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Supplier Selection through Application of DEA

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Abstract

In the increasing competition it has become important in business world to understand the different aspects of production and purchasing to understand the need for desired material in the organization. The managers have an important responsibility of selecting a good supplier by evaluating them on different parameters which is directly or indirectly associated with their overall performance. For decision making based on multiple criteria evaluation many methods of Multi-Criteria Decision Making (MCDM) is used by firms. Data Envelopment Analysis (DEA) is prominently used by firms nowadays. In this paper, analysis of DEA is done by measuring supplier performance of two firms: multi-national telecommunication corporation and a manufacturing firm. The firm uses the methodology according to their requirement and criteria for evaluating their suppliers and find best among them.

Index Terms: Supplier efficiency, Data Envelopment Analysis (DEA), multi criteria decision making, Supplier evaluation.

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1. Introduction

In current scenario production cost is affected by supplier linkages to a great extent. Supplier evaluation and selection methods were earlier based on quoted price which neglected significant direct and indirect costs associated with important operational factors like quality, use and service elements of parts and materials being purchased and delivery, etc. Thus, lowest bidder was selected irrespective of the service which the supplier will provide in terms of other factors. Also, it was waste of time and resources which hampered firm's overall performance. Now, it has become pivotal for all business to evaluate its vendors according to

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some method to get desired service that can give business cutting edge over other products in the market. The decision methods used for evaluating vendors must be selected as per the requirement of the business. The parameters like cost, quality, performance, etc. should be considered as per firm's requirement. The company has to select suppliers strategically to withstand the market pressure and its impact on different areas of a firm. Selection involves evaluation of different suppliers on different criteria. Thus, firms have to decide among the different MCDM methods of selecting supplier depending upon the working style and top priorities of the firm. Previous researchers have proposed various MCDM techniques for easy and effective way to tackle with vendor selection problem which includes techniques Analytical Hierarchy process (AHP), Data Envelopment Analysis (DEA), etc. Among all the methods used DEA has been extensively used for supplier evaluation and selection. The main aim is to study the application of DEA technique depending on firm's strategy to do business. This paper will help in further research in DEA and in understanding different aspects of this method in selection of suppliers.

2. Literature Review

Supplier evaluation and selection is an important criterion in both large and small firms for development of companies. Data Envelopment Analysis or DEA is widely used approach for supplier evaluation and selection for individual products. The decision making units were analyzed and relative efficiencies were calculated based on weighted sum of costs as input and weighted sum of deliverables as outputs (Charnes, 1978). Identify the major technical inefficiencies in inputs or outputs to give best possible results (Banker, 1984). Further calculating inefficiencies by exogenously fixing some of the inputs or outputs which cannot be controlled (Banker, 1985). Detailed evaluation of inputs and outputs and issues involved in the practice of DEA (Boussofiene, 1991). Weber (1996) proposed a model of supplier evaluation on the basis of multiple criteria and setting a benchmark for evaluation. The main factors discussed were reduction in cost, good quality and efficient delivery. Depending on the changing market scenario Braglia and Petroni (2000) conducted a survey with 89 manufacturing firms in Brescia (Europe) for proper formulation of sourcing strategies and applied DEA to measure the related performance of various suppliers based upon the article of Baker and Talluri (1997). Liu et al. (2000) came up with the simplified DEA model to evaluate the supplier performance with 3 inputs (Price Index, Delivery Performance and Distance Factor) and 2 output criteria (Supply Variety and Quality). Forker and Mendez (2001) proposed the application of DEA to measure comparative efficiency of suppliers. Comparative Efficiency was calculated as a ratio of single input to multiple outputs. Similar to Braglia and Petroni (2000), focused on evaluation of supplier performance depending on cross efficiencies. Narasimhan et al. (2001) focused on supplier evaluation specifically for a Multi-national corporation in telecommunication industry. Eleven factors were considered in which six inputs denoted supplier's capability and rest five outputs symbolized supplier's performance. Talluri and Baker (2002) used three phase approach for logistic distribution network design in which 2 input factors and 4 output factors were used to evaluate potential stakeholders (suppliers, manufacturers, distributors, retailers). The optimal supplier was selected for different locations and products as per the requirements.

Using the same evaluating factors proposed by Talluri and Baker (2002), DEA was used to measure the supplier performance by Talluri and Sarkis (2002) and showed that the model works. Talluri and Narasimhan (2004) used DEA for effective sourcing and proposed a model using cross efficiencies and statistical methods in clustering the supply base. Garfamy (2006) applied DEA for supplier performance evaluation on the basis of Total Cost of Ownership (TCO) and tried to simulate data of a hypothetical firm with the strategic aim of being able to reduce TCO with identification of benchmarks. Ross et al. (2006) identified DEA method to be the core of an analytical framework - namely Action Research (AR). The proposed methodology fused both buyer and supplier performance attributes and was found capable of delivering measurable and actionable outputs. There were two main goals: first, to set up a mutual and reciprocal understanding of the opposite needs of the buyers and suppliers in the relationship dyad. Second was to set an approach for performance evaluation in the relationship. Saen (2006) developed a model based on DEA method to select technology

suppliers with respect to three factors. Seydel (2006) used DEA with a different approach with no input selected in the model. The article used seven point scales for ranking of the qualitative aspects of the suppliers. Further the article illustrates the benefit of DEA as it required less effort than Simple Multi-Attribute Rating Technique (SMART). Talluri et al. (2006) proposed a chance-constrained DEA approach to evaluate supplier performance taking into consideration the stochastic performance measures. This study takes into account the need for variability in vendor attributes in selecting and evaluating supplier. The input criteria considered was Price, while outputs were quality and delivery. The usefulness of the model was shown by comparing it with the deterministic DEA. Wu et al. (2007) discussed an augmented DEA approach for selection of suppliers. The model handled imprecise data (rank the efficient suppliers) and covered the discrimination among them (discriminate efficient suppliers from relatively poor performers). To allow interested parties in supplier selection and evaluation, a web-based system was designed by researchers. Kao (2010) proposed common weight DEA for ranking alternatives and focused on measurement of the relative distance from the ideal (best alternative as per the criteria) and anti-ideal alternative (worst alternative). If in case two options have the identical distance from the ideal alternative, then the one with higher distance from the anti-ideal would be most suitable option of the two and hence ranked higher. Mondal and Chakraborty (2010) proposed the idea of selection of flexible manufacturing system in an organization using DEA. Initially, the alternatives were selected based on best criterion as per the DEA model of Charnes, Cooper and Rhodes (CCR) and then the shortlisted alternatives were rated on the basis of the weighted efficiency ranking method of MCDM theory.

3. The DEA Model

DEA is a non-parametric methodology of efficiency calculation of decision making units (DMUs) which considers multiple inputs and outputs. This approach does not depend on specifications like production function, weights, etc of different selected inputs and outputs. Using DEA, assessment of comparative efficiencies of supplier, one of the decision making unit, is done in this paper. Different inputs used for measuring performance and analyzing decision making unit (DMU), considering a supplier, to get desired output depending on industry is shown in Fig. 1.

3.1 DEA Model for measuring Supplier Efficiency

In this approach we will utilize Pareto-Koopmans efficiency measure of suppliers proposed by Charnes et al (1978). In this Farrell's measure is used as a base for measurement of efficiency. Efficiency of decision making unit (DMU), here it is supplier, can be determined through absence of slack. Pareto- Koopmans relation with slack and efficiency of DMU is shown in Table 1.

Table 1 is utilized in evaluating supplier through the formula: minimize X,

$$\text{where: } X = \theta_o - \xi \left(\sum_{i=1}^m S_i^- \right) \quad (1)$$

θ_o is Farrell's efficiency measure for vendor o ;

S_i^- are input criteria slack variables;

ξ is an infinitesimally small number;

m is the number of criteria;

Vendor is efficient as compared other vendors if in the above equation Farrell efficiency value is 1.0, with 0.0 slack values. If Farrell efficiency value is less than 1.0 or slack values are greater than 0.0, then vendor is inefficient and its performance is worse as compared others as shown in table above.

Also general formula of calculation of efficiency is also used.

$$\text{Efficiency} = \frac{\text{Weighted sum of Output}}{\text{Weighted sum of Inputs}} \quad (2)$$

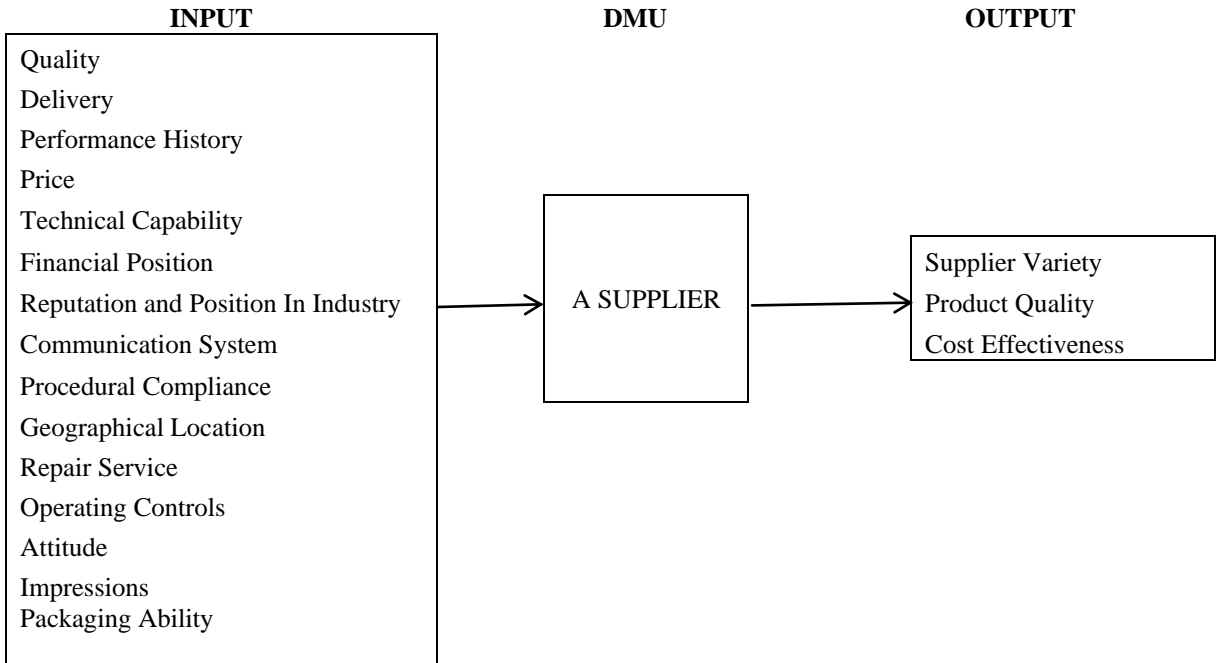


Fig. 1. DEA Model for Supplier selection

Table 1. Pareto-Koopmans Efficiency Relationship with DEA

Farrell Efficiency Value	Slack Value	DEA Efficiency Status
1.0	0.0	Efficient
1.0	>0.0	Inefficient
<1.0	0.0	Inefficient
<1.0	>0.0	Inefficient

4. Illustrative Example

Example 1:

Considering data of a multi-national telecommunications company from Talluri and Narashimhan (2004) in which twenty three suppliers were evaluated on the basis of six input parameters: quality management practices and systems(QMP), process/manufacturing capability (PMC), management of the firm (MGT), documentation and self-audit (SA), design and development capabilities (DD), cost reduction capability (CR) and five output parameters: price, delivery, quality, cost reduction performance (CRP), other. The designing

of questionnaire was in such a way to evaluate the output of suppliers on the composite score of 0 to 1. The calculated efficiency score of the suppliers from the data of the firm's survey in different category is shown in Table 2.

Taking into account the efficiency score, in terms of the supplier performance vendor 15 is most suitable for the firm and supplier 18 is worst. In this evaluation, according to efficiency vendors can be evaluated and selected without giving any information for their improvement.

Table 2. Efficiency calculation on the basis of different input and output parameters

Vendor	QMP	SA	PMC	MGT	DD	CR	Quality	Price	Delivery	CRP	Other	Efficiency Score
1	0.9662	0.9742	1.0385	1.0808	1.1417	0.7839	0.6211	0.892	0.1284	1.2107	0.6359	0.5828
2	0.7054	1.0438	0.75	0.8782	0	0.875	0.6932	0.892	0.3855	0	0.3179	0.5382
3	0.5611	0.8947	0.7789	0.7205	0.8372	0.7404	1.0205	0.434	1.542	0	1.2719	0.9417
4	1.1272	1.0438	0.952	0.9607	0.9661	1.1402	1.6639	1.133	1.542	1.2107	1.8019	1.1877
5	1.1272	1.0438	1.1251	1.0808	1.256	1.2115	0.9983	1.35	1.1565	1.2107	0.954	0.8284
6	0.9877	1.0438	0.9376	1.0808	1.0466	0.9422	1.0426	1.326	1.799	2.4214	1.2719	1.3018
7	0.8051	0.8351	1.0385	0.9607	1.256	1.0768	1.2201	1.206	0.771	2.4214	1.2719	1.1537
8	1.1809	1.0438	1.1251	1.0208	1.0627	1.0096	0.8429	1.133	0.6424	1.2107	0.8479	0.726
9	1.2346	1.0438	1.1251	1.0808	1.256	1.1442	0.6433	0.892	0.3855	0	0.5299	0.356
10	0.5904	1.0438	0.6058	0.7629	0.5796	0.4038	1.4419	0.434	1.4135	0	1.2719	1.1443
11	0.8642	0.8118	0.8182	0.9536	0.9661	0.8076	0.4215	0.892	1.0279	0	0.8479	0.6108
12	0.6441	0.8351	1.0227	1.0208	0.9661	1.0768	1.0205	1.326	0.771	1.2107	0.7418	0.911
13	1.2346	1.0438	1.1251	1.0808	1.256	1.2115	0.5546	1.109	1.0279	1.2107	1.166	0.7291
14	1.0662	1.0438	1.1251	1.0808	1.1593	1.2115	0.8208	0.892	0.8994	1.2107	0.8479	0.6986
15	1.01	1.0438	0.8654	1.0208	0.7322	0.6815	1.2423	1.567	1.4135	2.4214	1.2719	1.4787
16	0.8978	0.9742	1.0385	1.0208	0.942	0.8076	1.0205	0.892	0.3855	0	0.424	0.4792
17	1.1272	0.9742	1.0385	1.0208	1.256	1.0768	1.0205	0.868	0.771	0	0.5299	0.4912
18	1.1809	1.0438	1.1251	1.0808	1.256	1.2115	1.2201	0.241	0	0	0.424	0.2733
19	1.0735	1.0438	1.1251	0.9007	1.1593	0.9422	1.1647	0.892	1.4135	1.2107	1.0599	0.9194
20	1.0735	1.0438	1.1251	1.0808	0.6762	1.1442	0.8429	1.055	1.4135	1.2107	1.4839	0.9776
21	1.2346	1.0438	1.1251	1.0133	1.256	1.2115	0.7764	0.892	1.0279	0	0.954	0.5303
22	1.2346	1.0438	0.952	1.0808	1.0466	1.2115	1.4642	1.326	1.799	2.4214	1.4839	1.2931
23	1.0735	1.0438	1.0385	1.0172	0.8695	1.0768	1.2423	1.35	1.2849	2.4214	1.59	1.2892

Example 2:

In terms of sensitivity evaluation, an example considering Farrell's efficiency is studied.

Consider an example of a manufacturing firm from Weber et al (1996) in which six suppliers competed for an item being purchased at test plant. Since company was operating in JIT environment so three criteria: price, quality and delivery were taken for measurement of supplier efficiency. The measurement of different criteria was done independently. Price was measured by minimizing total price of purchase, delivery criterion by calculating percentage of ordered units that were late and quality criterion by percentage of units being shipped and were discarded.

Out of material demand of 10,790,000 units with annual cost of \$3.5 million approximately the allocation to individual vendor is shown in Table 3.

Table 3. Data of resource allocation to individual vendors

Vendors	V1	V2	V3	V4	V5	V6
Price/unit	0.1958	0.1881	0.2204	0.2081	0.2118	0.2096
% Late deliveries	5.0	7.0	0.0	0.0	3.0	4.0
% Rejects	1.2	0.8	0.0	2.1	2.3	1.2
Business allocation (units)	2.0m	200k	1.09m	3.0m	2.0m	2.5m

$$k = 1,000, m = 1,000,000$$

With data given in Table 3, three DEA models were proposed, firstly with two criteria: price and delivery and with price and quality and secondly, considering all three criteria.

Taking one modeling criteria at a time evaluation of the performance of suppliers is being done. Price and delivery analysis by applying DEA is shown in Table 4.

Table 4. DEA analysis considering price and delivery

Vendor	Farrell Efficiency	Slack Values	Reference Weights	Point of Efficiency
1	0.9505	Price - 0 Delivery - 0	V2 - 0.7075 V4 - 0.2925	Price - 0.1939 Delivery - 4.953
2	1.0	Price - 0 Delivery - 0	V2 - 1.0	Price - 0.1881 Delivery - 7.0
3	1.0	Price - 0.0123 Delivery - 0	V4 - 1.0	Price - 0.2081 Delivery - 0.0
4	1.0	Price - 0 Delivery - 0	V4 - 1.0	Price - 0.2081 Delivery - 0.0
5	0.9403	Price - 0 Delivery - 0	V2 - 0.4047 V4 - 0.5953	Price - 0.2000 Delivery - 2.833
6	0.9400	Price - 0 Delivery - 0	V2 - 0.5380 V4 - 0.4620	Price - 0.1973 Delivery - 3.7

Calculation of point of efficiency is done by taking data from Table 3 of the vendor selected and then multiplying with its reference weights. Efficiency of individual suppliers is being calculated using reference weights. The efficiency points being calculated are the major evaluation points for supplier negotiation. For example, for becoming DEA efficient vendor 6 needs to reduce price factor by \$0.0123 and delivery delay which is calculated by late deliveries by 0.3%. Similarly other vendors can be evaluated and vendors also can increase their efficiency by checking their performance through analysis of different criteria. After analyzing through price and delivery, next analysis is done through price and quality as shown in Table 5. In this model efficiency is calculated considering price and quality as major evaluating criteria. For example, for good and acceptable performance, vendor 1 needs price reduction of \$0.0077 per unit, and its percentage rejection from 0.4 to 0.8. Combination of all the three criteria for DEA analysis: price, quality and delivery is shown in Table 6. In the third model, evaluation of vendors is done on the basis of price, quality and delivery according to vendor reference weights. According to this analysis, vendors 2, 3 and 4 are DEA efficient. In this analysis, the model output can evaluate and set different negotiation points for vendors as done in above two models

considering two criteria. For example, Vendor 6 can be DEA efficient if it reduces its price by 0.0108 per unit, late deliveries reduction of 0.21 per cent, and reduction in rejected units by 0.07 per cent.

Table 5. DEA analysis considering price and quality

Vendor	Farrell Efficiency	Slack Values	Reference Weights	Point of Efficiency
1	0.9607	Price – 0 Quality – 0.2904	V2 – 1.0	Price – 0.1881 Quality – 0.8
2	1.0	Price – 0 Quality – 0	V2 – 1.0	Price – 0.1881 Quality – 0.8
3	1.0	Price – 0 Quality – 0	V3 – 1.0	Price – 0.2204 Quality – 0.0
4	0.9034	Price – 0 Quality – 0.5229	V2 – 1.0	Price – 0.1881 Quality – 0.8
5	0.8881	Price – 0 Quality – 0.5403	V2 – 1.0	Price – 0.1881 Quality – 0.8
6	0.8974	Price – 0 Quality – 0.2307	V2 – 1.0	Price – 0.1881 Quality – 0.8

Table 6 DEA analysis considering price, quality and delivery

Vendor	Farrell Efficiency	Slack Values	Reference Weights	Point of Efficiency
1	0.9905	Price – 0 Delivery – 0 Quality – 0.007	V2 – 0.7075 V4 – 0.2925	Price – 0.1939 Delivery – 4.953 Quality – 1.180
2	1.0	Price – 0 Delivery – 0 Quality – 0	V2 – 1.0	Price – 0.1881 Delivery – 7.0 Quality – 0.8
3	1.0	Price – 0 Delivery – 0 Quality – 0	V3 – 1.0	Price – 0.2204 Delivery – 0.0 Quality – 0.0
4	1.0	Price – 0 Delivery – 0 Quality – 0	V4 – 1.0	Price – 0.2081 Delivery – 0.0 Quality – 2.1
5	0.9443	Price – 0 Delivery – 0 Quality – 0.598	V2 – 0.4047 V4 – 0.5953	Price – 0.2000 Delivery – 2.833 Quality – 1.574
6	0.9483	Price – 0 Delivery – 0 Quality – 0	V2 – 0.5419 V3 – 0.1226 V4 – 0.3355	Price – 0.1988 Delivery – 3.3793 Quality – 1.138

5. Conclusions

In this paper, both the examples are based on application of DEA method of supplier selection and evaluation. In the first example, the vendor performance data is used by the firm for selection of vendors after calculating their efficiency point on the basis of six inputs and five outputs. With an extended approach the

company of second example selects vendor on the basis of three parameters: price, quality and delivery. The three models used in this example also present negotiation points which can be beneficial for both the firm and supplier for the improvement of their efficiency and performance. Thus, it can be seen that DEA methodology can be applied depending upon the firm's requirement.

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