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An integrated neural network and data envelopment analysis for supplier evaluation under incomplete information

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Abstract

Supplier evaluation and selection are critical decision making processes that require consideration of a variety of attributes. Several studies have been performed for effective evaluation and selection of suppliers by utilizing several techniques such as linear weighting methods, mathematical programming models, statistical methods and AI based techniques.

One of the successful evaluation methods proposed for this purpose is data envelopment analysis (DEA), that utilizes techniques of mathematical programming to evaluate the performance of a set of homogeneous decision making units, when multiple inputs and outputs need to be considered. It is often complicated, costly and sometimes impossible to acquire all necessary information from all potential suppliers to attain a reasonable set of similar input and output values which is an essential for DEA.

The purpose of this study is to explore a novel integration of neural networks (NN) and data envelopment analysis for evaluation of suppliers under incomplete information of evaluation criteria.

Keywords: Supplier evaluation; Neural networks; Data envelopment analysis

1. Introduction

Tough rules of competition require quick response to rapid market changes while maintaining profitability. Effective management of collaborative supply chain networks (SCNs) is a fruitful solution to increase the efficiency of production and service performances and competitiveness of companies because of their direct impact on a variety of final product dimensions such as cost, product and design quality, and producibility (Talluri, 2002). Once a well-managed and established supply chain is developed, it has a lasting effect on the competitiveness of the entire supply chain (Chen, Lin, & Huang, 2006) in that selecting right suppliers has a significant effect on improving corporate competitiveness (Boer, Labro, & Morlacchi, 2001). As a result, supplier evaluation has become more critical and effective and robust evaluation methods are required for measuring the supplier performance.

Supplier evaluation is a complicated and difficult process as a consequence of possibly conflicting multiple criteria, involvement of many alternatives and internal and external constraints imposed on the buying process (Jayaraman, Srivastava, & Benton, 1999). Therefore, a wide range of techniques which include conceptual, empirical, and modeling approaches have been applied in various studies to address the issue of supplier evaluation.

1.1. Data envelopment analysis

Data envelopment analysis (DEA), is a mathematical programming formulation based technique, that develops an efficient frontier to provide an estimate of relative efficiency for each decision making unit (DMU) in the problem set. DEA is built around the concept of evaluating the efficiency of a decision alternative based on its performance of creating outputs in means of input consumption. So, the efficiency of a DMU is defined as the ratio of the weighted sum of its outputs (i.e. performance) to the weighted sum of its inputs (i.e. resources utilized). For each

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DMU, DEA finds the most favorable set of weights, i.e. the set of weights that maximizes the DMUs efficiency rating without making its own or any other DMUs rating greater than one. As a result, it aids the decision maker in classifying the DMUs into two categories: the efficient ones and the inefficient ones (Boer et al., 2001). A general description of the model may be found in several studies (Weber, 1996; Shafer & Bryd, 2000), and a detailed explanation is given in Cooper (1999) and Charnes, Cooper, Lewin, and Seiford (1995).

As mentioned earlier, supplier evaluation inherently is a multi-criteria decision-making problem which may involve both quantitative and qualitative factors (Ghodsypour & O'Brien, 2001). DEA offers an estimate of comparative efficiency in situations in which multiple inputs and multiple outputs are under consideration (Cooper, 1999) and can handle large numbers of variables and relations (constraints). This relaxes the requirements that are often encountered when one is limited to choosing only a few inputs and outputs that the techniques employed will otherwise encounter difficulties. Consequently, DEA has been popular for providing an effective technique for supplier selection and evaluation problems.

Weber and Ellram (1992), Weber and Desai (1996), Weber, Current, and Desai (1998) have discussed the application of DEA in supplier selection in several studies, and apart from just categorizing suppliers, they showed how DEA can be used as a tool for negotiating with inefficient suppliers. Talluri and Baker (2002), present a multi-phase mathematical programming approach for effective supply chain design by: (1) evaluation of supplier, manufacturer and distribution candidates, (2) identification of the optimal number of suppliers, and (3) identification of optimal routing decisions. They use DEA to determine the suppliers' efficiency scores in the first phase. In a later study, Talluri, Narasimhan, and Nair (2006) presented a chance-constrained data envelopment analysis (CCDEA) for evaluation of vendor performances more accurately. CCDEA considers variability in vendor attributes in the presence of multiple uncertain performance measures.

1.2. Drawbacks associated with DEA

Although DEA is used in several number of studies dealing with the supplier selection and evaluation problem, it still includes following drawbacks which makes it infeasible to be applied in various cases:

- The *efficient frontier* is the boundary of the convex hull of the set of best performing decision making units, based on a set of observations of the levels of actual inputs and outputs. The implicit assumption here is that the observations refer to reasonably homogenous decision making units whose performances are comparable in the sense that they share a common production feasibility set. Consequently, DEA is a valid evaluation method only when decision making units are comparable, meaning they use the same set of inputs to produce the same set of outputs (Cooper, 1999).
- DEA assumes that the collected data accurately reflects all relevant input and output variables that describe the evaluation process. In practice, this is a restrictive assumption that gathering complete information on all relevant inputs and outputs may not be feasible. One way of dealing with this drawback is to use only evaluation criteria which are shared by all suppliers and also accurate and complete information can be acquired about. However, numerous decision criteria need to be considered to come up with a complete and accurate way of measuring supplier performance. This raises the issue of supplier rating systems: the more accurate the system, the more difficult and expensive it is to gather supporting data.
  Another approach is to simplify the evaluation task by paying more attention to only a few most important criteria and ignore the rest. However, the less important factors may indeed be the major determinants in the final decision because the most competitive suppliers are similar in the most important factors (Dempsey, 1978). As a result, the factors which ultimately determine the winning suppliers may be the ones which are not initially considered as important as main factors.
- In DEA, the number of different inputs and outputs included in the model defines the number of constraints. As the number of constraints increases, the efficiency scores of DMUs will also increase (Nunamaker, 1985) and more suppliers tend to lie on or close to the frontier.

In order to overcome with limitations associated with homogeneity and accuracy assumptions of DEA, this paper aims to propose a supplier evaluation method which integrates neural networks and data envelopment analysis. Neural networks are used to reduce the general evaluation criteria set into a set of common performance measures which all decision units share and can be compared upon. The choice of use of neural network systems over traditional classification methods depends on their success on estimating the nonlinear functions (Wei, Zhang, & Li, 1997). Also they provide reduction on dependence on personal experience, improvement in decision quality and shorter response times.

2. An integrated neural network and data envelopment analysis for supplier evaluation

This paper develops an integrated NN–DEA method for evaluation of the most favorable suppliers among potentials under incomplete information of evaluation measures.

First step of the study is identification of evaluation criteria that need to be considered in the problem. Then, by use of performance history data and opinions of the experts or decision makers, back propagated neural networks are trained to reduce the set of the attributes into predefined