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A flexible deterministic, stochastic and fuzzy Data Envelopment Analysis approach for supply chain risk and vendor selection problem: Simulation analysis

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ABSTRACT

This study consists of three types of vendor selection models in supply chains and presents a decision making scheme for choosing appropriate method for supplier selection under certainty, uncertainty and probabilistic conditions. These models are, Data Envelopment Analysis (DEA), Fuzzy Data Envelopment Analysis (FDEA), and Chance Constraint Data Envelopment Analysis (CCDEA). In FDEA model we use α-cut method in five levels for α, to convert fuzzy DEA into interval programming. Also, we solve the CCDEA model for two levels of probabilities. It is assumed that inputs are random variables. Under this assumption the efficiency scores of Decision Making Units (DMUs) are random variables. Obtained results form each model is: average efficiency scores of DMUs, variance of efficiency scores, and 95% confidence interval for average. Results from three models are compared. Our decision making scheme allows decision makers to perform analysis among input factors which are expected costs, quality of acceptance levels, and on-time delivery. This is the first study to a present a flexible approach for supply chain risk and vendor selection. The superiority of the flexible algorithm is shown for 10 suppliers. Its features are also compared with previous models to show its advantages over previous models.

1. Introduction

Supplier selection is one of the most important functions performed by the purchasing department. The supplier selection is a multi-criterion problem, which includes both qualitative and quantitative factors. The relationship between a company and its supplier has always been critical and companies generally establish a set for evaluation criteria to be used to compare potential sources. The basic criteria typically utilized for this purpose are pricing structure, delivery product quality and service. Sometime these evaluation criteria are in conflict with one another. Supplier selection is a key supply management decision. For example, a tire manufacturer would be considered a supplier to an automobile manufacturer. In this case, the tire supplier would view the automobile manufacturer as the "customer" (SirajUuddin & Varghese, 2005). There are several supplier selection methods available in the literatures. Some of these methods are: Analytical Hierarchical Process (Bayazit & Karpak, 2005), Fuzzy Goal Programming (Kumar, Vrat, & Shankar, 2004), Fuzzy Programming Model (Junyan, Ruiqing, & Wansheng, 2006), Interpretive Structural Modeling (Mandal & Deshmukh, 1994), Particle Swarm Optimization (Mouli, Subbaiah, & Rao, 2006), Simulation–Optimization Approach (Ding, Benyoucef, & Xie, 2003), intelligent model (Das & Shahin, 2003), Multiple Attribute Utility Approach (MAUT) (Min, 1994). Mathematical programming models often consider only the more quantitative criteria. Also some different methods such as, Fuzzy Logic approaches (Bevilacqua & Petroni, 2002; Lee, 2008; Noorul Haq & Kannan, 2006; Wanga, Zhaoa, & Tang, 2008; Yang, Chiu, & Tzeng, 2008; Ying, 2008), Analytical Hierarchy Process approaches (Al-Faraj, Alidi, & Al-Zayer, 1993; Bhutta & Huq, 2002; Chan, 2003; Venkata Rao, 2007; Yao & Hongli, 2007), Multi-Objective Programming (MOP) (Arunkumar, Karunamoorthy, Anand, & Ramesh Babu, 2006; Karpak, Kasuganti, & Kumcn, 1999), Mixed Integer Programming (Hartmut, 2007), Chance-Constrained and Genetic algorithm (He, Chaudhry, & Lei, 2008), Taguchi method (Pi & Low, 2005, 2006; Pi & Low, 2006), Data Envelopment Analysis (DEA), Optimization Techniques (OP) (Arunkumar, Karunamoorthy, Lobo Shenoy, Thamizhvaanan, & Naidu, 2008), TOPSIS approach (Li, Chen, & Fu, 2008), Integrated Approach (Ting & Cho, 2008), Total Cost of Ownership approach (TCO) (Bhutta & Huq, 2002), Hybrid AHP (Sevkli, Koh, Zaim, Demirbag, & Tatoglu, 2008) and etc. are exists.

1.1. Objectives

The objective of this study is to present a flexible DEA–FDEA–CCDEA approach for vendor selection problem. The flexible approach uses DEA when the input data is crisp. It would also use FDEA or CCDEA when data is not crisp. This is an important issue

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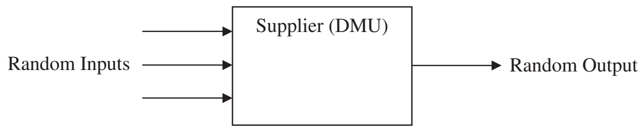

Fig. 1. A DMU as a supplier.

in real world supplier selection problems. Moreover, in real situations, we may face with deterministic, probabilistic or fuzzy data and the flexible approach is capable of handling such situations for managers and decision makers.

1.2. Methods

In this study a DMU define as a supplier. Fig. 1 shows a DMU structure in supply chain management SirajUuddin and Varghese (2005).

In the all models (DEA, FDEA, CCDEA), the DMU structure are the same as Fig. 1 to solve the vendor selection problem. Monte Carlo simulation approach is used to solve the above models. For each model we determine the mean DEA efficiency score, variance and 95% confidence interval for mean. To solve the DEA, FDEA and CCDEA model we use the LINGO 8.0 and MS Excel 2003.

1.3. Significance

In the real world, we face with insecure data. The one advantage of FDEA and CCDEA model is that, these models deal with insecure data. And in this paper, we scrutinize the vendor selection problem in certainty, uncertainty and probabilistic conditions and present a flexible approach to make decision for choosing appropriate method for vendor selection.

2. The flexible approach

The proposed flexible approach of this study is shown in Fig. 2. After data is collected, it is checked for its status: crisp or non-crisp. FDEA is used for non-crisp data. However, for crisp data the probability level (β) is checked. If probability level is equal to 1 then DEA is used. Otherwise, CCDEA is implemented to rank and locate best and worst vendors. The value of β is divided into two classes: equal to 1, or not equal to 1. Based on this approach we deal with three conditions as follows:

1. Data is crisp, and $\beta = 1$, then use DEA method.
2. Data is crisp, and $\beta \neq 1$, then use CCDEA method.
3. Data is non-crisp, then, use FDEA method.

Next section provides the mathematics of DEA, FDEA and CCDEA. Also, the know how of evaluating β is described.

2.1. Data Envelopment Analysis (DEA)

Data Envelopment Analysis (DEA) by Charnes et al. (1978) is a method for evaluating the relative efficiency of comparable entities referred to as Decision Making Units (DMU). The DMUs are characterized by several inputs and outputs. The efficiency score in the midst of multiple input and output factors is defined as Talluri (2000):

$$E = \frac{\text{weighted sum of outputs}}{\text{weighted sum of inputs}}. \tag{1}$$

Assuming that there are n DMUs, each with same 'm' inputs and same 's' outputs. The relative efficiency score of a test DMU p is obtained by solving the following model proposed by Charnes et al. (1978):

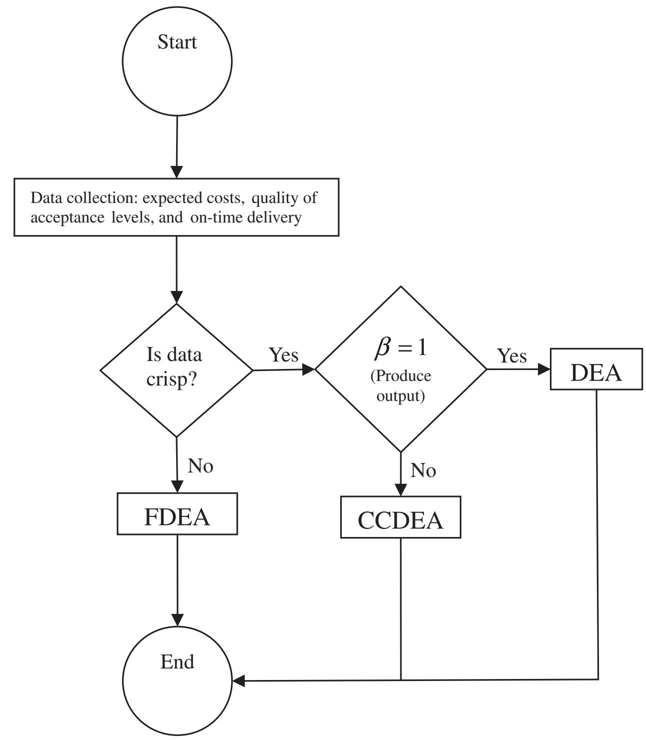

Fig. 2. Decision making flowchart to choose from DEA, FDEA and CCDEA.

$$\begin{aligned} Max \quad & \frac{\sum_{k=1}^{s} u_k y_{kp}}{\sum_{j=1}^{m} v_j x_{jp}} \\ s.t. \quad & \frac{\sum_{k=1}^{s} u_k y_{ki}}{\sum_{j=1}^{m} v_j x_{ji}} \leqslant 1 \\ & v_k, u_k \geqslant 0 \end{aligned} \tag{2}$$

where k = 1 to s, j = 1 to m, i = 1 to n, y_{ki} is the amount of output k produced by DMU_i, x_{ji} is the amount of input j utilized by DMU_i, v_k is the weight given to input k, and u_k is the weight given to output j.

The nonlinear program shown as (2) can be converted to a linear program as shown in (3).

$$\begin{aligned} Max \quad & \sum_{k=1}^{s} u_k y_{kp} \\ s.t. \quad & \sum_{j=1}^{m} v_j x_{jp} = 1 \\ & \sum_{k=1}^{s} u_k y_{ki} - \sum_{j=1}^{m} v_j x_{ji} \leqslant 0 \\ & v_k, u_j \geqslant 0 \end{aligned} \tag{3}$$

We should run program (3), n-times to calculate the efficiency of n DMUs. In general, a DMU is considered to be efficient if it obtains a score of 1 and a score of less than 1 implies that it is inefficient. For LINGO model, see Appendix A.

2.2. Fuzzy Data Envelopment Analysis (FDEA)

Evaluating the performance of one decision making unit (DMU) by traditional Data Envelopment Analysis (DEA) models requires crisp input/output data. However, in real-world problems inputs and outputs are often imprecise. This section develops DEA models using imprecise data represented by fuzzy sets.