and requirements' for Table 27.4 the following model is used.

$$\mathbf{Objective\,function}: \ \mathbf{Maximization\,Z} = \mathbf{1y_{11} + 3y_{12} + 4y_{13} + 2y_{14}}$$

$$\mathbf{Subject\,to}:$$

$$\mathbf{x_{11} = 1},$$

$$\mathbf{1y_{11} + 3y_{12} + 4y_{13} + 2y_{14} \leq 0},$$

$$\mathbf{1/3y_{11} + 1y_{12} + 1/2y_{13} + 1/3y_{14} \leq 0},$$

$$\mathbf{1/3y_{11} + 1y_{12} + 1/2y_{13} + 1/3y_{14} \leq 0},$$

$$\mathbf{1/4y_{11} + 2y_{12} + 1y_{13} + 1/3y_{14} \leq 0},$$

$$\mathbf{1/2y_{11} + 3y_{12} + 3y_{13} + 1y_{14} \leq 0},$$

$$\mathbf{y_{11}, y_{12}, y_{13}, y_{14}, x_{11}, x_{12}, x_{13}, x_{14} \geq 0}.$$

Similarly, to obtain the local weights for other criteria, similar models are used by changing the objective functions in following manner-

Table 27.4 Evaluation of sub-criteria with respect to QUALITY for DEAHP

DMU	Output 1	Output 2	Output 3	Output 4	Input	AHP	DEAHP
Meeting minimum standard and requirements	1	3	4	2	1	0.462	1.000
Reliability	1/3	1	1/2	1/3	1	0.103	0.333
Customer rejection	¼	2	1	1/3	1	0.134	0.666
Defect rate	½	3	3	1	1	0.301	1.000

$$\textbf{Maximization Z} = \mathbf{1/3y_{11} + 1y_{12} + 1/2y_{13} + 1/3y_{14}} \text{ (for reliability)}$$
$$\textbf{Maximization Z} = \mathbf{1/4y_{11} + 2y_{12} + 1y_{13} + 1/3y_{14}} \text{ (for customer rejection)}$$
$$\textbf{Maximization Z} = \mathbf{1/2y_{11} + 3y_{12} + 3y_{13} + 1y_{14}} \text{ (for defect rate)}$$

The local weights of decision making units may be seen in Table 27.5. Once local weights of suppliers are obtained, then next step is to aggregate the local weights of suppliers in order to obtain overall weights of the decision alternatives.

Table 27.5 DEAHP priorities for criteria, sub-criteria and alternatives

Goal		S_1	S_2	S_3
Quality (1.000)	MMSR (1.000)	0.500	1.000	0.167
	Reliability (0.333)	1.000	1.000	0.333
	CR (0.666)	0.250	0.750	1.000
	DR (1.000)	0.428	0.142	1.000
Cost (0.800)	LP (0.667)	0.750	1.000	0.250
	LC (0.167)	1.000	0.333	1.000
	Discount (1.000)	0.750	1.000	0.250
Delivery (0.400)	OTD (1.000)	1.000	0.500	1.000
	GP (0.250)	1.000	0.333	1.000
	OFLT (0.500)	1.000	1.000	0.250
Service (0.600)	TS (0.750)	0.750	0.250	1.000
	IS (0.250)	0.600	0.200	1.000
	WCP (1.000)	0.667	1.000	0.167
	Capabilities (0.750)	0.500	0.167	1.000
Long term relationship (0.200)	Honesty (1.000)	1.000	0.666	0.333
	Reputation (0.600)	0.400	1.000	0.200
	TP (0.600)	0.285	0.142	1.000
	EC (0.200)	0.750	1.000	0.250
Flexibility (0.400)	AQCP (0.667)	0.400	0.200	1.000
	SNPLT (1.333)	1.000	0.666	0.333
	SLT (0.333)	0.800	0.200	1.000
	SC (1.000)	0.400	1.000	0.200

Table 27.6 Overall DEAHP priorities of suppliers

DMU	Output 1	Output 2	Output 3	Output 4	Output 5	Output 6	Input	AHP	DEAHP
S_1	0.722	0.822	1.000	1.287	1.000	1.084	1	0.306	0.981
S_2	1.000	1.000	0.619	1.000	0.994	1.000	1	0.421	1.000
S_3	0.984	0.338	0.785	1.406	0.706	0.786	1	0.273	0.883
y11 = 5/4y12 = 5/2y13 = 5/3y14 = 5y15 = 5/2y16									

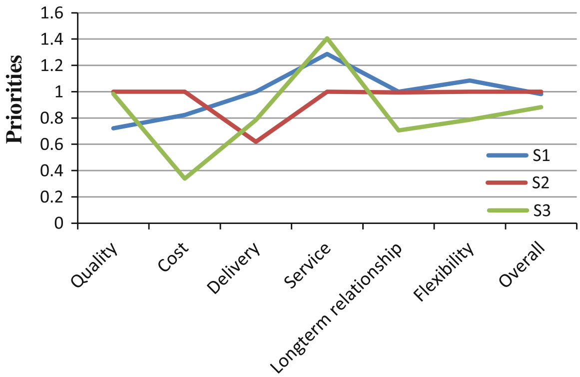
The calculations for aggregation are same as of local weights but the only difference is to include additional constraints that are related to the local weights of criteria. The overall priorities for alternative suppliers are shown in Table 27.6.

The final results of the model are illustrated in Table 27.6, due to the maximum overall weight supplier 2 is ranked as number 1 as obtained from both methodologies (i.e. AHP and DEAHP) and suppliers 1 and 3 are ranked as number 2 and number 3 respectively from both methodologies, so in this model, results obtained from both methodologies are same. Therefore, supplier 2 is recommended to be selected.

However, the evaluation of suppliers based on each criterion also provides interesting insights. Figure 27.3 shows the sensitivity graph with respect to the goal. It is clearly seen from the graph that supplier 1 has been ranked as number 1 with respect to criteria delivery, service, long-term relationship and flexibility whilst, supplier 2 is ranked as number 1 with respect to criteria quality and cost.

In DEAHP, the weights of alternatives (i.e., the efficiency scores) are calculated separately for each alternative using a separate linear programming model. However, in AHP weights of all the alternatives are derived simultaneously with the help of EVM. In addition to it, while traditional AHP uses arithmetic normalization, no such normalization is done in case of DEAHP. Further, the DEAHP weights are calculated relative to the weight of the best rated alternative. Efficient alternatives are interpreted as relevant alternatives because they play an important role in the rank ordering of all the alternatives. In case the alternative other than the best one is eliminated from the model, then the new ranking calculated will again be relative to

Fig. 27.3 Sensitivity analysis graph for DEAHP



the highest ranked one alternative, and the ordering of alternatives will not change. But the common problem in both the methodologies is inconsistency in the pair wise comparison.

27.5 FAHP Model for Supplier Selection

In order to deal with uncertainties in the decision making problem and overcome the limitations of AHP and DEAHP, another MCDM approach known as fuzzy AHP is preferred in supplier selection studies. It proposes an intelligent supplier selection model which may help decision makers to choose suppliers based on the different criteria. Fuzzy-AHP was introduced by Van laarhoven and Pedrycz in 1983. Basically, fuzzy analytic hierarchy process (FAHP) is an integrated approach, which consist fuzzy sets theory and analytic hierarchy process. Fuzzy sets theory resembles the human reasoning and mathematically represents the uncertainty and vagueness. In this study Chang's extent analysis method is used to select the best supplier among the number of alternative supplier available. Chang (1996) used triangular fuzzy numbers (TFN) for the pair-wise comparison in AHP. Chang's approach is less time taking and less computational expense than many other FAHP approaches.

Let $X = \{x_1, x_2, x_3, \ldots, x_n\}$ be an object set, and $U = \{u_1, u_2, u_3, \ldots, u_m$ be a goal set. According to the method of Chang's extent analysis, each object is taken and extent analysis for each goal, g_i, is performed respectively. Therefore, m extent analysis values for each object can be obtained, with the following signs:

$$M_{gi}^1, M_{gi}^2, M_{gi}^3, \ldots\ldots, M_{gi}^m; \quad i = 1, 2, 3, \ldots, n$$

Where all M_{gi}^j are TFN; j = 1, 2, 3,…..,m

The steps of Chang's (1996) extent analysis can be given as in the following:

Step 1: The fuzzy synthetic extent with respect to *i*th object is defined as:

$$S_i = \sum_{j=1}^{m} M_{gi}^j \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^j\right]^{-1} \tag{27.1}$$

To obtain $\sum_{j=1}^{m} M_{gi}^j$ the fuzzy addition operation of m extent analysis values for a particular matrix is performed such that

$$\sum_{j=1}^{m} M_{gi}^j = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j \sum_{j=1}^{m} u_j\right) \tag{27.2}$$

and to obtain $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^j\right]^{-1}$ the fuzzy addition operator of M_{gi}^j values is performed such that

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i\right) \tag{27.3}$$

and then inverse of the vector of computed, such that

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right) \tag{27.4}$$

Step 2: The degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ can be defined as

$$V(M_2 \geq M_1) = \sup_{y \geq x}[\min(\mu_{M1}(x), \mu_{M2}(y))] \tag{27.5}$$

Equation (27.5) can be expressed as follows:

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M2} = \begin{bmatrix} 1, & if\ m_2 \geq m_1 \\ 0, & if\ l_1 \geq u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & otherwise \end{bmatrix} \tag{27.6}$$

where d is the ordinate of the highest intersection point D between μ_{M1} and μ_{M2}. In Fig. 27.4, the intersection between M_1 and M_2 can be seen. To compare M_1 and M_2, both the values of $V(M_1 \geq M_2)$ and $V(M_1 \leq M_2)$ are needed.

Step 3: The degree of possibility for a convex fuzzy number to be greater than k convex fuzzy numbers $M_i (i = 1, 2, \ldots, k)$ can be defined by

$$V(M \geq M_1, M_2, \ldots, M_k) = V[(M \geq M_1) \text{ and } (M \geq M_2) \text{ and } \ldots \text{ and } (M \geq M_k)] = \min V(M \geq M_i)$$

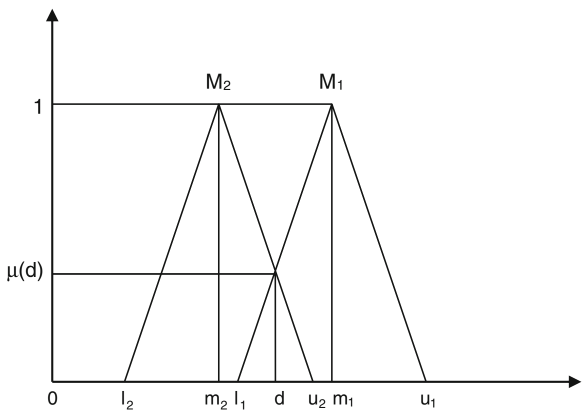


Fig. 27.4 Intersection of M_1 and M_2

Assume that

$$d'(A_i) = \min V(S_i \geq S_k) \tag{27.8}$$

For $k = 1, 2, \ldots, n;\ k \neq i$, weight vector is given by Eq. (27.9)

$$W' = (d'(A_1),\ d'(A_2),\ \ldots,\ d'(A_n))^T \tag{27.9}$$

where $A_i (i = 1, 2, \ldots, n)$ are n elements.

Step 4: After normalization, the normalized weight vectors are:

$$W = (d(A_1),\ d(A_2),\ \ldots,\ d(A_n))^T \tag{27.10}$$

where W is a non-fuzzy number.

First the managers compared the criteria with respect to the goal; then compared the sub-criteria with respect to the main criteria. Finally the managers compared the supplier with respect to each sub-criterion. The linguistic variables were used to make the pair-wise comparisons. Then the linguistic variables were converted to triangular fuzzy numbers. In order to find the priority weights of the decision variables (criteria, sub-criteria and alternatives) the fuzzy extent analysis is used. The local priorities of decision variables are shown in Table 27.7. At last the local priorities of decision variables are synthesized into overall priorities which are shown in Table 27.8.

According to the final scores as shown in Table 27.8, S_3 (supplier 3) has been found as the most preferred choice due to its highest priority weight. S_1 is the next recommended alternative followed by S_2. The difference between priority weights of S_1 and S_3 is very high, so, it is strongly recommended to select the alternative S_3 over other options.

27.6 Conclusion

On the basis of the existing literature it may be concluded that the supplier selection process is one of the most critical issues within the supply chain management. It becomes more important in the context of an automobile industry. A typical manufacturer spends 60 % of its total sales on purchased items such as raw materials, parts, subassemblies components etc. (Krajewski and Ritzman 1996). In automotive industries, these costs may be more than 50 % of the total revenues. That can go up to 80 % of the total product costs for high technology firms (Weber et al. 1991). Selection of the best suppliers significantly reduces the purchasing costs and improves corporate competitiveness.

In this study three multi-criteria decision making (MCDM) approaches are used to address the supplier selection problem of an automobile company. Six decision criteria are identified by an extensive review of literature and subsequently held

Table 27.7 FAHP priorities for criteria, sub-criteria and alternatives

Goal		**S_1**	**S_2**	**S_3**
Quality (0.41)	MMSR (0.50)	0.26	0.65	0.09
	Reliability (0.10)	0.45	0.03	0.52
	CR (0.00)	0.00	0.96	0.04
	DR (0.40)	0.00	0.14	0.86
Cost (0.25)	LP (0.68)	0.45	0.03	0.52
	LC (0.27)	0.44	0.20	0.36
	Discount (0.05)	0.43	0.57	0.00
Delivery (0.11)	OTD (1.00)	0.33	0.33	0.33
	GP (0.00)	0.47	0.06	0.47
	OFLT (0.00)	0.46	0.21	0.33
Service (0.11)	TS (0.27)	0.45	0.52	0.03
	IS (0.015)	0.44	0.36	0.20
	WCP (0.29)	0.56	0.00	0.44
	Capabilities (0.29)	0.36	0.20	0.44
Long term relationship (0.06)	Honesty (0.53)	0.45	0.03	0.52
	Reputation (0.36)	0.03	0.52	0.45
	TP (0.11)	0.00	0.35	0.65
	EC (0.00)	0.43	0.57	0.00
Flexibility (0.06)	AQCP (0.00)	0.03	0.45	0.52
	SNPLT (0.55)	0.44	0.33	0.23
	SLT (0.00	0.68	0.27	0.05
	SC (0.45)	0.03	0.52	0.45

Table 27.8 Overall priority weights with respect to goal

Goal	Quality	Cost	Delivery	Service	Long term relationship	Flexibility	Priority weights
Weights →	0.41	0.25	0.11	0.11	0.06	0.06	
S_1	0.175	0.4395	0.33	0.4543	0.2493	0.2555	0.299
S_2	0.384	0.1029	0.33	0.2524	0.2416	0.4155	0.287
S_3	0.441	0.4576	0.33	0.2933	0.5091	0.3290	0.414

interviews with the company management to evaluate the suppliers. Firstly, AHP approach is used to rank the available supplier with respect to identified criteria. Further DEAHP approach is employed to validate the outcomes of AHP model. And finally a fuzzy AHP model is developed to deal with the problem of uncertainty or inconsistency in the previous models.

The results of all three models are shown in Table 27.9. It may be clearly seen from the second and third column of Table 27.9 that top priority has been assigned to supplier 2 followed by supplier 1 and supplier 3 as suggested by AHP and

Table 27.9 Overall priorities of suppliers

	AHP	DEAHP	FAHP
S_1	0.306	0.981	0.299
S_2	0.421	1.000	0.287
S_3	0.273	0.883	0.414

Table 27.10 Overall priorities of criteria

Criteria	AHP	DEAHP	FAHP
Quality	0.420	1.000	0.410
Cost	0.243	0.800	0.250
Delivery	0.093	0.400	0.110
Service	0.126	0.600	0.110
LTR	0.051	0.200	0.060
Flexibility	0.068	0.400	0.060

DEAHP analysis. Hence it may be concluded that results of AHP and DEAHP models are similar for the problem in question. However, the results of FAHP model are different from other models as shown in last column of Table 27.9. According to it, top priority has been assigned to supplier 3 followed by supplier 1 and supplier 2.

It is worth to notice that the relative score difference between the first and the last supplier in the ranking is quite limited ((0.421–0.273)/0.421 = 35.15 %). Therefore, slight variation in managers' judgment can modify the final ranking.

It can be concluded from this study that quality and cost are the most crucial criteria for the automobile company. Other researchers also identified quality (Bruno et al. 2012; Zhang et al. 2011; Sen et al. 2010) and cost (Zhang et al. 2011; Sevkli et al. 2007) as key criteria for supplier selection problem. Priorities given to the quality criterion by AHP, DEAHP and FAHP are 0.420, 1.000 and 0.410 respectively as shown in Table 27.10. Hence quality criterion is the top priority criterion among the other criteria. However, the cost criterion from AHP, DEAHP and FAHP are 0.243, 0800 and 0.25 respectively. Table 27.10 provides priorities to other criteria also in the similar fashion.

This study has contributed important findings of supplier selection process in following ways:

- It contributes to supplier selection process and points out the importance of supplier selection.
- This study proposes an intelligent supplier selection model for an automobile industry which often faces heterogeneous supply environments.
- The models provide key criteria for supplier selection in Indian context.
- It provides case applications of AHP, DEAHP and FAHP models for supplier selection problem.
- This study further provides useful insights in the dynamics of the supplier selection process by varying the selection criteria by conducting sensitivity analysis.

- The findings provide important directions and guidelines in choosing appropriate suppliers in dynamic situations in order to enhance long term relationship with them.

However this study should be viewed in the light of some limitations. As this analysis and findings are based on only one case study of an Indian automobile company, and this necessitates caution in interpreting the results. The limited number of interviewed managers in a company restricts the generalizability of the results. Though the company selected for this study is typical of developing country businesses, the findings of the study may not be readily extensible to other companies. Future research could examine these results using a larger sample set or field surveys in developing country settings. Secondly, this study used retrospective settings, based on the interviewed feedback after the events had occurred. This method naturally poses limitations due to respondent recall and the accuracy of information provided. Thirdly, the problem chosen for this study is based in a single country context and further additional research will be required to examine if the findings could be extended to other automobile companies in other developing nations. Fourthly, this study can be extended to add more supplier alternatives, which encompass both domestic and international suppliers; however, it may increase computational complexities and efforts.

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References

Agarwal, P., Sahai, M., Mishra, V., Bag, M., Singh, V.: A review of multi-criteria decision making techniques for supplier evaluation and selection. Int. J. Ind. Eng. Comput. **2**(4), 801–810 (2011)

Ahmady, N., Azadi, M., Sadeghi, S.A.H., Saen, R.F.: A novel fuzzy data envelopment analysis model with double frontiers for supplier selection. Int. J. Logistic Res. Appl. Lead. J. Supply Chain Manage. **16**(2), 87–98 (2013)

Arikan, F.: A fuzzy solution approach for multi objective supplier selection. Expert Syst. Appl. **40** (3), 947–952 (2013)

Aydin, S., Kahraman, C.: Multiattribute supplier selection using fuzzy analytic hierarchy process. Int. J. Comput. Intell. Syst. **3**(5), 553–565 (2010)

Bayazit, O.: Use of analytic network process in vendor selection decisions. Benchmarking Int. J. **13**(5), 566–579 (2006)

Boran, F.E., Genc, S., Kurt, M., Akay, D.: A multi criteria intuitionistic fuzzy group decision making fir supplier selection with TOPSIS method. Expert Syst. Appl. **36**(8), 11363–11368 (2009)

Bruno, G., Esposito, E., Genovese, A., Passaro, R.: AHP-based approaches for supplier evaluation: problems and perspectives. J. Purchasing Supply Manage. **18**(3), 159–172 (2012)

Cebi, F., Bayraktar, D.: An integrated approach for supplier selection. Logistics Inf. Manage. **16** (6), 395–400 (2003)

Chan, F.T.S., Chan, H.K.: An AHP model for selection of suppliers in the fast changing fashion market. Int. J. Adv. Manuf. Technol. **51**(4), 1195–1207 (2010)

Chan, F.T.S., Kumar, N.: Global supplier development considering risk factors using fuzzy extended AHP-based approach. OMEGA—Int. J. Manage. Sci. **35**(4), 417–431 (2007)

Chang, B., Chang, C., Wu, C.: Fuzzy DEMATEL method for developing supplier selection criteria. Expert Syst. Appl. **38**(3), 1850–1858 (2011)

Chang, D.Y.: Applications of the extent analysis method on fuzzy AHP. Eur. J. Oper. Res. **95**(3), 649–655 (1996)

Chen, C.T., Lin, C.T., Huang, S.F.: A fuzzy approach for supplier evaluation and selection in supply chain management. Int. J. Prod. Econ. **102**(2), 289–301 (2006)

Chen, Y.H., Chao, R.H.: Supplier selection using consistent fuzzy preference relations. Expert Syst. Appl. **39**(3), 3233–3240 (2012)

Deng, X., Hu, Y., Deng, Y., Mahadevan, S.: Supplier selection using AHP methodology extended by D numbers. Expert syst. Appl. **41**(1), 156–167 (2014)

Dickson, G.W.: An analysis of vendor selection systems and decisions. J Purchasing **2**(1), 5–17 (1966)

Dotoli, M., Falagario, M.: A hierarchical model for optimal supplier selection in multiple sourcing contexts. Int. J. Prod. Res. **50**(11), 2953–2967 (2012)

Florez-Lopez, R.: Strategic supplier selection in the added-value perspective: a CI approach. Inf. Sci. **177**(5), 1169–1179 (2007)

Forker, L.B., Mendez, D.: An analytical method for benchmarking best peer suppliers. Int. J. Oper. Prod. Manage. **21**(1–2), 195–209 (2001)

Garfamy, R.M.: A data envelopment analysis approach based on total cost of ownership for supplier selection. J. Enterp. Inf. Manage. **19**(6), 662–678 (2006)

Gencer, C., Gurpinar, D.: Analytic network process in supplier selection: a case study in an electronic firm. Appl. Math. Model. **31**(11), 2475–2486 (2007)

Ghorbani, M., Arabzad, S.M., Shahin, A.: A novel approach for supplier selection based on the Kano model and fuzzy MCDM. Int. J. Prod. Res. **51**(8), 5469–5484 (2013)

Gonzailez, M.E., Quesada, G., Monge, C.A.M.: Determining the importance of the supplier selection process in manufacturing: a case study. Int. J. Phys. Distrib. Logistics Manage. **34**(6), 492–504 (2004)

Ho, W., Xu, X., Dey, P.K.: Multi-criteria decision making approaches for supplier evaluation and selection: a literature review. Eur. J. Oper. Res. **202**(1), 16–24 (2010)

Hong, G.H., Park, S.C., Jang, D.S., Rho, H.M.: An effective supplier selection method for constructing a competitive supply-relationship. Expert Syst. Appl. **28**(4), 629–639 (2005)

Hou, J., Su, D.: EJB–MVC oriented supplier selection system for mass customization. J. Manuf. Technol. Manage. **18**(1), 54–71 (2007)

Jain, V., Wadhwa, S., Deshmukh, S.G.: Select supplier-related issues in modelling a dynamic supply chain: potential, challenges and direction for future research. Int. J. Prod. Res. **47**(11), 3013–3039 (2009)

Jiang, W., Chan, F.T.S.: A new fuzzy dempster MCDM method and its application in supplier selection. Expert Syst. Appl. **38**(8), 9854–9861 (2011)

Kahraman, C., Cebeci, U., Ulukan, Z.: Multi-criteria supplier selection using fuzzy AHP. Logistics Inf. Manage. **16**(6), 382–394 (2003)

Kahraman, C., Cebeci, U., Ruan, D.: Multi-attribute comparison of catering service companies using fuzzy AHP: the case of Turkey. Int. J. Prod. Econ. **87**(2), 171–184 (2004)

Karpak, B., Kumcu, E., Kasuganti, R.R.: Purchasing materials in the supply chain: managing a multi-objective task. Eur. J. Purchasing Supply Manage. **7**(3), 209–216 (2001)

Kilincci, O., Onal, S.A.: Fuzzy AHP approach for supplier selection in a washing machine company. Expert Syst. Appl. **38**(8), 9656–9664 (2011)

Krajewski, L.J., Ritzman, L.P.: Operations Management Strategy and Analysis. Addison-Wesley Publishing Co., London (1996)

Kull, T.J., Talluri, S.: A supply-risk reduction model using integrated multicriteria decision making. IEEE Trans. Eng. Manage. **55**(3), 409–419 (2008)

Kumar, J., Roy, N.: Analytic hierarchy process (AHP) for a power transmission industry to vendor selection decisions. Int. J Comput Appl. **12**(11), 26–30 (2011)

Liu, F., Ding, F.Y., Lall, V.: Using data envelopment analysis to compare suppliers for supplier selection and performance improvement. Int. J. Supply Chain Manage. **18**(6), 143–150 (2000)

Mendoza, A., Santiago, E., Ravindran, A.R.: A three-phase multicriteria method to the supplier selection problem. Int. J. Ind. Eng. **15**(2), 195–210 (2008)

Muralidharan, C., Anantharaman, N., Deshmukh, S.G.: A multi-criteria group decision-making model for supplier rating. J. Supply Chain Manage. **2**(45), 22–33 (2002)

Ng, W.L.: An efficient and simple model for multiple criteria supplier selection problem. Eur. J. Oper. Res. **186**(3), 1059–1067 (2008)

Ni, M., Xu, X., Deng, S.: Extended QFD and data-mining-based methods for supplier selection in mass customization. Int. J. Comput. Integr. Manuf. **20**(2–3), 280–291 (2007)

Partovi, F.Y.: Selecting suppliers for a long-term relationship. Int. J. Manage. Sci. Eng. Manage. **8** (2), 109–116 (2013)

Percin, S.: An application of the integrated AHP–PGP model in supplier selection. Measuring Bus. Excellence **10**(4), 34–49 (2006)

Pitchipoo, P., Venkumar, P., Rajakarunakaran, S.: Fuzzy hybrid decision model for supplier evaluation and selection. Int. J. Prod. Res. **51**(13), 3903–3919 (2013)

Ramanathan, R.: Data envelopment analysis for weight derivation and aggregation in the analytic hierarchy process. Comput. Oper. Res. **33**(5), 1289–1307 (2006)

Saaty, T.L.: The Analytic Hierarchy Process. McGraw-Hill Book Co., New York (1980)

Sarkis, J., Talluri, S.: A model for strategic supplier selection. J. Supply Chain Manage. **38**(1), 18–28 (2002)

Sen, C.G., Sen, S., Baslıgil, H.: Pre-selection of suppliers through an integrated fuzzy analytic hierarchy process and max-min methodology. Int. J. Prod. Res. **48**(6), 1603–1625 (2010)

Sevkli, M., Koh, S.C.L., Zaim, S., Demirbag, M., Tatoglu, E.: An application of data envelopment analytic hierarchy process for supplier selection: a case study of BEKO in Turkey. Int. J. Prod. Res. **45**(9), 1973–2003 (2007)

Seydel, J.: Data envelopment analysis for decision support. Ind. Manage. Data Syst. **106**(1), 81–95 (2006)

Shaw, K., Shankar, R., Yadav, S.S., Thakur, L.S.: Supplier selection using fuzzy AHP and fuzzy multi-objective linear programming for developing low carbon supply chain. Expert Syst. Appl. **39**(9), 8182–8192 (2012)

Songhori, M.J., Tavana, M., Azadeh, A., Khakbaz, M.H.: A supplier selection and order allocation model with multiple transportation alternatives. Int. J. Adv. Manuf. Technol. **52**(1–4), 365–376 (2011)

Talluri, S.: A buyer–seller game model for selection and negotiation of purchasing bids. Eur. J. Oper. Res. **143**(1), 171–180 (2002)

Talluri, S., Narasimhan, R.: Vendor evaluation with performance variability: a max min approach. Eur. J. Oper. Res. **146**(3), 543–552 (2003)

Talluri, S., Narasimhan, R.: A note on a methodology for supply base optimization. IEEE Trans. Eng. Manage. **52**(1), 130–139 (2005)

Tas, A.: A Fuzzy AHP approach for selecting a global supplier in pharmaceutical industry. Afr. J. Bus. Manage. **6**(14), 5073–5084 (2012)

Vokurka, R.J., Choobineh, J., Vadi, L.: A prototype expert system for the evaluation and selection of potential suppliers. Int. J. Oper. Prod. Manage. **16**(12), 106–127 (1996)

Weber, C.A., Current, J.R., Benton, W.C.: Vendor selection criteria and methods. Eur. J. Oper. Res. **50**(1), 2–18 (1991)

Wu, T., Shunk, D., Blackhurst, J., Appalla, R.: AIDEA: A methodology for supplier evaluation and selection in a supplier-based manufacturing environment. Int. J. Manuf. Technol. Manage. **11**(2), 174–192 (2007)

Yadav, V., Sharma, M.K.: An application of hybrid data envelopment analytical hierarchy process approach for supplier selection, J. Enterprise Inf. Manage. **28**(1 or 2) (2015a) (In press)

Yadav, V., Sharma, M.K.: Multi-criteria decision making for supplier selection using fuzzy AHP approach. Benchmarking Int. J. **22**(7) (2015a) (In press)

Yu, C., Wong, T.N.: A supplier pre-selection model for multiple products with synergy effect. Int. J. Prod. Res. (2014). doi:10.1080/00207543.2014.900199

Zhang, X., Lee, C.K.M., Chen, S.: Supplier evaluation and selection: a hybrid model based on DEAHP and ABC. Int. J. Prod. Res. **50**(7), 1–13 (2011)

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