Efficiency and Ranking Measurement of Vendors by Data Envelopment Analysis

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Abstract

One of the key issues in logistics management context is the measurement of the vendors' efficiency which helps companies to achieve the most appropriate services. In today's competitive condition, most of the firms have changed from a single vendor to a multi-vendor point of view. A number of conceptual and analytical models have also been developed for identifying the vendor selection problems. It has been recognized that a lot of factors may influence the vendors' efficiency therefore a suitable approach is required to consider major factors in order to select the most efficient ones. This paper presents a practical approach for evaluating vendors which provide the required services in a procurement situation. This approach uses data envelopment analysis to evaluate the vendors' efficiency. Anderson and Peterson model is also applied to rank the efficient vendors. The criteria considered in this model are service quality, price, average of late deliveries and rate of rejected parts. A case study is implemented in a pipe manufacturing company to prove the mentioned methods. Findings pinpoint that the vendors which present better services are not necessarily the most efficient one. This research also provides an appropriate framework for organization to examine the vendors' efficiency and also choose some effective ways to improve vendors' performance.

Keywords: Data Envelopment Analysis, Vendor Selection, Service Quality, Efficiency, Ranking

1. Introduction

Vendor evaluation and selection is a critical subject in providing a suitable procurement situation. Recent studies have highlighted the necessity of vendors' evaluations. Based on the literature, supplier/vendor selection may be the most critical way in purchasing process. Therefore, purchasing departments should periodically evaluate their supplier/vendor performance in order to recognize the best supplier/vendor (Braglia and Petroni, 2000; Wu and

Blackhurst, 2009).

There must be an appropriate process to define the procurement requirement which support the company's business plan. The value of these requirements should be identified as well as price of vendors' products. The value of product quality, service levels and on time delivery are some of the factors which can be considered in the process of vendor's evaluation. This method can help the organization to evaluate its vendors and to recognize the most efficient ones (Hugos, 2003).

Vendor selection is the process which review, evaluate and ultimately select the best vendors. It is one of the most important decision making problems, because selecting the proper vendors may reduce the purchasing costs and improves competitiveness corporation situation. Different methodologies from simple weighted scoring models to advanced mathematical programming models have been used to solve this problem. Some of the multi-criteria, mathematical programming, and advanced methodologies which have been utilized for vendor selection problems are depicted in Table 1 (Talluri et al., 2006).

Appropriate vendors or suppliers selection is one of the fundamental strategies of organization to enhance the best quality of output which has a direct influence on the company's performance. The importance of vendor selection has been stated in the literature (Weber et al., 1991). Vendor selection decisions are also a crucial component of production and logistics management in many firms. These decisions are typically complicated due to the several reasons. First of all, potential options may require to be assessed on more than one criterion. Multi-criteria evaluation has been recognized to be particularly important in manufacturing strategies (Chapman, 1990). The second complication of vendor selection decisions is that individual vendors may have different performance characteristics based on the different criteria. For example, the vendor which can supply an item for the least per unit price may not have the best delivery, quality or performance in compare with other vendors. The third complication surrounding the vendor selection decision comes from internal policy limitations and externally imposed system constraints placed on the procurement process. Internal policy constraints exist either implicitly or explicitly in the purchasing process such as the number of vendors, minimum or maximum order quantities, the use of minority vendors, etc. Similarly, suppliers may impose some constraints in the buying process like their own minimum/maximum order quantities based on their production capacity or their willingness to be in contact with a particular firm. These constraints ultimately influence the number of vendors and the order quantities in procurement situation (Weber et al., 2000).

In this paper, service quality, price, average of late delivery times and rate of rejected parts are considered as one output and some inputs of data envelopment analysis (DEA) model, respectively. The Parasuraman model is also used to measure the vendors' service quality. Data are gathered through a checklist based on the five dimensions of the mentioned model and vendors' corporation tenure. The vendors' efficiency is measured through Russell model in DEA approach. Anderson and Peterson model is also applied to rank the efficient vendors. Finally, a case study is presented to prove the capability of proposed model. In this study, 12 vendors are examined based on the stated approach. Findings of this study pinpoint that the vendors which provide the best services are not necessarily efficient.

This paper is organized as follows. The relevant literature on the vendor/supplier area is reviewed. Then, service quality concept, applied data envelopment analysis approach are explained. In the following, a case study is proposed to examine the applicability of stated methodology. Finally, results and conclusions of the proposed methodology are presented.

2. Literature Review

For the first time, Data envelopment analysis were applied as a tool for analytical decision making in the field of purchasing and logistics management in a study by Kleinsorge et al. (1989). The authors illustrated how DEA can be used for analyzing the distribution of goods to markets. DEA has also been stated in the literature of vendor performance evaluation (Talluri et al., 2006; Weber et al., 2000; Weber, 1996, Weber and Desai, 1996; Weber et al. 1998; Narasimhan et al. 2001). Weber (1996) used DEA to evaluate vendors by considering unit price, percentage of rejects, percentage of late deliveries, business allocation units, etc and identified how DEA can be used to analyze vendors' performances based on multiple criteria. Weber et al. (2000) used DEA in conjunction with multi-objective programming (MOP). Talluri et al. (2006) also used the stochastic form of DEA for evaluating vendors' performance.

Garfamy (2006) proposed data envelopment analysis approach on the basis of total cost of ownership (TCO) for supplier selection. This research use DEA approach in evaluating the overall performance of suppliers based on multiple factors and TCO concept. Ramanathan (2007) integrated total cost of ownership and analytic hierarchy process approaches through the application of DEA in order to select appropriate suppliers. The recommended methodology utilizes three types of DEA models including: the classical DEA model, supper-efficiency model and the assurance region model to aggregate the results of analytic hierarchy process (AHP) and TCO. Wu and Olson (2008) considered three kinds of risk evaluation for vendor selection within a supply chain including: chance constrained programming (CCP), data envelopment analysis and multi-objective programming (MOP) models. In the three stated method of risk evaluation, different risks were modeled in the style of probability and simulation of specific statistics distribution functions. Wu and Blackhurst (2009) presented a supplier and evaluation and selection methodology based on an extension of data envelopment analysis. They proposed a methodology termed augmented DEA to rank suppliers.

Wu (2010) developed a method to measure suppliers' performance by considering risk and uncertainty associated with supplier performance on multiple variables. The proposed methodology is an extension to the traditional stochastic DEA model. Chen (2010), described a methodology for supplier selection and evaluation in a supply chain which take into account strengths, weakness, opportunities, threats (SWOT) analysis and applied DEA and TOPSIS to evaluate and rank suppliers. Farzipoor Saen (2010) utilized data envelopment analysis for restricting weights in supplier selection decisions in the presence of dual role factors. The mentioned study considered multiple factors which play both inputs and outputs roles. Kang and Lee (2010) developed a supplier performance evaluation model based on AHP and DEA. In this research DEA is applied to evaluate quantitative factors and to transform the results into pair wise comparison values for AHP analysis. The ultimate rankings of suppliers are determined by utilizing both qualitative and quantitative results. Kuo et al. (2010) combined artificial neural network (ANN) and two multi-attribute decision analysis (MADA) methods: data envelopment analysis and analytic network process (ANP) in order to develop a green supplier selection model. The model which is called ANN-MADA hybrid method involves both practicality in traditional supplier selection attributes and environmental regulations. Zeidan et al. (2011) stated a method which considers both quantitative and qualitative variables in evaluating performance suppliers based on their efficiency and effectiveness. In the mentioned study, for qualitative performance evaluation of data fuzzy AHP and Fuzzy TOPSIS were used. DEA were also utilized to transform qualitative variables into quantitative variables. The Main attributes considered in literature related to DEA Models are shown in Table 2.

3. Service Quality

A service is an activity or series of activities in a less intangible nature that normally, but not necessarily, take place in interactions amongst customer and service employees and/or physical resources or goods and/or systems of the service provider, which are delivered to customer (Fitzsimmons, J.A., & Fitzsimmons; 2000). There are also several definitions for quality. Reeves and Bednar (1994) defined quality as excellence, value, conformance to specifications and meeting or exceeding customers' expectations. During the past few decades, scholars have recognized and discussed about this concept.

Service quality is a concept that has agitated considerable interest and discussed because of its difficulties in both defining and measuring it with no overall consensus (Wisniewski, 2001). A number of different "definitions" has been stated to explain service quality concept. One that is commonly used to explain service quality is the extent to which a service meets customers' needs or expectations (Wisniewski and Donnelly, 1996). Hence, Service quality can be defined as the difference between customer expectations of service and perceived service. If expectations are greater than performance, then perceived quality is less than satisfactory and hence customer dissatisfaction occurs (Parasuraman et al. 1985).

The concept of service quality was established after there had been a growing interest in the quality of goods served. Garvin (1988) was amongst the first scholars who examined the quality concepts to cover both goods and services. Garvin explained the perceived quality as the subjective perception of quality through indirect measures of quality comparison. Gronross (1993) introduced perceived service quality as a result of comparing the real experience with the expectation of a customer before consuming the service. Based on the perceived service quality concept Parasuraman et al. (1985) applied premises from other previous studies to form their model of service quality. The conceptual model of Parasuraman et al. (1985) includes five generic dimensions or factors which are as follows: (Kang et al., 2002)

(1) Tangibles. Physical facilities, equipment and appearance of personnel.

(2) Reliability. Ability to perform the promised service dependably and accurately.

(3) Responsiveness. Willingness to help customers and provide prompt service.

(4) Assurance (Including competence, courtesy, credibility and security). Knowledge and courtesy of employees and their ability to inspire trust and confidence.

(5) Empathy (including access, communication, understanding the customer). Caring and individualized attention

that the firm provides to its customers.

4. Data Envelopment Analysis

DEA is a powerful aggregate comparative method for evaluating the efficiency of organizations with multiple inputs and outputs. DEA has been developed by Charnes et al. (1978) as a generalization of the framework of Farrell (1957) on the measurement of efficiency. Farrell's approach was based on the production possibility set consisting of the conical hull of input-output vectors. This framework was generalized to include multiple inputs and outputs and reformulated as a mathematical programming model to assess the comparative efficiency of Decision-Making Units (DMUs). DMUs refer to the collection of firms, departments, divisions or administrative units with the same goals and objectives, and which have common inputs and outputs. The DEA approach uses a linear programming model to construct a hypothetical composite unit based on all units in the reference group. The performance of each DMU measured, is relative to the performance of all other DMUs (Al-Shammari , 1999).

4.1. The DEA Model for Measuring Vendor Efficiency

Data envelopment analysis is a mathematical programming methodology. It has been employed successfully for assessing the relative performance of a set of firms, usually called decision-making units (DMU), which use the same inputs to produce the same outputs. Assume that there are N DMUs, and the DMUs under consideration convert I inputs to J outputs. In particular, let the m_{th} DMU produce outputs y_{jm} using x_{im} inputs. The objective of the DEA exercise is to identify the DMUs that produce the greatest amount of outputs by consuming the least amount of inputs. A DMU is deemed to be efficient if the ratio of weighted sum of outputs to the weighted sum of inputs is the highest. The DMU defined in this study with input and output criteria are as follows: (Figure 1)

The DEA model used in this study takes the form of multiple inputs and single output. The multiple inputs, single output DEA modeling form measures the efficiency of DMUs by how well they minimize multiple input criteria to produce a single unit of output. In the following the revised Russell model will be used in order to solve the vendor selection problem.

The Russell measure model, named by Fare and Lovell (1978) and later revisited by Pastor et al. (1999) (referring to it as the enhanced Russell measure), is equivalent to Tone's SBM. Specifically, the model is as follows:

$$\text{Minimize} R_e = \frac{\frac{1}{m}\sum_{i=1}^{m}\theta_i}{\frac{1}{s}\sum_{r=1}^{s}\varphi_r}$$

where

$$\sum_{j=1}^{n}\lambda_j x_{ij} \le \theta_i x_{io} \qquad i = 1,\ldots,m$$

$$\sum_{j=1}^{n}\lambda_j y_{rj} \ge \varphi_r y_{rio} \qquad r = 1,\ldots,s$$

$$\theta_i \le 1 \qquad i = 1,\ldots,m$$

$$\varphi_r \ge 1 \qquad r = 1,\ldots,s$$

$$\lambda_j \ge 0 \qquad j = 1,\ldots,n$$

Re is the efficiency number

φ_i is the efficiency measure for output r

θ_i is the efficiency measure for input i;

λ_j are reference weights associated with vendor j;

m is the number of input criteria;

s is the number of output criteria.

n is the number of vendors;

x_{ij} is the input criteria value for the i_{th} criteria and the j_{th} vendor;

y_{rj} is the output criteria value for the r_{th} criteria and the j_{th} vendor;

The linear programming of the above model is as follows:

$$Minimize\ \beta = \frac{1}{m}\sum_{i=1}^{m}\frac{t_i^-}{x_{io}}$$

where

$$\beta + \frac{1}{s}\sum_{r=1}^{s}\frac{t_r^+}{y_{ro}} = 1$$

$$\sum_{j=1}^{n}\mu_j x_{ij} = \beta x_{io} - t_i^- \qquad i = 1,\dots m$$

$$\sum_{j=1}^{n}\mu_j y_{rj} = \beta y_{ro} + t_r^+ \qquad r = 1,\dots s$$

$$\sum_{j=1}^{n}\mu_j = \beta$$

$$\beta, \mu_j, t_i^-, t_r^+ \geq 0,\ \ j = 1,\dots,n,\quad i = 1,\dots m,\quad r = 1,\dots,s$$

5. Case Study

The empirical study in this paper is performed in Darakar Company. Darakar Co. is the greatest manufacturer company in water pipes industry in Iran. One of the most important materials which encompass more than 75 percent of the products is PVC. Hence, this material is so critical in this industry. So a set of 12 vendors is considered in the evaluation process. The vendors have been in contact with this company for more than two years. Management has considered price, the average of late deliveries, rate of rejected parts and service quality as four main factors in evaluating vendors. “Price” is represented on a per unit basis for each delivered item. “The average of late delivery times” is the average times that items have not been delivered on time and “Rate of rejected parts” is the percentage of parts that has not been compatible with the expected products in the past two years. Service quality is also Darakar Co.’s perception from the vendors’ quality of services.

In this research, price, the average of late delivery times and rate of rejected parts are utilized as the input factors because they represent the cost paid by the company. Service quality is treated as output factor since it represent the benefit obtained by the company. The data of service quality criterion are gathered through a service quality checklist which is filled by experts of company. The data of DEA model are represented in table 3.

The service quality value is just measured through the perception of company from the vendors' services. The real PVC prices are also changed because of the sensitivity of company’s information. Based on the proposed model, higher values of output and lower values of inputs are considered valuable.

6. Results

In order to follow this model, linear programming solution is performed for all vendors in this study. Results of the DEA model utilization are depicted in table 4. It is evident that vendor 2, 4, 7 and 11 are efficient with a rating of 1.000. The remaining vendors are inefficient. These scores assist the company in vendor selection decisions based on relative performance. The efficiency of vendors means that the higher output is achieved with the lower inputs. The vendor which has the lowest price is efficient. The vendor 11 with a price equal to 285 which is relatively high in compare with other vendors is classified as an efficient vendor. Vendor 2 has also the service quality score of 88 which is fairly less than others although this is an efficient vendor.

In order to rank efficient DMUs, Andersen-Petersen model is used. The ranking model in this study is as follows: (Andersen and Petersen, 1993)

$$\text{Minimize } \theta_o'$$

where

$$\theta_o' x_{io} - \sum_{\substack{j=1 \\ j\neq o}}^{n} x_{ij}\lambda_j \geq 0 \quad \text{for all} \quad i = 1,\dots,m$$

$$-\sum_{\substack{j=1 \\ j\neq o}}^{n} y_{rj}\lambda_j \leq -y_{ro} \quad \text{for all} \quad r = 1,\dots,s$$

$$\sum_{\substack{j=1 \\ j\neq o}}^{n} \lambda_j = 1$$

$$\lambda_j \geq 0 \qquad j = 1,\dots,n$$

$\theta_o^{'}$ Unconstrained but assumed positive

Where:

$\theta_o^{'}$ is the efficiency measure for employee o;

λ_j are reference weights associated with employee j;

m is the number of input criteria;

n is the number of employees;

s is the number of output criteria.

x_{ij} is the input criteria value for the i_{th} criteria and the j_{th} employee;

y_{rj} is the output criteria value for the r_{th} criteria and the j_{th} employee;

Ranking results are represented in table 5.

Results indicate that 4 DMUs are efficient. But it is possible to rank these 4 efficient vendors. These DMUs necessarily don't have better inputs and outputs criteria than others. The vendor 4, 2 and 7 have higher rank respectively while the rank of vendor 12 cannot be identified due to the inefficiency of Anderson and Peterson model. According to the tables 3, 4 and 5, vendor 4 has the highest rank amongst efficient vendors. This vendor has appropriate condition considering inputs and outputs. However it is not the best in all criteria. For example, service quality score of this DMU which is equal to 90, is not the best score. This vendor has not also the best price and average of late deliveries. So, it can be concluded that all the factors should be considered in evaluation process. A similar analysis can also be performed for inefficient vendors. The best efficiency amongst inefficient vendors is related to vendor 6. A general comparison of vendor 4 and vendor 6 reveals that both units have the same output. Amongst input criteria, DMU 6 has better condition than DMU 4 in average of late deliveries factor. Both vendors have somehow the same price. Therefore, it can be concluded that the difference between these two vendors is referred to rate of rejected parts. As it is shown in table 3, rate of rejected parts of vendor 6 is three times more than vendor 4. Thus, vendor 6 can move toward efficiency frontier through improving this criterion.

7. Conclusions

A key issue in the successful management of vendors is the measurement of vendor's efficiency to ensure that the best services are enhanced. An effective measurement system provides a fair framework for vendor selection. Efficiency measurement systems can be different in organizations. Thus a suitable and comprehensive approach is required to encompass all the vendors' services.

Development and application of multi criteria models for vendor evaluation have also received significant attention during the past decade. The utilization of multiple factors in vendor evaluation has been received significant attention in the literature (Weber et al., 1991). Weber et al. (1991) concluded that most of the articles reviewed in their work have utilized more than one criterion. The issue of efficiency associated with supplier performance is receiving more attention in the purchasing literature in compare with other functions. Efficiency evaluation is considered to be a critical element in selecting the most appropriate vendors with increasing number of vendors and with multiple criteria on which these vendors are evaluated, selecting the most efficient vendors is going to be more difficult.

In this paper, a model through DEA approach was developed in order to evaluate the efficiency of vendors. The paper also described how one firm can implement the DEA technique and use DEA modeling for measuring vendors' performance in multiple criteria relative to other vendors competing in the same marketplace. Based on results of the research, companies should consider multi criteria in vendors' evaluation because the vendors which are better at one criterion in compare with others necessarily do not provide the best services in other items. Thus, this approach can be useful for those organizations which they do consider multi criteria in vendor' evaluation.

This approach allows the purchasing manager to evaluate effectively each vendor's performance relative to the performance of the "best vendors" in the marketplace. This is possible through calculation of DEA efficiency measures. The results derived from DEA model can be used in order to calculate/determine benchmark values to compare with inefficient vendors. Another advantage of this model is the simplicity of calculating the factors of DEA model. In compare with the traditional subjective vendor evaluation techniques, the DEA approach provides an objective statement of how well vendors are performing, Provided that the firm has been collecting data on key vendor performance measures. The further researches can be done with more critical factors. Sensitivity analysis can also be used for the measuring the influence of each factor for the efficient vendors. It is the hope of authors that the results of the DEA model presented in this paper will stimulate further researches in the use of DEA for vendor evaluation.

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Table 1. Vendor evaluation methodologies (Talluri et al., 2006)

Methodology	Authors
Weighted Linear Models	Lamberson et al. (1976), Timmerman (1986), Wind and Robinson (1968)
Linear Programming	Pan (1989), Turner (1988)
Mixed Integer Programming	Weber and Current (1993)
Grouping Methods	Hinkle et al. (1969)
Analytical Hierarchy Process	Barbarosoglu and Yazgac (1997), Hill and Nydick (1992), Narasimhan (1983)
Analytical Network Process	Sarkis and Talluri (2002)
Matrix Method	Gregory (1986)
Multi-objective Programming	Weber and Ellram (1993)
Total Cost of Ownership	Ellram (1995)
Human Judgment Models	Patton (1996)
Principal Component Analysis	Petroni and Braglia (2000)
Data Envelopment Analysis	Narasimhan et al. (2001), Weber and Desai (1996), Weber et al. (1998)
Interpretive Structural Modeling	Mandal and Deshmukh (1994)
Game Models	Talluri (2002), Talluri and Narasimhan (2003)
Statistical Analysis	Mummalaneni et al. (1996)
Discreet Choice Analysis Experiments	Verma and Pullman (1998)
Neural Networks	Siying et al. (1997)

Table 2. Main attributes considered in DEA Models

Authors (years)	Main attribute in DEA model
Kleinsorge et al. (1992)	Bills, On time, Experience, Credence, Total cost and Shipments
Weber (1996)	Price, Percent rejects and Percent late deliveries
Weber et al. (1998)	Price, Percent rejects and Percent late deliveries
Liu et al. (2000)	Price, Delivery and Quality
Forker and Mendez (2001)	Role of the quality department, Role of top management and quality policy, Product/service design, Employee relations, Quality data and reporting, Training, Process management/operating procedures and Supplier quality management
Narasimhan et al.(2001)	Quality management practices, Documentation, Process/manufacturing capability, Management, Design/development capabilities, Cost and Delivery
Talluri and Narasimhan (2003)	Price, Quality and Delivery performance
Talluri and Narasimhan (2004)	Quality management practices and systems, Documentation and self-audit, Process/manufacturing capability, Management of the firm, Design and development capabilities, Cost reduction capability, Quality, Price, Delivery, Cost reduction performance and Other
Ahn and Lee (2004)	Capability and Price
Talluri and Narasimhan (2005)	Quality management practices and systems, Documentation and self-audit, Process/manufacturing capability, Management of the firm, Design and development capabilities, Cost reduction capability, Quality, Price, Delivery, Cost reduction performance and Other
Liu and Hai (2005)	Quality, Delivery, Responsiveness, Technical Capability, Facility, Financial, Discipline and Management
Talluri rt al. (2006)	Price, Quality and Delivery performance
Garfamy (2006)	Manufacturing cost, Quality cost, Technology cost, After sale service cost, Price and Item unit
Ramanathan (2007)	Manufacturing costs, Quality costs, Technology, Service
Wu T. and Olson (2008)	Cost, Accept rate and On-time Rate
Wu D. (2009a, 2009b)	Price, Quality and Delivery performance
Wu D. (2010)	Quality personnel, Quality procedure, Concern for Quality, Company history, Price-quality, Actual price, Financial ability, Technical performance, Delivery, Technical assistance, Production capability and Equipment

Table 3. Main attributes considered in DEA Models (Continued)

Authors (years)	Main attribute in DEA model
Kuo et al. (2010)	Quality, Cost, Delivery, Service, Environment and Corporate social responsibility
Kang and Lee (2010)	Defect rate, Price, Response to change time, On-time delivery rate, Process capability, Capacity, Technology, Partnership relationship
Chen (2010)	Quality, Cost, Delivery time, Service, Technical and production capability, Relation Combination and Organizational management
Zeydan et al. (2011)	New project management, Supplier management, Quality and environmental management, Production process management, Test and inspection and Corrective/preventive actions management

Table 4. Data of the DEA model

Vendor	Criteria				Vendor	Criteria			
	Input			Output		Input			output
	Price	The average of late Deliveries	Rate of Rejected Parts	Service Quality		Price	The average of late Deliveries	Rate of Rejected Parts	Service Quality
1	290	14	3	85	7	245	14	4	82
2	240	6	5	88	8	285	12	4	63
3	300	8	6	28	9	270	12	6	65
4	255	10	3	90	10	270	24	4	71
5	295	20	8	53	11	285	4	5	98
6	260	7	9	90	12	275	10	8	75

Table 5. Results of the DEA model

Vendor	Efficiency	Vendor	Efficiency
1	0.9445	7	1.0000
2	1.0000	8	0.6703
3	0.2857	9	0.6867
4	1.0000	10	0.7551
5	0.5409	11	1.0000
6	0.9736	12	0.7831

Table 6. Ranking results

DMU	θ'
2	1.3510
4	1.6410
7	1.0091
11	Infeasible

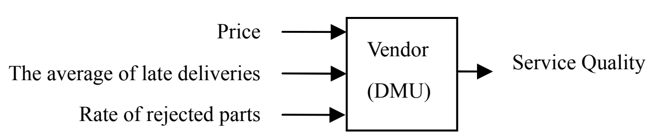

Figure 1.The DEA model for vendor selection problem