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Hybrid DEA Decision Model for Supplier Evaluation and Selection

K.Balakannan[1*], Dr. S. Nallusamy [2], Dr. Gautam Majumdar[3]

[1*]Department of Mechanical Engineering, Sri Muthukumaran Institute of Technology, Chennai-600 069, E-Mail: kbalakannan@gmail.com
[2]Department of Mechanical Engineering, Dr. M.G.R. Educational and Research Institute University, Chennai, 600 095, E-Mail: ksnallu@gmail.com
[3]Department of Mechanical Engineering, Jadavpur University, Kolkata -700 032,
E-Mail: gmajumdar59@yahoo.com

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Abstract

Competitive international business environment has forced many firms to focus on supply chain management to cope with highly increasing competition. Selecting the right suppliers in the supply chain significantly reduces the purchasing costs and improves corporate price competitiveness. The emphasis on quality and timely delivery in today's globally competitive marketplace plays a major role, since most of the firms have been spending considerable amount of their revenues on purchasing. The supplier selection problem involves multiple conflicting issues that are tangible and intangible. Hence, the purpose of this study is to propose an integrated model for supplier selection based on Data Envelopment Analysis (DEA). It has been used to evaluate suppliers' performance when there are multiple inputs and outputs in the supplier selection problem. The DEA determines the relative efficiencies of multiple suppliers. In this paper, the Factor Relationship (FARE) is used to determine the weights of criteria involved in supplier selection process. A case study is made in chemical process industry based on the above model and its efficiency is verified.

Keywords: Supplier Evaluation, Supplier Selection, Data Envelopment Analysis, FARE

1 Introduction

Supply chain management (SCM) is the process of planning and monitoring the transformation of raw material into product in an organization. The concept of SCM was originally introduced by consultants in 1980s and has gained tremendous attention now. Several issues were identified and addressed by the researchers such as network planning, supplier management and physical distribution. Among those, supplier management is the key issue because more than 60% of the sales revenue is spent for the purchase of raw material. Supplier management comprises supplier evaluation, supplier selection and supplier development. Selecting a good set of suppliers to work with is crucial to a company's success. Over the years, the significance of supplier selection has been long recognized and emphasized. In today's competitive operating environment it is impossible to successfully produce low cost, high quality products without satisfactory vendors. Thus one of the important purchasing decisions is the selection and maintenance of a competent group of suppliers (Weber et al., 1991). More recently, with emergence of the concept of Supply Chain Management (SCM), more and more scholars and practitioners have realized that supplier selection and management was a vehicle that can be used to increase the competitiveness of the entire supply chain (Lee et al., 2001). The evaluation of supplier is an unstructured decision problem because of lack of adequate needed information and the availability of qualitative information in the form of intangible sense. In supplier decisions, two fundamental questions must be addressed. Firstly, what criterion should be used and secondly, what methods can be used compare suppliers. The objective of this paper is to develop a hybrid model by combining AHP and for selecting the best supplier for a chemical processing industry. The remaining part of the paper is organized as follows: Section 2 illustrates the review of related literatures; Section 3 explains the development of model for supplier selection. In section 4, the case study is discussed. Finally, Section 5 concludes the study and outlines some future research directions.

2 Literature Review

Dickson (1966) carried out a study by the help of a survey which was conducted in 300 business organizations. The purchasing managers of those organizations were requested to identify the factors that were influencing the supplier selection. As an outcome of the survey, totally 23 factors were identified as important factors for the supplier selection decision problem. Supplier selection is complicated by the fact that various criteria must be considered in the decision making process. The analysis of criteria for selection and measuring the performance of the suppliers has been the focus of many research papers. Weber et al. (1991) reviewed a total of 74 research papers on supplier selection and identified net price (cost), delivery, quality, production capability, geographical location, technical capability, reputation, financial position, performance history and warranty are the most contributed criteria for supplier selection. Wilson (1994) reviewed the relative importance of supplier selection criteria and observed that quality, service, price and delivery are the most important selection criteria. Ho et al. (2010) made review about the literatures of the multi-criteria decision making approaches for supplier evaluation and selection. This research not only provided evidence that the multi-criteria decision making approaches are better than the traditional cost-based approach, but also aided the researchers and decision makers in applying the approaches effectively. Narasimhan et al. (2001) applied DEA model to evaluate alternative suppliers for a multinational corporation in the telecommunications industry. Eleven evaluating factors were considered in the model, in which there are six inputs related to the supplier capability, and five outputs related to the supplier performance. Talluri and Sarkis (2002) developed DEA based model for performance monitoring of suppliers. Wu et al. (2007) proposed an augmented DEA approach for selection of suppliers. The model was capable to handle imprecise data to rank the efficient suppliers and covered the discrimination among them based on discriminating efficient suppliers from relatively poor performers. Wu and Blackhurst (2009) proposed a supplier evaluation and selection methodology based on an extension of DEA to evaluate suppliers. The weight constraints were introduced to reduce the possibility of having inappropriate input and output factor weights. Mishra and Patel (2010) developed an application guideline for the assessment, improvement, and control of quality in SCM using DEA. Improvement in the quality of all supply chain processes lead to cost reductions as well as service enhancement. The data is collected from 25 suppliers of food and agro based industry. Amindoust et al. (2012) stated that the multiple attribute utility theory based on DEA applied to tackle this problem with consideration of some inputs and outputs. A real case study was implemented to show the application of DEA method and through this method the efficient and inefficient suppliers were identified to ranking them.

3 Model Development

In this study the best supplier is selected by using Data Envelopment Analysis (Figure 1). It can be used to evaluate the efficiency of a number of producers, generally referred as decision making unit (DMU).

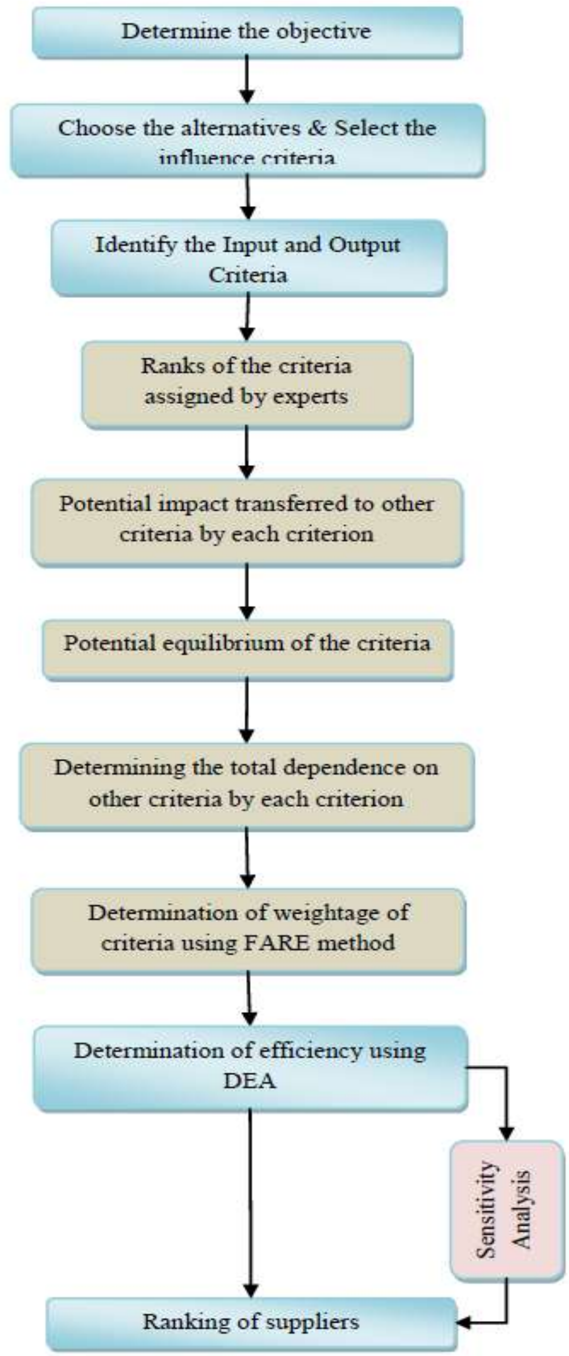

Figure 1 Proposed model

DEA compares each producer with only the "best" DMU in the group, which is better than the comparison with average of the group. In DEA, we can consider number of DMUs, each of them consuming similar inputs to varying level to produce.

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A fundamental assumption behind this method is that if a given DMU, is capable of producing units of output with inputs, then other DMUs shall also be able to do the same if they were to operate efficiently. Similarly, if DMU is capable of producing units of output with inputs, then other DMUs should also be capable of the same. DMUs and others can then be combined to form a composite producer i.e. virtual producer with composite inputs and composite outputs. The emphasis of DEA is on finding the "best" virtual producer for each real producer. Figure 1 explains the frame work for the supplier selection. DEA was used to evaluate the performance of hospitals, universities, cities, business firms etc. A general mathematical formulation is needed to handle the case of multiple inputs and multiple outputs. This mathematical formulation was provided by Charnes et al. (1978). Let us use x and y to represent inputs and outputs, respectively. Let the subscripts i and j to represent particular inputs and outputs respectively. Thus xi represents the ith input, and yj represent the jth output of a decision-making unit. Let the total number of inputs and outputs be represented by I and J respectively, where I, J > 0. In DEA, multiple inputs and outputs are linearly aggregated using weights. Thus, the virtual input (eqn. 1) of a firm is obtained as the linear weighted sum of all its inputs.

$$Virtual\ Input = \sum_{i=1}^{I} u_i\, x_i \qquad (1)$$

Similarly, the virtual output (eqn. 2) of a firm is obtained as the linear weighted sum of all its outputs.

$$Virtual\ Output = \sum_{j=1}^{J} v_j\, y_j \qquad (2)$$

Given these virtual inputs and outputs, the Efficiency (eqn. 3) of the DMU in converting the inputs to outputs can be defined as the ratio of outputs to inputs.

$$Efficiency = \frac{Virtual\ Output}{Virtual\ Input} \qquad (3)$$

$$Efficiency = \frac{\sum_{j=1}^{J} v_j\, y_j}{\sum_{i=1}^{I} u_i\, x_i}$$

Where,

i = 1, 2, 3.....I are inputs

j = 1, 2, 3.....J are outputs

s = 1, 2, 3.....N are DMU_S

u_i = weight of i^{th} input

v_i = weight of j^{th} output

x_{is} = amount of the i^{th} input for s^{th} DMU

y_{js} = amount of the j^{th} output for s^{th} DMU

In this paper Factor Relationship (FARE), a new weight determining method is used to compute the weights of each criterion. Romualdas (2011) developed FARE method for determining the criteria weights in multi criteria decision making environment. First the potential impact of the criteria is determined using equation (4).

P = S (m - 1) (4)

where

P – Potential of the system's criterion impact;

S – Maximum value of the scale of evaluation

used (Table1);

m – Number of the system's criteria.

Next the criteria are ranked by the experts based on the importance. Then the relationship between the criteria is determined based on the rank using table 1. The procedure is as follows: the criterion of a lower rank has the smaller impact on the criteria having higher ranks and, therefore, it should transfer a larger part of its potential impact to them.

Table 1 Scale of quantitative evaluation of interrelationship between the system's criteria

No.	Type of the Effect Produced	Rating of the Effect Produced by interrelationship (in points)
1	Almost none	1
2	Very Weak	2
3	Weak	3
4	Lower than Average	4
5	Average	5
6	Higher than average	6
7	Strong	7
8	Very Strong	8
9	Almost absolute	9
10	Absolute	10

The impact of the criteria a_i on the main criterion is determined and then, this impact is transformed as follows:

$$a_{1i} = S - \tilde{a}_{1i} \quad (5)$$

where,

a_i – the impact of i^{th} criterion on the first main criterion;

$\tilde{a}^i$ – the part of i^{th} criterion's potential impact transferred to the main criterion The total impact of any criterion, as well as the consistency level of a subset may be determined based on the data provided in the form of matrix. The subset considered in the matrix is consistent and stable if the total impact of its criteria with a positive sign is equal to their total impact with a negative sign, i.e. their sum is equal to zero.

Next the total impact Pi calculated using equation (6).

$$P_i = \sum_{i=1}^{m} a_{ij}, \; j \neq i \quad (6)$$

After that, the total potential, required for determining the criteria weights, will be calculated based on the data presented in the first row of the matrix, thereby making the filling of all other rows of the matrix unnecessary. The following equation (7) is used for determining the total potential.

$$P_i = P_1 - m.\, a_{1i}, \quad (7)$$

where

P_i – the total impact (dependence) of the i^{th} criterion. Finally, the criteria weights can be determined using equation (8).

$$\omega_i = \frac{P_i^f}{P_S} = \frac{P_1 - m a_{1i} + S(m-1)}{mS(m-1)} \quad (8)$$

where PS = Total potential of a set of criteria which is found using equation (9) and

p^i_f = Actual total impact of the i^{th} criterion of the system which is calculated using equation (10)

P_S = m. P = mS (m - 1) (9)

$$P_i^f = P_i + P \quad (10)$$

Where Pi = Total impact produced by the i^{th} criterion of the system or its total dependence on other criteria.

4 Case Study

The case study was performed in a chemical industry which is located in the southern part of Tamilnadu. For this study, the supplier selection model was developed based on five suppliers (S1, S2, S3, S4 and S5) with five evaluating factors, that include three inputs and two outputs namely, delivery (D) in days, apacity (Ca) in units, warranty (W) in number of days, cost (C) in rupees and quality (Q) in percentage of acceptance respectively. The Table 2 shows the data of suppliers and corresponding inputs and outputs.

Table 2 Datasets of inputs and outputs

Suppliers	Inputs			Outputs	
	D	Ca	W	C	Q
S1	12	170	28	2439	0.87
S2	12	260	21	2567	0.90
S3	14	280	21	2711	0.92
S4	10	260	24	2800	0.96
S5	13	290	18	2302	0.89

The weights of the attributes are calculated by using FARE method using equations (4) to (10). The weights are shown in Table 3.

Table 3 Weights of the attributes

Criteria	Inputs			Outputs	
	Delivery	Capacity	Warranty	Quality	Cost
Weights	0.167	0.500	0.333	0.625	0.375

Then DEA efficiency for all suppliers is determined by using eqn. 3 and the values are

tabulated in Table 4.

Table 4 Efficiency of suppliers

Suppliers	Efficiency	
	Using FARE	With Equal weights
S1	76.34	65.45
S2	83.39	67.24
S3	78.90	64.77
S4	92.09	73.34
S5	79.06	62.78

Figure 2 depicts the DEA Efficiency of the suppliers. From the table 4, the supplier with higher efficiency (ie. Supplier 4) is selected as best supplier. For this case study supplier 4 is selected as best supplier.

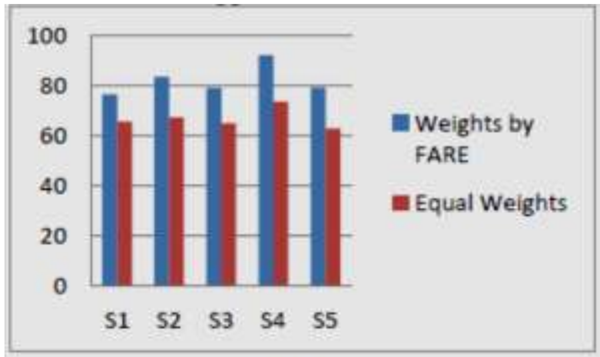

Figure 2 DEA efficiency

Sensitivity analysis is used to determine how "sensitive" a model is during the changes in the value of the parameters of the model and in the structure of the model.

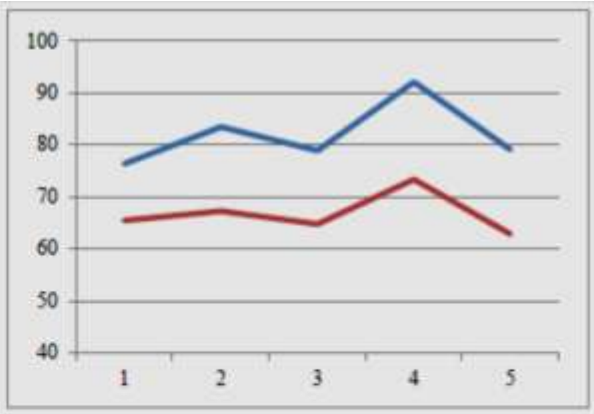

Figure 3 Sensitivity of the DEA model

It is performed to do a tradeoff study and to check the robustness of the model. In sensitivity analysis, the values of any one input parameter were changed and the changes in output performance indices were measured. In this study, equal weights were assumed for the criteria and the efficiency was observed. Figure 3 shows the result of the sensitivity analysis. From the Figure 2, it is observed that the ranking of the suppliers is not changing and hence the robustness of the proposed model is proved.

5 Conclusions

Decisions of evaluation and selection of a supplier is an important part of chain management. In today's intense competition, producing high quality products with minimum cost without satisfactory suppliers is not possible. In this work a multi-criteria decision making model based on DEA for selecting the best supplier was developed. For the selection of supplier, multiple criteria which include quality, delivery, cost, capacity and warranty were considered. And the weights of the criteria were computed in FARE technique. The results were compared and finally the robustness of the developed model was checked by the sensitivity analysis. This model gives a reliable result and it can be extended for the same kind of industries. This proposed model can be more flexible to accommodate the qualitative and quantitative criteria for supplier selection. DEA can help to evaluate and compare suppliers on different evaluation criteria which can offer a more robust tool to select and evaluate suppliers based on both qualitative and quantitative criteria. Future research can be possible by taking different factors relating to the supplier side by the help of soft computing multi criteria decision making approach like fuzzy set theory.

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