A mathematical programming model for suppliers selection

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Abstract: In this paper we propose a new weighted nonlinear model to solve the multiple criteria supplier selection problem. Our model not only incorporates multiple criteria for supplier selection, but also maintains the effects of weights in the final solution. An illustrative example is presented to compare our model and those in the literature.

Key–Words: Supplier selection, Multiple criteria analysis, Mathematical programming

1 Introduction

In today's highly competitive environment, an effective supplier selection process is very important to the success of any manufacturing organization and selecting the right supplier is always a difficult task. The success of a supply chain is highly dependent on selection of good suppliers. Supplier selection and evaluation is the process of finding the appropriate suppliers who are able to provide the buyer with the right quality products and/or services at the right price, in the right quantities and at the right time [12]. Indeed supplier selection is a multiple criteria decision-making (MCDM) problem affected by several conflicting factors such as price, quality and delivery [6]. Early in 1960s, Dickson identified 23 criteria that ought to be considered by personnel in evaluating suppliers [4].
Over the years, several techniques have been developed to solve the problem efficiently. Analytic hierarchy process (AHP), analytic network process (ANP), linear programming (LP), mathematical programming , multi-objective programming, neural networks (NN), case-based reasoning (CBR), simple multi-attribute technique (SMART) and fuzzy set theory (FST) methods have been applied in literature [1, 2, 3, 5, 6, 8, 11] . These models provide systematic approaches for purchasing managers to evaluate and score suppliers with multi-criteria. Nevertheless, these models are not easy to implement. For instance, models based on multi-objective optimization require the decision makers to exogenously specify the exact values of weights of individual criteria. It is however difficult to obtain precise weight values [7].
The rest of this paper is organized as follow. In the following section we propose our new model. Section 3 is devoted to a numerical illustration. Finally, concludes and future research directions are presented.

2 Proposed model

We consider a situation in which a set of suppliers is available. The manager would like to rank these suppliers based on J criteria. The measure of supplier i under criteria j is denoted as x_{ij} $(j = 1, 2, ..., J)$. We evaluate a supplier by converting multiple measures under all criteria into a single score. A common scale for all measures is also an important issue. A particular criterion measure, in a large scale, may always dominate the score. For this, we propose normalizing all measures x_{ij} into a 0-1 scale. We denote all transformed measures as y_{ij}. In order to transform the performance ratings, the performance ratings are normalized into the range of [0, 1] by the following equations

(i) The larger the better type:

$$y_{ij} = \frac{x_{ij} - \min\{x_{ij}\}}{\max\{x_{ij}\} - \min\{x_{ij}\}} \quad (1)$$

(ii) The smaller the better type:

$$y_{mn} = \frac{\max\{x_{ij}\} - x_{ij}}{\max\{x_{ij}\} - \min\{x_{ij}\}} \quad (2)$$

The score of a supplier is expressed as the weighted sum of transformed measures. Now let w_j be the relative importance weight attached to the jth criteria $(j = 1, 2, ..., J)$ and y_{ij} be the the performance of ith supplier in terms of jth criteria. The proposed model

ISBN: 978-960-474-270-7

is as follows:

$$\begin{aligned} \max \quad & S_i = \sum_{j=1}^{J} y_{ij} w_j \\ s.t. \quad & \sum_{j=1}^{J} w_j^2 = 1, \\ & w_j \geq w_{j+1} \geq 0, \quad j = 1, 2, ..., J-1 \\ & w_j \geq 0, \qquad\qquad j = 1, 2, ..., J \end{aligned} \tag{3}$$

The model (3) is a nonlinear programming model, which determines the most favourable weights for each supplier. The model (3) is a variant of the following multiple attribute decision making model

$$\begin{aligned} \max \quad & S_i = \sum_{j=1}^{J} s_{ij} w_j \\ s.t. \quad & \sum_{j=1}^{J} w_j^2 = 1, \\ & w_j \geq 0, \qquad j = 1, 2, ..., J \end{aligned} \tag{4}$$

where s_{ij} is the normalized attribute value of the ith decision alternative with respect to the j th attribute and w_j is the relative importance weight of the j th attribute. Using Lagrangian multipliers method, the analytical solution to model (4) is found to be

$$w_j^* = \frac{s_{ij}}{\sqrt{\sum_{j=1}^{J} s_{ij}^2}}, \quad j = 1, 2, ..., J \tag{5}$$

However, due to the presence of the ordering constraint $w_1 \geq w_2 \geq ... \geq w_J \geq 0$, the model (3) cannot usually be solved analytically, but can be solved using Microsoft Excel Solver or the LINGO software package very easily.

3 Numerical illustrations

We illustrate implementation of our proposed model with a multi-criteria supplier selection problem as in the literature [9, 10]. Five criteria, including supply variety, quality, distance, delivery and price are under consideration by a firm manufacturing agricultural and construction equipment. Supply variety is the number of parts supplied by the supplier. It is considered first as the company would like to reduce the number of suppliers. The quality of supplied parts is also an important criterion for a company in supplier evaluation. The distance is related to delivery efficiency. A longer distance will affect the delivery service of the supplier due to a longer lead time or restricted delivery time windows. The criterion delivery measures the percentage of on-time delivery. Lastly, the price index indicates the estimated price level offered by a supplier as compared to the average market price. If the price level offered is higher than the average price, the price index will be of a value higher than 100% and vice versa.

There are 18 suppliers available. The measures of each supplier under the five criteria are listed in Table 1. We take a reciprocal transformation of price and distance measures so that the transformed values are positively related to the desired scores. Normalization is then preformed to scale all measures within a 0-1 range. In Table 2 we displayed the obtained weight for each criterion using Ng-model. As we see the Ng-model assigns zero weight to some criteria. This means that the Ng-model ignores most of data. Table 3 shows the supplier selection using proposed model. This table shows the rank of each supplier in the proposed model, Ng-model [10] and DEA model [9] as well.

For comparison purpose, we consider the best 5 suppliers as there were 5 efficient suppliers identified by the Ng-model, using the same dataset . The top 5 suppliers identified are suppliers 15, 17, 10, 5 and 11. These suppliers are good suppliers in the Ng-model as well, but with different ranking. In fact the top 5 suppliers in the Ng-model are 10, 17, 15, 5 and 11. As we see, suppliers 17 and 11 have the same rank in both Ng and the proposed model. It can be seen from Table 3 that supplier 15 has the first rank in the proposed model whereas its rank in the Ng-model is 3. The reason is that our model considers all of the five criteria while the Ng-model considers only the first and second criteria, that is, the weight of the third, fourth and fifth criteria is zero in the Ng-model. Now consider supplier 10. This supplier has the first rank in the Ng-model while the rank of this supplier in the proposed model is three. To explain this difference note that the Ng-model only considers the first criterion ($w_1 = 1$) and ignores the other criteria ($w_2 = w_3 = w_4 = w_5 = 0$); while our method considers all of the criteria. Furthermore, our model provides a robust ranking while as we saw the Ng-model does no have this property.

The above example has been solved (using DEA) in [9], too. For comparison purpose, we consider the best 5 suppliers as there were 5 efficient suppliers identified by the DEA model in [9]. The top 5 suppliers identified are suppliers 10, 17, 5, 15 and 11. Suppliers 10, 15 and 17 are good suppliers in both DEA and the proposed model. Suppliers 5 and 11 were not identified as good suppliers in the DEA model. On

the other hand, suppliers 1 and 12 were identified as good suppliers in the DEA model but were not identified by our proposed model. The reason for these difference are due to the incorporation of the relative importance of the criteria. Suppliers 1 and 12 were efficient suppliers in DEA models. However, the supply varieties of these two suppliers are only 2 and 7, which are relatively low, compared to other suppliers. When the supply variety is considered as a relatively important criterion, these two suppliers are eliminated. The good suppliers we identified are good not simply by the most important criterion (supply variety). Suppliers 5 and 11 with relatively low supply variety measures, 24 and 10 respectively, were rated high because of the advantage of relatively shorter distances. Finally note that similar to the Ng-model the DEA model proposed in [9] could not rank the suppliers.
As we see our model therefore provides a more reasonable and encompassing index for supplier selection problem as compared to the Ng-model and DEA model.

Supplier	w_1	w_2	w_3	w_4	w_5
1	0.333	0.333	0.333	0.000	0.000
2	0.500	0.500	0.000	0.000	0.000
3	0.500	0.500	0.000	0.000	0.000
4	0.500	0.500	0.00	0.000	0.000
5	0.333	0.333	0.333	0.000	0.000
6	0.333	0.333	0.333	0.000	0.000
7	0.500	0.500	0.000	0.000	0.000
8	0.500	0.500	0.000	0.000	0.000
9	0.500	0.500	0.000	0.000	0.000
10	1.00	0.000	0.000	0.000	0.000
11	0.250	0.250	0.250	0.250	0.000
12	0.250	0.250	0.250	0.250	0.000
13	0.500	0.500	0.000	0.000	0.000
14	0.250	0.250	0.250	0.250	0.000
15	0.500	0.500	0.000	0.000	0.000
16	0.500	0.500	0.000	0.000	0.000
17	0.500	0.500	0.000	0.000	0.000
18	0.500	0.500	0.000	0.000	0.000

Table 2. Obtained weights using the Ng-model

Supplier	S-V	Q(%)	D(Mile)	D(%)	P-I(%)
1	2	100	249	90	100
2	13	99.79	643	80	100
3	3	100	714	90	100
4	3	100	1809	90	100
5	24	99.83	238	90	100
6	28	96.59	241	90	100
7	1	100	1404	85	100
8	24	100	984	97	100
9	11	99.91	641	90	100
10	53	97.54	588	100	100
11	10	99.95	241	95	100
12	7	99.85	567	98	100
13	19	99.97	567	90	100
14	12	91.89	967	90	100
15	33	99.99	635	95	80
16	2	100	795	95	100
17	34	99.99	689	95	80
18	9	99.36	913	85	100

Table 1. Measures of suppliers under criteria

Supplier	Score	Ranking		
		Our model	Ng-model	DEA
1	1.2442	8	9	1
2	0.8914	14	10	13
3	0.8917	13	14	8
4	0.8178	15	14	8
5	1.4846	4	4	7
6	1.3077	6	7	9
7	0.7372	17	16	10
8	1.2272	7	6	2
9	0.9988	11	11	6
10	1.5260	3	1	1
11	1.4510	5	5	3
12	1.1681	9	12	1
13	1.1130	10	8	5
14	0.3918	18	17	12
15	1.6281	1	3	1
16	0.9707	12	15	4
17	1.6257	2	2	1
18	0.8072	16	13	11

Table 3. Obtained results using proposed model and a comparison of our, Ng and DEA-model

ISBN: 978-960-474-270-7

4 Conclusion

In this paper we presented a simple nonlinear programming model for multi-criteria supplier selection problem. The contribution of this paper is to provide a model for supplier selection problem that not only incorporates multiple criteria, but also maintains the effects of weights in the final solution.

Acknowledgements: The research was supported by the Islamic Azad University, Mobarakeh Branch.

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