Supplier selection problem: A literature review of Multi-criteria approaches based on DEA

Alexios-Patapios Kontis¹ and Vassilios Vrysagotis²

Abstract
Supplier selection problem usually is very complicated, because variety of uncontrollable and unpredictable factors affect on evaluation and decision-making process. Various decision making approaches have been proposed to tackle the problem as part of a general tendering process, particularly those of multi-criteria analysis which use both quantitative and qualitative data. Specifically for this problem have been proposed methodologies and techniques included methods such as Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), Case-Based Reasoning (CBR), Genetic Algorithms (GA), SMART theory (Simple Multi-Attribute Rating Technique) and Data Envelopment Analysis (DEA). This paper reviews the literature of the multi-criteria decision making approaches for evaluation and selection supplier based on Data Envelopment Analysis (DEA) and (its their) combinations.

¹ Department of Logistics Management, Technological Educational Institute of Chalkida, Greece, e-mail: alexis.kontis@gmail.com
² Department of Logistics Management, Technological Educational Institute of Chalkida, Greece, e-mail: brisxri@otenet.gr

Article Info: Revised: October 24, 2011. Published online: October 31, 2011
JEL Classification: C81

Keywords: Multi-criteria decision making, Data Envelopment Analysis (DEA), supplier evaluation and selection

1 Introduction

In an era of global sourcing, business’s success often hinges on the most appropriate selection of its partners and suppliers. Procurement is an increasingly important activity within most firms, and severe financial and operational consequences can result from the failure to optimize the procurement function. Specifically, appropriate suppliers selection is one of the fundamental strategies for enhancing the quality of output of any organization, which has a direct influence on the company’s competitiveness and reputation. Suppliers’ evaluation and selection process became vital for the entire width of business sizes and activities [1]. The selection process involves the determination of quantitative and qualitative factors so as to select the best possible suppliers, which ensure business competitiveness, sustainability and success. Consequently, the supplier selection problem requires the consideration of multiple objectives, and hence can be viewed as a multi-criteria decision-making (MCDM) problem [2]. Over the last decade the research community has extensively studied the problem of evaluating and selecting suppliers, adopting approaches and implementations from a wide range of mathematical practices and methodologies. Consequently, numerous multi-criteria decision support tools have been developed for structuring and supporting such decisions [3] [4]. Major part of total body of research for supplier’s evaluation and selection problem, consists from Data Envelopment Analysis (DEA) approaches. Other related approaches based on AHP (Analytic Hierarchy Process), Fuzzy Sets Theory, Goal Programming and combination of them have been proposed to solve the suppliers decision-making problem. Data
Data envelopment analysis was developed by Rhodes [5] and initially detailed and publicized by Charnes, Cooper and Rhodes [6] for evaluating more than two decision outcomes and/or Decision Making Units (DMUs) with respect to their relative efficiencies, based upon multiple criteria. DEA is built on the theoretical foundations provided by Farrell [7] and continues to be popular for a wide variety of applications [8] [9]. Beyond identifying efficient outcomes, DEA has been used to identify the existence of technical and managerial efficiencies.

2 Implementations of Data Envelopment Analysis (DEA) in supplier evaluation and selection

Much of the research for suppliers evaluation and selection lies in Data Envelopment Analysis (DEA) methods and its variants, because DEA is a non-parametric, linear programming based technique for measuring the relative efficiency of homogeneous units that consume incommensurable multiple inputs and produce multiple outputs. The inputs and outputs are assumed to be continuous positive variables and the weights are estimated in favor of each evaluating unit to maximize its efficiency. DEA achieves to classify the units into efficient units that achieve efficiency scores equal to the upper bound and inefficient units that are those that do not succeed to do so. DEA is a widely accepted evaluation method by researchers and practitioners because it has repeatedly proved its ability to effectively handle multiple conflicting properties associated with the modern requirements of administrative sciences inherent in supplier selection and beyond.

In order to facilitate readers, presented DEA approaches divided in individual and integrated.
2.1 Evaluation and selection processes based on individual approaches of DEA

- Weber in 1996 [10] suggests that Data Envelopment Analysis (DEA) can be used as an objective method to evaluate suppliers based on multiple criteria and identified benchmarking values.

- Four years later, Liu, Ding an Lall [11] recognizing the usefulness of DEA as a multi-criteria evaluating methodology and the need for more functional and efficiently suppliers selection systems, proposed a simplified model of DEA to evaluate the overall performance of suppliers, considering three inputs and two outputs. The model aimed to highlight the supplier who offering the greatest supplies variety.

- Forker and Mendez [12] applied DEA in order to benchmarking the comparative efficiency of suppliers in order to help companies save time and resources by identify the “best peer” supplier(s). “Best peer” suppliers can be imitated by companies with similar organizational structures by paying the least amount of effort. Forker and Mendez method for each supplier calculated the maximum ratio of multiple outputs for each single input and use Cross-Efficiency to filter the total results.

- Narasimhan, Talluri and Mendez [13] recognizing that business performance based on total performance of suppliers network propose a DEA model for effective supplier performance evaluation, based on eleven critical factors, six inputs and five outputs. Combining the results of DEA with managerial performance rating, suppliers identifying into 4 clusters: High performance and Efficient (HE), High performance and Inefficient (HI), Low performance and Efficient (LE) and Low performance and Inefficient (LI). Based on this categorization firms on HI, LE and LI suppliers clusters could improve their operations across a variety of dimensions by benchmarking and analyzing High performance and Efficient (HE) suppliers.
Talluri and Sarkis [14] using DEA to formulate a new model for performance monitoring of suppliers. The aims of this paper were to apply a new multi-criteria evaluation model for supplier performance evaluation by considering various performance criteria, such as to serve a monitoring and control mechanism for the performance of suppliers. The new model and its apply based on data of a previously published illustrative case study of Talluri and Baker [15].

Talluri and Narasimhan [16] aiming to propose an objective framework for effective supplier sourcing, which considers multiple strategic and operational factors in the evaluation process, applied a similar technique to Narasimhan, Talluri and Mendez (2001) based on statistical indicators and Cross-Efficiencies to classify suppliers compared to their effectiveness.

Ross, Buffà, Dröge and Carrington [17] at their Action Research (AR) framework developed and suggested a DEA model which examines supplier’s efficiency focused on buyer's perspective.

Garfamy [18] focused on Total Cost of Ownership (TCO) applied a DEA model to evaluate the overall performance of suppliers, claiming that the supplier with the lowest cost per unit is the most efficient supplier.

Sean’s [19] objective is to propose an innovative method based on DEA for selecting suppliers in the presence of nondiscretionary factors from supplier’s perspective. He introduce in evaluating process quality factors that measured by ordinal data. At this paper the factor "know-how transfer" was assessed on a qualitative scale of 5 points.

In Seydel’s [20] research, the suppliers’ evaluation model does not focus on inputs but on outputs which have qualitative characteristics rated on a seven level scale. Proposed method is compared with the SMART methodology, noting that requires less participation of decision maker and less data.

Talluri, Narasimhan and Nair [21] addressing the complexities associated with stochastic approaches for effectiveness assessment, suggest a
“Chance-Constrained Data Envelopment Analysis” (CCDEA) approach in the presence of multiple performance measures that are uncertain. In this model, the price used as an input while the quality and delivery is considered as outputs.

- Smirlis, Panta, Kaimakamis and Sfakianakis [22], in order to develop a systematic and reliability evaluation model for selecting Third Party Logistics (3PL) partners, suggest a DEA methodology based on the estimation of a superiority index which achieves to discriminate them into beneficiary and non beneficiary.

- Saen [23] facing with a main problem of supplier selection process, the use both quantitative and qualitative data, present an innovative variation of DEA (imprecise DEA) based on non-precise of Fuzzy data which include verity of cardinal and ordinal data. The proposed model can handle non-precise of fuzzy data as precise.

- Following the same path, Wu, Shunk, Blackhurst and Appalla [24] propose an improved version of supplier selection model based on non-precise data which had potential for further discrimination of efficiently selection.

- Wu and Blackhurst [25] in aim to eliminate the potential weaknesses of basic DEA model as well as the cross-efficiency and super-efficiency models, suggest an Augmented DEA approach with enhanced discriminatory power that can be used in supplier evaluation and selection. They have added two enhancements to the basic DEA model: the inclusion of “virtual standards” which are spanned across a range (rather than being a single point or benchmark); and the introduction of weight constraints.

- Panta, Smirlis and Sfakianakis [26] in order to propose a efficient decision making approach in relation with the existing fixed weighted framework for the procurement of products and services for Public Organizations, develop a DEA model that overcomes the above mentioned shortcoming. The main characteristics of this model are the ability to incorporate different price
levels and the flexibility of setting the weights in favor of each evaluated bid, ensuring that the winner has uncontested superiority.

2.2 Evaluation and selection processes based on integrated approaches of DEA

Except the approaches which use classical implementation of DEA to solve suppliers decision-making problem, research community suggest numerous of innovative combinations approaches whose at least a part based on DEA.

- Weber, Current and Desai [27] aiming to determine the optimal order quantity, suggests DEA in conjunction with Multi-Objective Programming (MOP). According to this approach, MOP is used to develop vendor-order quantity solutions, whom calls “supervendors” and then evaluating the efficiency of these “supervendors” on multiple criteria using DEA.

- Braglia and Petroni [28] applied Data Envelopment Analysis to measure the efficiencies of candidates’ suppliers. In order to evaluate and rank alternative suppliers they use nine key factors. For ensuring selection process they apply both Cross-Efficiency and Maverick index.

- Talluri and Baker [15] present a multi-phase mathematical programming approach for designing effectively supply chain networks. Specifically, they develop and apply a combination of multi-criteria efficiency models, based on Game Theory concepts, and Linear and Integer Programming methods. In first stage, potential suppliers and manufacturers were evaluated separately in two inputs and four outputs using DEA. Based on the results of this phase, at the second phase developed a supply and distribution model of goods in warehouses by identifying the optimal number of suppliers, manufactures and distributors. Finally, the third phase involves
the initial deployment plans, which identify the optimal routing of material from selected suppliers to manufacturers by minimizing the total cost. 

- Saydel [29] aiming to support sole-sourcing decision-making discussion, uses an example of ten supplier to present SMART (Simple Multi-Attribute Rating Technique) and DEA and demonstrate their efficiency. The results from these two approaches are compared to those based upon a pure aggregation and averaging procedure.

- Saen [30] aiming to evaluating and selecting slightly non-homogeneous suppliers proposed an innovative approach which combines AHP and DEA. Recognizing that suppliers do not consume common inputs to supply common outputs, used AHP to identify the relative weight of each supplier and DEA to compute the relative efficiency of each supplier.

- Ramanathan [31] study attempted to extend the analysis proposed by Bhutta and Huq [2], which evaluate suppliers performance using Total Cost of Ownership (TCO) considering the quantitative factor of cost, and Analytical Hierarchy Process (AHP) to consider a mix of qualitative factors. Through his research suggests a combination of objective and subjective information provided by the results of the Total Cost of Ownership (TCO) and Analytical Hierarchy Process (AHP) approaches via Data Envelopment Analysis (DEA).

- In order to select competitive suppliers in a supply chain, Ha and Krishnan [32] outlined a hybrid method, which incorporates multiple techniques (i.e., AHP, DEA, and ANN) into an integrated process. Proposed hybrid method uses an AHP to assign weight to the qualitative selection criteria, and combination of Artificial Neural Network (ANN) and DEA in order to rated the overall performance index of vendors. Final selection process is based in cluster analysis which returns a Supplier Map (SM) that imprints suppliers position within different segments, according to performance of qualitative and quantitative dimensions.
Ozdemir and Temur [33] developed an expert system on supplier evaluation process by designing Artificial Neural Network (ANN) that is supported with Data Envelopment Analysis (DEA). Proposed model uses a total of variables such as Material Quality (MQ), Discount Of Amount (DOA), Discount Of Cash (DOC), Payment Term (PT), Delivery Time (DT) and Annual Revenue (AR).

Desheng Wu [34] presents a hybrid model which combining Data Envelopment Analysis (DEA), Decision Trees (DT) and Neural Networks (NNs) to evaluate supplier performance aiming to a favorable classification and prediction accuracy rate. Proposed hybrid model is consisted of two modules, can function as both a classification model and a regression model. Module 1 applies two-stage DEA and classifies suppliers into efficient and inefficient clusters based on the computed efficiency scores. Module 2 is a classification or regression module based on the Decision Tree or the Neural Network.

3 Observations and recommendations

The primary advantages of Data Envelopment Analysis are that it considers multiple factors and does not require parametric assumptions of traditional multivariate methods. However, in the application of DEA models there are some critical factors which have to be considered. Efficiency scores could be very sensitive to changes in the data and depend heavily on the number and type of input and output factors considered. In general, inputs can include any resources utilized by a DMU, and the outputs can range from actual products to a range of performance and activity measures. The size of the data set is also an important factor when using some of the traditional DEA models, however, some of these sample size problems can be overcome by using cross-efficiency models.
4 Conclusions

In this paper we review recently literature about solving supplier's evaluation and selection problem, based on DEA and some methodological extensions that could be utilized to improve its discriminatory power in performance evaluation, therefore by no means exhausts all the developments occurring on DEA technique. In general literature, in the last period there is significant work in the field of sensitivity analysis in DEA, target setting in DEA, stochastic DEA, profiling in DEA, among other developments. In the field of supplier evaluation, it’s clear over the time, that DEA methodology develops, enriches and improves both the discretionary ability and effectiveness in managing multi-criteria, decisions-making problems. Moreover, research community adds new, innovative and integrated methodological approaches utilizing the multiple capabilities of DEA creatively, making the method more user-friendly, handling and functional.

References


