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A new DEA method for supplier selection in presence of both cardinal and ordinal data

Mehdi Toloo [a,*], Soroosh Nalchigar [b]

[a] Department of Mathematics, Islamic Azad University of Central Tehran Branch, Tehran, Iran
[b] Department of Information Technology Management, Faculty of Management, University of Tehran, Tehran, Iran

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ABSTRACT

The success of a supply chain is highly dependent on selection of best suppliers. These decisions are an important component of production and logistics management for many firms. Little attention is given in the literature to the simultaneous consideration of cardinal and ordinal data in supplier selection process. This paper proposes a new integrated data envelopment analysis (DEA) model which is able to identify most efficient supplier in presence of both cardinal and ordinal data. Then, utilizing this model, an innovative method for prioritizing suppliers by considering multiple criteria is proposed. As an advantage, our method identifies best supplier by solving only one mixed integer linear programming (MILP). Applicability of proposed method is indicated by using data set includes specifications of 18 suppliers.

1. Introduction

Competitive advantages associated with supply chain management (SCM) philosophy can be achieved by strategic collaboration with suppliers and service providers. The success of a supply chain is highly dependent on selection of good suppliers (Ng, 2008). Supplier selection involves the need to trade-off multiple criteria, as well as the presence of both quantitative and qualitative data (Wu, 2009). To manage this strategically important purchasing function effectively, appropriate method and criteria have to be chosen for the problem (Guneri, Yucel, & Ayyildiz, 2009).

Over the years, several techniques have been developed to solve the problem efficiently. Analytic hierarchy process (AHP), analytic network process (ANP), linear programming (LP), mathematical programming, multi-objective programming, data envelopment analysis (DEA), neural networks (NN), case-based reasoning (CBR) and fuzzy set theory (FST) methods have been applied in literature (Guneri et al., 2009). Using DEA, this paper proposes a model for supplier selection.

Traditionally, supplier selection models are based on cardinal data with less emphasis on ordinal data. However, with the widespread use of manufacturing philosophies such as just-in-time (JIT), emphasis has shifted to the simultaneous consideration of cardinal and ordinal data in supplier selection process (Farzipoor Saen, 2007). The main contribution of this paper is to propose a new integrated DEA model for finding most efficient supplier by considering both cardinal and ordinal data. In addition, by using this model, a method is presented for ranking suppliers with cardinal and ordinal data.

DEA is a widely recognized approach for evaluating the efficiencies of decision making units (DMUs). Because of its easy and successful application and case studies, DEA has gained too much attention and widespread use by business and academy researchers. Selection of best vendors (Liu, Ding, & Lall, 2000; Weber, Current, & Desai, 1998), evaluation of data warehouse operations (Mannino, Hong, & Choi, 2008), selection of flexible manufacturing system (Liu, 2008), assessment of bank branch performance (Camanho & Dyson, 2005), examining bank efficiency (Chen, Skully, & Brown, 2005), analyzing firm's financial statements (Edirisinghe & Zhang, 2007), measuring the efficiency of higher education institutions (Johnes, 2006), solving facility layout design (FLD) problem (Ertay, Ruan, & Tuzkaya, 2006) and measuring the efficiency of organizational investments in information technology (Shafer & Byrd, 2000) are samples of using DEA in various areas.

The organization of this paper is as follows. Section 2 reviews previous studies in supplier selection and Section 3 introduces previous related DEA models. In Section 4, a new DEA model is proposed which is able to find most efficient unit with imprecise data. Using this model, Section 5 presents a method for ranking DMUs by simultaneously considering cardinal and ordinal data. Section 6 illustrates application of proposed method. Finally, paper closes with some concluding remarks in Section 7.

2. Literature review

In previous studies, various methods have been proposed for supplier selection. For instance, Weber et al. (1998) described three approaches for selection and negotiation with vendors who were

* Corresponding author. Tel.: +98 9122390003.
E-mail addresses: m_toloo@yahoo.com (M. Toloo), nalchigar@ut.ac.ir (S. Nalchigar).

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not selected. Furthermore, they explained how in certain situations two multi-criteria analysis tools, multi-objective programming and DEA, can be used together for this selection and negotiation process. Karpak, Kumcu, and Kasuganti (2001) presented one of the "user friendly" multiple criteria decision support systems-visual interactive goal programming (VIG). VIG facilitates the introduction of a decision support vehicle that helps improve the supplier selection decisions. Talluri and Baker (2002) presented a multi-phase mathematical programming approach for designing effective supply chain. It should be noted that their method develops and applies a combination of multi-criteria efficiency models, based on game theory concepts, and linear and integer programming methods. Kumar, Vrat, and Shankar (2004) proposed a fuzzy goal programming approach for vendor selection with multiple objectives with some fuzzy parameters. They formulated vendor selection problem as a fuzzy mixed integer goal programming vendor selection problem that includes three primary goals: minimizing the net cost, minimizing the net rejections, and minimizing the net late deliveries subject to realistic constraints regarding buyer's demand, vendors' capacity, vendors' quota flexibility, purchase value of items, budget allocation to individual vendor, etc. Liu and Hai (2005) compared the weighted sum of the selection number of rank vote, after determining the weights in a selected rank. They presented a novel weighting procedure in place of pairwise comparison of AHP for selecting suppliers. They provided a simpler method than AHP that is called voting analytic hierarchy process, but which do not lose the systematic approach of deriving the weights to be used and for scoring the performance of suppliers. Chang, Wang, and Wang (2006) proposed a fuzzy multiple attribute decision making (FMADM) method based on the fuzzy linguistic quantifier to satisfy the current product competition strategies, and also improve the effectiveness and efficiency of the entire supply chain.

Chen, Lin, and Huang (2006) developed a fuzzy decision-making approach for the supplier selection problem in supply chain system. In their method, they used linguistic values to assess the ratings and weights for criteria. These linguistic ratings can be expressed in trapezoidal or triangular fuzzy numbers. Then, a hierarchy multiple criteria decision-making (MCDM) model based on fuzzy-sets theory is proposed to deal with the supplier selection problems in the supply chain system. Finally, they showed applicability of their method in a high-technology manufacturing company. Gencer and Gurpinar (2007) used ANP and proposed a model for supplier selection. Their method include seven steps as follows: analysis of supplier selection problem, determining the goal and supplier selection criteria, determining the alternative suppliers, identification of the network structure and relationships, making the paired comparisons, building the supermatrix and finding the limiting priorities. Finally, they implemented their method in an electronic company. Xia and Wu (2007) developed an integrated approach of AHP improved by rough sets theory and multi-objective mixed integer programming to simultaneously determine the number of suppliers to employ and the order quantity allocated to these suppliers in the case of multiple sourcing, multiple products, with multiple criteria and with supplier's capacity constraints.

Önüt, Kara, and Isik (2009) proposed a supplier evaluation approach based on the analytic network process (ANP) and the technique for order performance by similarity to ideal solution (TOPSIS) methods to help a telecommunication company in the GSM sector in Turkey under the fuzzy environment. They used triangular fuzzy numbers in all pairwise comparison matrices in their method to evaluating suppliers by considering six criteria (cost, reference, quality of product, delivery time, institutionality and execution time). Demirtas and Üstün (2008) combined analytic network process (ANP) and multi-objective mixed integer linear programming (MOMILP) and proposed an approach for selecting best suppliers and defining the optimum quantities among selected suppliers to maximize the total value of purchasing and minimize the budget and defect rate. Wang, Cheng, and Huang (2009) proposed a fuzzy hierarchical TOPSIS method, which not only is well suited for evaluating fuzziness and uncertainty problems, but also can provide more objective and accurate criterion weights, while simultaneously avoiding the problem of its previous Fuzzy TOPSIS method. Ng (2008) proposed a weighted linear program for the multi-criteria supplier selection problem. Furthermore, he studied a transformation technique which enables our proposed model to be solved without an optimizer. Guneri et al. (2009) proposed an integrated fuzzy and linear programming approach for supplier selection problem. Their approach, firstly, assesses weights and ratings of supplier selection criteria with linguistic values expressed in trapezoidal fuzzy numbers. Then a hierarchy multiple model based on fuzzy set theory is expressed and fuzzy positive and negative ideal solutions are used to find each supplier's closeness coefficient. Finally, a linear programming model based on the coefficients of suppliers, buyer's budgeting, suppliers' quality and capacity constraints is developed and order quantities assigned to each supplier according to the linear programming model. Wu (2009) used grey related analysis and Dempster–Shafer theory to deal supplier selection in a fuzzy group decision making problem. It is to be noted that proposed approach uses both quantitative and qualitative data for international supplier selection.

Farzipoor Saen (2007) proposed an innovative method for selecting suppliers in conditions that both ordinal and cardinal data are present (without relying on weight assignment by decision makers). His method identifies best suppliers whose efficiency score is equal to one and is not able to find most efficient supplier. Indeed, by using his method, decision maker cannot decide which supplier is the best among other units.

Investigation of previous related works shows that identifying the best supplier whit imprecise data has gained less attention. This paper tries to fill the gap by proposing a DEA model which is able to find most efficient supplier by considering both cardinal and ordinal data. Moreover, by using this model, an innovative method for ranking suppliers is presented. In the next section, previous related DEA models are explained.

3. DEA models

Performance evaluation is an important task for a DMU to find its weaknesses so that subsequent improvements can be made. Since the pioneering work of Charnes, Cooper, and Rhodes (1978), DEA has demonstrated to be an effective technique for measuring the relative efficiency of a set of DMUs which utilize the same inputs to produce the same outputs.

Assume that there are n DMUs, (DMU_j: $j = 1, 2, \ldots, n$) which consume m inputs ($\mathbf{x}_i : i = 1, 2, \ldots, m$) to produce s outputs ($\mathbf{y}_r : r = 1, 2, \ldots, s$). The CCR input oriented (CCR-I) model evaluates the efficiency of DMU_o, DMU under consideration, by solving the following linear program:

$$
\begin{aligned}
&\max \sum_{r=1}^{s} u_r y_{rj} \\
&\text{s.t.} \\
&\sum_{i=1}^{m} w_i x_{io} = 1 \\
&\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} w_i x_{ij} \leqslant 0 \quad j = 1, 2, \ldots, n \\
&w_i \geqslant \varepsilon \quad i = 1, 2, \ldots, m \\
&u_r \geqslant \varepsilon \quad r = 1, 2, \ldots, s
\end{aligned}
\tag{1}
$$

where x_{ij} and y_{rj} (all nonnegative) are the inputs and outputs of the DMU_j, w_i and u_r are the input and output weights (also referred to as