Applied Mathematical Modelling 34 (2010) 2820–2830

Contents lists available at ScienceDirect

Applied Mathematical Modelling

journal homepage: www.elsevier.com/locate/apm

Restricting weights in supplier selection decisions in the presence of dual-role factors

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ARTICLE INFO

Article history:
Received 26 July 2009
Received in revised form 1 November 2009
Accepted 16 December 2009
Available online 23 December 2009

Keywords:
Data envelopment analysis
Supplier selection
Weight restrictions
Dual-role factors

ABSTRACT

One of the uses of data envelopment analysis (DEA) is supplier selection. Weight restrictions allow for the integration of managerial preferences in terms of relative importance levels of various inputs and outputs. As well, in some situations there is a strong argument for permitting certain factors to simultaneously play the role of both inputs and outputs. The objective of this paper is to propose a method for selecting the best suppliers in the presence of weight restrictions and dual-role factors. This paper depicts the supplier selection process through a DEA model, while allowing for the incorporation of decision maker's preferences and considers multiple factors which simultaneously play both input and output roles. The proposed model does not demand exact weights from the decision maker. This paper presents a robust model to solve the multiple-criteria problem. A numerical example demonstrates the application of the proposed method.

1. Introduction

Supplier selection is the process by which suppliers are reviewed, evaluated, and chosen to become part of the company's supply chain. Shin et al. [1], Farzipoor Saen [2], Farzipoor Saen and Zohrehbandian [3], Farzipoor Saen [4,5] argue that several important factors have caused the current shift to single sourcing or a reduced supplier base. First, multiple sourcing prevents suppliers from achieving the economies of scale based on order volume and learning curve effect. Second, multiple supplier system can be more expensive than a reduced supplier base. For instance, managing a large number of suppliers for a particular item directly increases costs, including the labor and order processing costs to managing multiple source inventories. Meanwhile multiple sourcing lowers overall quality level because of the increased variation in incoming quality among suppliers. Third, a reduced supplier base helps eliminate mistrust between buyers and suppliers due to lack of communication. Fourth, worldwide competition forces firms to find the best suppliers in the world.

One of the uses of data envelopment analysis (DEA) is supplier selection. In original DEA formulations the assessed decision making units (DMUs) can freely choose the weights or values to be assigned to each input and output in a way that maximizes its efficiency, subject to this system of weights being feasible for all other DMUs. This freedom of choice shows the DMU in the best possible light, and is equivalent to assuming that no input or output is more important than any other.

The free imputation of input–output values can be seen as an advantage, especially as far as the identification of inefficiency is concerned. If a DMU (supplier) is free to choose its own value system and some other supplier uses this same value system to show that the first supplier is not efficient, then a stronger statement is being made. The advantages of full flexibility in identifying inefficiency can be seen as disadvantages in the identification of efficiency. An efficient supplier may become so by assigning a zero weight to the inputs and/or outputs on which its performance is worst. This might not be

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doi:10.1016/j.apm.2009.12.016

Table 1
Classification of supplier selection techniques.

Technique name	References
Integer programming	Zeng et al. [10], Ghodsypour and O'Brien [11], Dahel [12], Talluri and Baker [13], Ip et al. [14]
Goal programming	Talluri and Narasimhan [15], Kumar et al. [16], Hajidimitriou and Georgiou [17], Cebi and Bayraktar [18], Cakravastia and Takahashi [19], Arunkumar et al. [20], Karpak et al. [21], Kameshwaran et al. [22], Wang et al. [23]
Analytic hierarchy process (AHP)	Pi and Low [24], Noorul Haq and Kannan [25], Kahraman et al. [26], Wang et al. [27], Sha and Che [28], Min [29], Xia and Wu [30], Dulmin and Mininno [31], Bhutta and Huq [32], Liu and Hai [33], Chan [34]
Analytic network process (ANP)	Bayazit [35]
Fuzzy mathematical programming	Lin and Chen [36], Ohdar and Ray [37], Bevilacqua and Petroni [38], Chen et al. [39], Chang et al. [40], Kwong et al. [41]
Case-based reasoning (CBR)	Choy et al. [42], Choy and Lee [43], Choy et al. [44], Lau et al. [45]

acceptable by decision makers as well as by the analyst, who after spending time in a careful selection of inputs and outputs sees some of them being completely neglected by suppliers.

Decision makers may have in supplier selection problems value judgments that can be formalized *a priori*, and therefore should be taken into account in supplier selection. These value judgments can reflect known information about how the factors used by the suppliers behave, and/or "accepted" beliefs or preferences on the relative worth of inputs, outputs or even suppliers. For example, in supplier selection problem in general, one input (material price) usually overwhelms all other inputs, and ignoring this aspect may lead to biased efficiency results. Suppliers might also supply some outputs that require considerably more resources than others and this marginal rate of substitution between outputs should somehow be taken into account when selecting a supplier. To avoid the problem of free (and often undesirable) specialization, input and output weights should be constrained in DEA.

In some situations there is a strong argument for permitting certain factors to simultaneously play the role of both inputs and outputs. In supplier selection context, the research and development cost can be considered as both an input and an output. Remembering that the simple definition of efficiency is the ratio of output to input, an output can be defined as anything whose increase will cause an increase in efficiency. Similarly, an input can be defined as anything whose decrease will cause an increase in efficiency. If the research and development cost is considered as an output, then the increase in the research and development cost will increase the efficiency of the supplier. Likewise, if the research and development cost is considered as an input, then any decrease in the research and development cost without a proportional decrease in the outputs will increase efficiency. So, depending on how one looks at it, either increasing or decreasing the research and development cost can increase efficiency. As well, as Farzipoor Saen [6] discussed, the factors such as ratings for service-quality experience (EXP) and service-quality credence (CRE) were considered dual-role factors. From the perspective of decision maker who intends to select the best supplier, such measures may play the role of proxy for "high quality of services", hence can reasonably be classified as outputs. On the other hand, from the perspective of supplier that intends to supply reverse logistics services, they can be considered as inputs that help the supplier in obtaining more customers.

Beasley [7,8], in a study of the efficiency of university departments, treated research funding on both the input and output sides. However, as Cook et al. [9] addressed, the model proposed by Beasley [7,8] has two limitations. The first limitation is that in the absence of constraints (e.g., assurance region or cone-ratio) on the multipliers, each DMU will be 100% efficient. The second limitation is that the dual-role factor is considered as a discretionary factor.

Cook et al. [9] developed a new model that has not the above mentioned limitations. However, their development pertains to a single dual-role factor and does not consider multiple dual-role factors.

The objective of this paper is to propose a method for selecting the best suppliers in the presence of both weight restrictions and dual-role factors. This paper depicts the supplier selection process through a DEA model, while allowing for the incorporation of decision maker's preferences and considers multiple factors which simultaneously play both input and output roles.

This paper proceeds as follows. In Section 2, literature review is presented. Section 3 introduces the method which selects the suppliers. Numerical example and concluding remarks are discussed in Sections 4 and 5, respectively.

2. Literature review

Some mathematical programming approaches have been used for supplier selection in the past. Table 1 categorizes the reviewed papers based on applied techniques. However, because of the complexity of the decision making process involved in supplier selection, all the aforementioned references in Table 1, rely on some form of procedures that assigns weights to various performance measures. Meanwhile, they do not consider dual-role factors.

The primary problem associated with arbitrary weights is that they are subjective, and it is often a difficult task for the decision maker to accurately assign numbers to preferences. It is a daunting task for the decision maker to assess weighting information as the number of performance criteria increased.

To this end, Weber [46] demonstrated how DEA can be used to evaluate vendors on multiple criteria and identified benchmark values which can then be used for this purpose. Weber et al. [47] presented an approach for evaluating the number of vendors to employ in a procurement situation using multi-objective programming (MOP) and DEA. The approach advocates