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Supplier Selection in B2B Manufacturing Commerce using AHP-DEA

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Abstract: Supplier selection is a critical and demanding task for companies that participate in B2B manufacturing e-commerce. In this paper, we propose anintegrated analytic hierarchy process- data envelopment analysis (AHP-DEA) for multiple criteria supplier selection. The proposed AHP–DEA methodology uses the AHP to determine the weights of criteria, the dataenvelopment analysis (DEA) method to determine the values of the linguistic terms. A numerical example demonstrates the application of the proposed method.

Introduction

The advent of the Internet has led to the flourishing development of e-commerce. As indicated by the Economic Review of the Federal Reserve Bank of Kansas City, between 1999 and 2002, B2B e-commerce sales grew at an annual rate of 5.5 percent in the United States. In e-commerce era, the complexity and levity ofprocurement management become greatly outstandingbecause customer demands are changing faster and faster. There is an agreement in relevant literature that selecting appropriate suppliers is a complicated issue because of the large number of criteria to be considered as well as because criteria are both quantitative and qualitative. Thus, there is a strongly urge for a more systematic and transparent method to purchasing decision making, especially regarding the area of supplier selection.

Supplier selection problem (SSP) is essentially a multiple criteria decision making (MCDM) problem, which involve multipleassessment criteria such as price, quality, design/technological capability, finances and so on. Of the MCDM approaches, the analytic hierarchy process (AHP) method isparticularly suitable for modeling qualitative criteria and has found extensive applications in a wide variety of areassuch as selection, evaluation, planning and development, decision making forecasting, and so on. However, due to thefact that there are tenths or hundreds of items to be evaluated and prioritized, while the AHP method can only comparea very limited number of decision alternatives, the pair-wise comparison manner is obviously infeasible in this situation. To overcome this difficulty, we combine the AHP with the data envelopment analysis (DEA) and propose an integratedAHP–DEA methodology in this paper. The effectiveness of our approach is demonstrated through the provision of a numerical example of a metal manufacturing company that finds and selects suppliers in the environment of an electronic marketplace providing decision support services on this basis.

The remainder of this study is structured as follows:Section 2 describes a background of the supplier selection process and related work. Section 3 introduces the proposed approach for supplier selection. In Section 4 the proposed method is illustrated by a numerical example. Section 5 wraps up the paper with some concluding remarks

Background

A large number of the researches dealing with procurement decision are concerned with selecting the best suppliertaking into account the multi-objective nature of the problem. In this area, several methods have been suggested in theliterature. The most common approach that has been firstly endorsed by Wind and Robinson [1] in supplier selectionuses linear weighting models to assess the vendor's performance. Except for Grando and Sianesi [3] that do not combine ratings on different criteria into one overall score and DeBoer et al. [4] which propose a partially compensatory approach, these and similar methods are usually referred toas compensatory approaches. Dulmin and Mininno [5] focused on the problem of criteria weights'assessment. They propose an interesting survey of most commonly used methods and contend that the set of weightsshould be a dynamic vector.

Using pairwise comparison, a more accurate scoring method that has been applied on supplier selection is theanalytical hierarchy process (AHP). Narasimhan [2], Partovi et al. [6], Nydick and Hill [7], Barbarosoglu andYazgac [8],Yahya and Kingsman [9], Masella and Rangone [10], Tam and Tummala [11], Lee et al. [12], Handfieldet al. [13] and Colombo and Francalanci [14] propose the use of this technique to cope especially with determiningscores.

Simple linear weighting models have also been adapted to deal with uncertainty in decision making deriving fromincomplete and qualitative data and unstructured purchasing situations. Soukup [15] presents a method to deal with the uncertainty issue that focuses on the requirements' uncertainty. Other approaches not requiring precise weight assessments are statistical, such as those proposed byWilliams [16],Min [17] and Petroni and Braglia [18]. Thompson [19] introduces Monte Carlo simulation to reduce the uncertainty innate to the rating mechanism. Afterward,he applied the Thurstone Case V scaling technique [20].

Data envelopment analysis (DEA) proposed by Charnes et al. (1978) (CCR model) and developed by Banker et al. (1984) (BCC model) is an approach for evaluating the efficiencies of decision making units (DMUs). Consequently, a number of alternative DEA models have been proposed.DEA-AHP (Data Envelopment Analytic Hierarchy Process) is a new model that has been developed by Ramanathan (2006); it is a hybrid methodology of DEA and AHP, used to prove that DEAcorrectly estimates the true weight when applied to a consistent matrix formed using a known set of weights. Theuse of DEA was further proposed to aggregate the local weights of alternatives in terms of different criteria tocompute the final local weight.

Proposed method for suppliers selection

In this section we present our proposal for a supplier selection method in a B2B e-marketplace environment.Consider a generic MC-SSP problem with C criteria and R items, where any decision criterioncan be further broken down into more sub-criteria if necessary. The normalized weight vector of decisioncriteria,$\mathrm{W} = (W_1, \cdots, W_C)$, is assumed to have been obtained through AHP.

Suppose there is a set of n peer DMU_s,$\{DMU_j: j = 1,2,\cdots,n\}$,which produce multiple out-puts $y_{rj}(r = 1,2,\cdots,s)$,by utilizing multiple inputs $x_{ij}(i = 1,2,\cdots,m)$. When a DMU_0 is under evaluation by the CCR model, there is.

$$\max\theta_0 = \sum_{r=1}^{s} u_r y_{r0}$$

$$\text{s.t.}\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0, \ \forall j \tag{1}$$

$$\sum_{i=1}^{m} w_i x_{i0} = 1$$

$$u_r, v_i \geq 0, \forall r, i$$

Where$u_r$is weight of the rth output andv_i is weight of the ith input. They are calculated by AHP method.

Obviously, model Eq. (1) is nonlinear and non-convex, because some of the outputs and inputsbecome unknown decision variables. Since modelEq. (1) is nonlinear and non-convex, consequentlylocal optimum is produced and we cannot be surewhether this is the global optimum or not.

To convert model Eq. (1) into the linear program, Zhu (2003) developed a simple approach bydefining

$$X_{ij} = v_i x_{ij} \ \forall i, j$$

$$Y_{rj} = u_i y_{rj} \ \forall r, j \tag{2}$$

Then model Eq. (1) can be converted into the following linear program:

$$\max\theta_0^* = \sum_{r=1}^{s} Y_{r0}$$

$$\text{s.t.}\sum_{r=1}^{s} Y_{rj} - \sum_{i=1}^{m} X_{ij} \leq 0, \ \forall j \tag{3}$$

$$\sum_{i=1}^{m} X_{i0} = 1$$

$$X_{ij}, Y_{rj} \geq 0, \forall r, i$$

In the next section, a numerical example is presented.

Numerical example

The data set for this example is contains specificationson 12 suppliers. The input considered is price, distance whiledelivery time, qualitywill serve as the bounded data output, thus $s = 2,\ m = 2$. This qualitative variable is measured on an ordinal scale. Table 1 depicts the supplier's attributes.

The normalized weight vector of decisioncriteria $u_r = (0.6, 0.4)$, $v_i = (0.35, 0.65)$, is assumed to have been obtained through AHP.

Applying model in Eq. (3), the efficiency scores of suppliers (DMUs) have been presented in the last column of Table 1.

Table 1Related attributes for 12 suppliers and efficiency scores

Supplier (DMU)	Inputs		Output		Efficiency
	$price_j$	distance	delivery time	quality	
weight	0.6	0.4	0.35	0.65	
1	53	39	0.84	0.92	0.86
2	67	23	0.91	0.91	0.97
3	45	45	0.72	0.94	0.92
4	56	56	0.75	0.88	0.82
5	54	72	0.73	0.93	0.89
6	56	35	0.68	0.85	0.78
7	46	47	0.93	0.74	0.69
8	48	58	0.78	0.88	0.77
9	62	46	0.69	0.92	0.83
10	58	67	0.98	0.96	1
11	49	57	0.83	0.89	0.79
12	73	66	0.97	0.98	0.94

Model Eq. (3) identified suppliers 10 to be efficient with a relative efficiencyscore of 1. The remaining 11 suppliers with relativeefficiency scores of less than 1 are considered inefficient. Therefore, decision maker can choose one ormore of these efficient suppliers.

Concluding remarks

The effectiveness and rationalityof the critical task of supplier selection have become central forthe decision makers of buyer organizations. This paper proposed an integrated model by integration of DEA, AHP for complex SSP in B2B e-commerce. The integratedmodel can be used for selecting optimum alternative by considering multi objectives criteria. Qualitative outputsare evaluated by AHP and then DEA is used to identify optimum alternatives.

To avoid making a large number of pairwise comparisons, the proposed AHP–DEA methodologyuses AHP to determine the weights of criteria, DEA model with common weights to determine the values of the linguisticterms. A numerical example has been investigated toillustrate the applications of the proposed AHP–DEA methodology. It is shown that the new integratedAHP–DEAmethodology is simple enough, easy to use, applicable to any number of decision alternatives, and particularly usefuland effective to complex MCDM problems with a large number of decision alternatives, where pairwise comparisonsare certainly impossible to be made.

The integrated modeling approach illustrated and explained in this paper can be used to solve otherreal world problems.

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