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Research Paper

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Supplier selection among alternative scenarios by Data envelopment analysis

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Abstract

A considerable problem in competitive trade world is choosing the best supply chain. As a result in much more serious circumstances of competitions looking for the best supplier for manufacturing, for preparing raw material, is very significant. Meantime suppliers have different scenarios to be fulfilled, such as changing selection variables like lead-time, transportation cost and transportation path. In this paper a mathematical model using Data Envelopment Analysis (DEA) technique and binary algorithm for selecting suppliers with different scenarios is used which can evaluate suppliers with variable preferences and replacement for other suppliers.

Keywords: Supply Chain Management, Data Envelopment Analysis, Mixed Integer Programming, Binary Variables

1. Introduction

In competitive market what gains an important attention, for those firms would like to increase quality and decreasing costs, is selecting the best supplier.

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What has been discussed above is the reason many companies are working on evaluating and selecting suppliers. (Shin et al. 2000) and (FarzipoorSaen, 2007,2008,2009) discussed several important factors caused the current shift to single sourcing or a reduced supplier base. First, suppliers can be prevented from achieving the economies of preference on basis of order volume and learning curve effect. Second, a reduced supplier base is less expensive than a multiple supplier system, as costs directly increase while a large number of suppliers for a specific item are being managed, (Farzipoor Saen, 2010). Third, a reduced supplier base helps omit any suspicion between buyers and suppliers for in existence of communication. Fourth, worldwide competition forces firms to find the best suppliers, (Farzipoor Saen, 2010). Any supply chain can be managed from various methods while in any supply chain management supplier selection is a fundamental aspect. As indicated in (Farzipoor Saen, 2010) several factors such as Transportation Lead time, Transportation Cost, Production Lead time, Order Cost, Quality Level, etc. play an important role in choosing suppliers. Lots of researches worked on the concepts of supply chain. (Ho et al, 2010) worked on Multi-criteria decision making approaches for supplier evaluation and selection. (Zolghadri et al, 2011) have considered Power-based supplier selection in product development projects.

Ongoing developments of DEA and its extensive application, in both theoretical and practical aspects, have been got scientists' attentions. Thus, it has been used in many fields for performance evaluation.

This technique has been discussed in the CCR paper by (Charnes et al, 1997), and then developed by various researchers (Hosseinzadeh et al, 2013). This method computes the relative efficiency of a set of DMUs which use multiple resources to produce multiple outputs. Finally divide DMUs into two groups of efficient and inefficient DMUs (Toloo et al. 2009). In original DEA formulations decision making units (DMUs) can freely choose the weights to maximize corresponding efficiency, under the condition that for all other DMUs this system of weights being feasible. This freedom of choice shows the DMU in the best possible scenario, and means no input or output is more important than any other. Meanwhile it can be a disadvantage as a unit may assign zero weights to the inputs and/or outputs on which its performance is worst. Thus to avoid such problem, freely assigned weights, input and output weights should be constrained in DEA.

To evaluate the aggregate performances of suppliers, (Liu et al. 2000) utilized DEA technique. Their work extends (Weber's, 1996) research in using DEA in supplier evaluation for an individual product. In order to select appropriate suppliers, (Talluri et al. 2006) suggested a chance-constrained data envelopment analysis (CCDEA). To select the best suppliers in the presence of both cardinal and ordinal data, (Farzipoor Saen, 2010) proposed an innovative method, which is based on imprecise data envelopment analysis (IDEA).

As Data envelopment analysis (DEA) is very strong technique which widely used for efficiency evaluation of systems with multiple inputs and outputs, thus it can be used in assessing process of supplier selection. Moreover, dealing with multiple properties in confliction with each other and connected with the modern necessities of ministerial sciences considered as an important part in supplier selection, DEA is a widely accepted evaluation method by researchers. In this paper a mixed integer DEA programming model is used to identify the best supplier.

This paper is prepared as following: In Section 2, literature review will be presented. In Section 3 the new method for selecting the suppliers will be discussed. Finally, a practical application of MILP model on five suppliers of a company in IRAN is used to get the best supplier.

2. Data envelopment analysis

As stated in literature data envelopment analysis is a mathematical programming technique for performance assessment of homogenous decision making units. Considering this analysis relative efficiency of a set of DMUs can be obtained. Consider a set of n DMUs to be evaluated. Each of which has an m-vector of inputs and an s-vector of outputs. CCR model, first presented by (Charnes et al, 1978) in input orientation is as follows:

$$
\begin{aligned}
& Min\ \ \theta \\
& s.t. \quad \sum_{j=1}^{n} \lambda_j x_{ij} \le \theta x_{io}, \qquad i = 1,\dots,m, \\
& \qquad \sum_{j=1}^{n} \lambda_j y_{rj} \ge y_{ro}, \qquad r = 1,\dots,s, \\
& \qquad \lambda_j \ge 0, \qquad\qquad j = 1,\dots,n.
\end{aligned} \tag{1}
$$

The optimal solution of this model satisfies $0 < \theta^* \le 1$. If $\theta^* = 1$ DMUo, DMU under consideration, is said to be relative efficient else it is inefficient.

Consider dual model of this LP problem, we will have the following model which is the multiplier form of CCR model.

$$
\begin{aligned}
& Max \quad \sum_{r=1}^{s} u_r y_{ro} \\
& s.t. \quad \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \le 0, \qquad j = 1,\dots,n, \\
& \qquad \sum_{i=1}^{m} v_i x_{io} = 1, \\
& \qquad u_r \ge \varepsilon, \qquad\qquad r = 1,\dots,s, \\
& \qquad v_i \ge \varepsilon, \qquad\qquad i = 1,\dots,m.
\end{aligned} \tag{2}
$$

In this model $u_r, r = 1,\dots,s$ and $v_i, i = 1,\dots,m$ are weights of inputs and outputs. If $\sum_{r=1}^{s} u^*{}_r y_{ro} = 1$ then DMUo is called as efficient else inefficient.

Mentioned models are presented in input orientation and can be easily written in output orientation if necessary, as well.

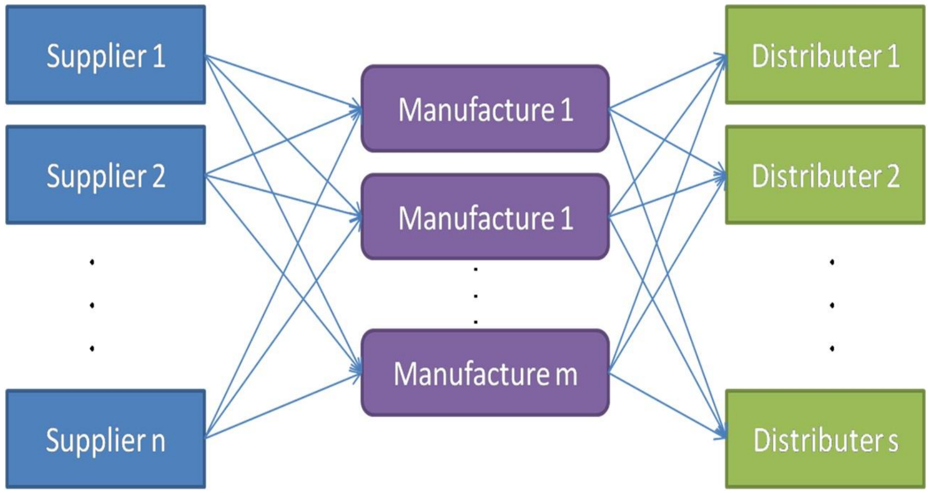
As regards of what has been discussed about DEA technique, evaluating a set of firms or organizations from relative efficiency aspects can be accurately performed. In DEA literature many applications are performed while using this technique. The results help manager for better decision making.

3. Selecting the best Supplier

For any factory choosing the best raw materials proportionate to production process among the best competitive alternatives is a privilege. As technology develops, finding suitable suppliers, all around the world, seems to be easy and immediate. But choosing a supplier with various scenarios among a vast number of suppliers is a matter of discussion and investigation. Being sure that selecting a specific supplier can reach the view point and conditions of organization, from quality, quantity, financial and etc., is one of the most important positive points in competition. In this paper a data envelopment analysis model which uses binary variables has been considered. Moreover, a new algorithm is also provided. Note that initial subjects and a general diagram of DEA model and choosing suppliers have been explained in previous sections. If the aim is to find a supplier with the best condition among peers then a list of indicators for each supplier with alternative scenarios must be prepared.

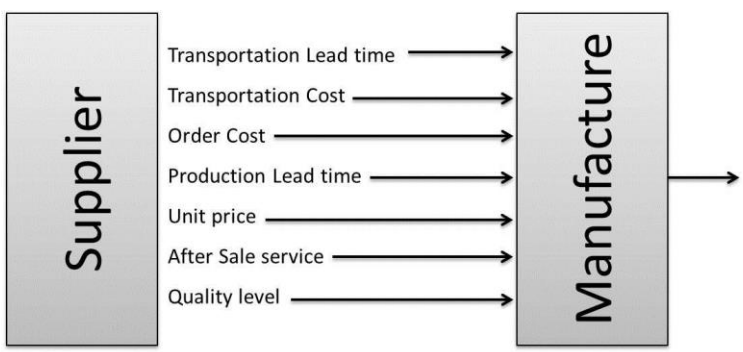
A general schema of the model is traced as following:

Figure 1: General template of Supply Chain Management



As said formerly, the purpose of this study is to find a supplier with the best condition and it is only needed to prepare the data for input variables because output variable, mathematically, translates to a single unit of an item to be purchased. And some of the inputs such as quality are as undesirable input so simplified figure for this purpose is as below:

Figure 2: A simplified DEA model for selecting Supplier



As an instance, if a supplier located in China it can supply required raw materials by air cargo or ship with different delivery times and costs thus there is need for preparation of list contains scenarios of the first supplier, as shows in following. For each supplier all scenarios should be recognized and codifies.

Table 1: different scenarios of supplier 1

Supplier 1	China		
Scenarios	Scenario 1	Scenario 2	Scenario 3
Delivery time	A1	A2	A3
Path	B1	B2	B3
Transportation cost	C1	C2	C3
Quality	D1	D2	D3
Service after sail	E1	E2	E3
.	.	.	.
.	.	.	.
.	.	.	.

In continue, in accordance with organizations' preferences suitable weights for each criterion should be considered. As an example, in an organization as regards of time conditions of the order one of the best criterions is delivery in the shortest possible time. Thus, corresponding weight of delivery time should be much more than that of service after sale, as an example. Further, a mathematical model for reaching the aim of the organization about choosing the best supplier should be formulated. In doing so, as declared earlier one of the key feature of the proposed method is using DEA technique as it is a strong performance evaluation mathematical programming technique. As respect to selecting the best criteria from among different scenarios, a binary model is proposed. This MIP model is as following:

$$\begin{aligned}
Max \quad & U\ Y_p(1-t_j)+U'Y'_p(1-t'_j) \\
s.t. \quad & V\ X_p = 1, \\
& U\ Y_j - V\ X_j \le M\ t_j, \qquad j=1,\dots,n, \\
& U'Y'_j - V'X'_j \le M\ t'_j, \qquad j=1,\dots,n, \\
& t_j + t'_j = 1, \qquad j=1,\dots,n, \\
& U \ge \varepsilon,\ V \ge \varepsilon,\ t_j, t'_j \in \{0,1\}.
\end{aligned} \tag{3}$$

It is perceived that this model is nonlinear mixed integer and this may cause considerable complexity on the subject of being binary. Therefore it needs to be converted into a linear programming problem. This model cannot be converted into linear form thus in following a linear mixed integer model will be presented which does the same as the nonlinear one. Introducing this linear mixed integer model is one of the key features of this article as it does not suffer from complexity of nonlinear model. Corresponding linear model is as follows.

$$
\begin{aligned}
Max \quad & U\ Y_p + U'Y'_p - 1 & & \\
s.t. \quad & V\ X_p = 1, & & (a) \\
& U\ Y_p \leq 1, & & (b) \\
& U'Y'_p \leq 1, & & (c) \\
& U\ Y_j - V\ X_j \leq M\ t_j, \quad j = 1,\ldots,n, & & (d) \\
& U'Y'_j - V'X'_j \leq M\ t'_j, \quad j = 1,\ldots,n, & & (e) \\
& t_j + t'_j = 1, \qquad j = 1,\ldots,n, & & (f) \\
& U \geq \varepsilon,\ V \geq \varepsilon,\ t_j, t'_j \in \{0,1\}. & &
\end{aligned}
\qquad (4)
$$

In the above model constraints (b) and (c) are added which helps removing nonlinearity in objective function of model (3). Considering binary variable s and condition (f) both of these binary variables cannot get positive value. Considering this condition one of the constraints (d) and (e) is satisfied and the other is redundant. Now considering the satisfied constrain, as an instance constraint (d). If $j = p$ in this constraint, then according to (a) $UY_p \leq 1$. In accordance to this fact that the aim of this model is to maximize UY_p thus it can be concluded that in optimal solution $U^* Y_p = 1$. Therefore, what will be remained in the objective function of this model is $U'Y'_p$ which constrained to get values less than one. In this way there is no need for binary variables in objective function.

This MIP model is made based on the principles of CCR model and has an authority of finding most efficient suppliers with the best scenarios. In this case, at first an internal assessment for each supplier with different scenarios using binary variables is implemented then the best scenario for that supplier with due attention to internal conditions is chosen, and then choosing the best scenario from among each of suppliers final assessment will be accomplished.

4. Application

In this section this method with the proposed model is performed for a company. Company under evaluation for supplying required raw materials for the considered supply chain uses five local and global suppliers. Each of suppliers has different scenarios. It should be noted that as some of the considered outputs in the model are undesirable therefore they are taken into consideration in the form of $1/Y_j$.

Seven significant criteria are considered as their preference weights are illustrated in the following table.

Table2: indexes and Importance

No	Index	Weight
1	Transportation Lead time	6
2	Transportation Cost	4
3	Production Lead time	6
4	Order Cost	5
5	Unit Price	9
6	After sale service	8
7	Quality Level	10

Following table contains suppliers with their scenarios:

Table3: Supplier and Scenarios data

State	Supplier	Scenario	Transportation Lead time	Transportation Cost	Production Lead time	Order Cost	Unit Price	Customer Service Level	Quality Level
Local	Supplier 1	scenario 1	4	102000	60	1000	510000	6	5
		scenario 2	22	25500	66	1000	510000	6	5
	Supplier 2	scenario 1	5	144500	55	1200	578000	7	6
		scenario 2	31	35700	62	1200	578000	7	6
	Supplier 3	scenario 1	1	59500	70	250	493000	2	3
		scenario 2	7	10200	75	250	493000	2	3
International	Supplier 4	scenario 1	50	357000	60	3500	204000	8	7
		scenario 2	50	357000	90	2500	238000	8	8
	Supplier 5	scenario 1	35	476000	50	3000	340000	10	10
		scenario 2	45	306000	55	3000	340000	10	10

The main subject of this paper is to find the best supplier from among others with different scenarios. It should be noted that here just the first node, supplier, is being investigated as a matter of simplicity. Thus, all criteria for each and every supplier have been considered as outputs for manufacturer. Some of the outputs are undesirable thus according to what has been proved and discussed in DEA literature they have been considered as inputs. Consider the following table consists of the obtained results.

Table 4: Result

Supplier	Rank	Scenario selection		Efficiency
Supplier 1	4	Scenario 1	0	0.556767
		Scenario 2	1	
Supplier 2	3	Scenario 1	0	0.653496
		Scenario 2	1	
Supplier 3	5	Scenario 1	0	0.303859
		Scenario 2	1	
Supplier 4	2	Scenario 1	1	0.801659
		Scenario 2	0	
Supplier 5	1	Scenario 1	1	1
		Scenario 2	0	

As you can see in the table of results, the fifth supplier with 100% efficiency, in the first scenario, have been working as the best supplier. After that, the fourth, second, first, third are arranged, in turn, in the next places. Supplier with the best scenario is determined by binary variables.

If the value of mentioned binary variable, related to first scenario of the first supplier, is obtained one it will be announced as a best scenario with better condition in comparison to the others. It needs to be note that at the beginning an internal assessment between scenarios in a supplier is completed with binary variables then with the best scenario of a supplier, the evaluation among other suppliers is accomplished.

4. Conclusion

Finding the best supplier with the best alternative scenarios is one of the critical point in supply chain management and decision makers want to solve this problem by lowest risk. In this regard, for each and every supplier, all scenarios should be specified and by paying attention to organization's decision preference, weights for each criterion should be accounted for.

In this paper a mathematical model, for evaluating supplier with their alternative scenarios, is presented. Indeed the best alternative scenario among others for a supplier is found and after that this supplier, in comparison to other suppliers, is evaluated. Converting mixed integer nonlinear model to a mixed integer linear programming problem is one of the key features of this study.

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