Theory of Approximation and Applications, 2020, Volume 14, No.1: 21-26, DOR: 20.1001.1.25382217.2020.14.1.11.3

Effective Approach for Solving the Supplier Selection Problem Under Multiple Criteria

Abdollah Hadi-Vencheh*

Department of Mathematics, Islamic Azad University, Khorasgan Branch, Isfahan, Iran

Article Info

Keywords
Supply chain
Multiple criteria analysis
Supplier selection
DEA.

Article History
Received: 2019 June 15
Accepted: 2020 February 11

Abstract

Supplier selection plays an essential role in organizations due to the cost of raw material constitutes the main cost of the final product. Thus, we develop a new approach to solve the multiple criteria supplier selection problem. The proposed method considers the effects of weights in the final solution. An illustrative example is presented to show the capabilities of our approach.

1 Introduction

The selection of suppliers plays a key role in an organization because the cost of raw material constitutes the main cost of the final product. A typical manufacturer spends 60% of its total sales on purchased items such as raw materials, parts, subassemblies and components [1-5]. In automotive industries, these costs may be more than 50% of the total revenues. That can go up to 80% of the total product costs for high technology firms [6-10]. Many experts believe that the supplier selection is the most important activity of a purchasing department [11-15]. Therefore, the supplier link in the supply chain appears to have significant cost-cutting opportunities. Determining selection criteria and selection techniques are the most important sides of supplier selection. Toloo Nalchigar [15] proposed an integrated data envelopment analysis model which was able to identify most efficient supplier in presence of both cardinal and ordinal data. Hadi-Vencheh [3] proposed a weighted nonlinear model to solve the multiple criteria supplier-selection problem. Hadi-Vencheh Niazi-Motlagh [4] presented an extended voting analytic hierarchy process method for selecting suppliers. Karsak Dursun [10] proposed a novel fuzzy multi-criteria group decision making framework for supplier selection integrating quality function deployment and data envelopment analysis. Izadikhah Farzipoor Saen [7] present a new two-stage DEA model considering negative input-intermediate-output data to evaluate 29 Iranian supply chains producing equipment of expendable medical devices. Izadikhah and Farzipoor Saen [9] developed a method for solving voting system by data envelopment analysis for selecting the most sustainable suppliers that supply self-supporting cable for a power distribution company. Dobos Vörösmarty [2] developed a data envelopment analysis supplier selection method, where green factors served as the output variables of a DEA model, and management variables were the inputs.

* Corresponding Author's E-mail: ahadi@khuisf.ac.ir

Tavassoli, Saen, Zanjirani [16] presented four types of supplier selection models in supply chains and provided a decision making scheme for selecting appropriate model for supplier selection by means of DEA models. Davoudabadi, Mousavi, Sharifi [1] developed a new integrated efficiency measurement model combining statistical techniques, decision making, and mathematical programming for resilient supplier analysis. Yazdani et al. [20] provided a sustainable supplier evaluation structure under multiple criteria and interval valued fuzzy neutrosophic model. Sivanagaraju Pitchaiah, Hussaian, Govardhan [15] reviewed the literature of multi-criteria dynamic methodologies for supplier assessment and choice. Kaur Prakash Singh [11] proposed a multi-stage hybrid model for integrated supplier segmentation, selection, and order allocation considering risks and disruptions. Izadikhah, Azadi, Toloo, Hussain [6] proposing a novel fuzzy chance-constrained two-stage data envelopment analysis model as an advanced and rigorous approach in the performance evaluation of sustainably the supply chains. Izadikhah and Farzipoor Saen [8] presented a new stochastic two-stage data envelopment analysis model for assessing the sustainability of supply chains. Hosseini, Flapper, Pirayesh [5] presented a method for supplier selection and order allocation under uncertainties for a multi-item, multi-period setting, where each supplier has its own pricing policy. Saputro, Figueira, Almada-Lobo [14] formulated a framework that provides guidance on how supplier selection should be formulated and approached for different types of items segmented in Kraljic's portfolio matrix and production policies.
In a recent paper Ng [7] proposed a weighted linear optimization model for multi-criteria supplier selection problem. The proposed model, hereafter called the Ng-model, converts all criteria measures of a supplier into a scalar score. The classification based on the calculated scores is then applied. With proper transformation, the Ng-model can obtain the scores of suppliers without a linear optimizer. The Ng-model is simple and easy to understand. Despite its many advantages, the Ng-model leads to a situation where the weight of a certain criteria becomes 0. That is, this criteria do not have any role for determining total score of the related supplier. This may lead to a situation where a supplier is inappropriately ranked. This may not reflect the real position of this supplier. The purpose of this short paper is to present an extended version of the Ng-model by considering weights values for multi-criteria supplier selection problem.

2 Ng-model

Assume that I suppliers is available for a company. The purchasing manager would like to evaluate these suppliers based on J criteria. In particular, let the performance of ith supplier in terms of each of the criteria be denoted as x_{ij}. For simplicity, further assume that all the criteria are benefit-type criteria, i.e. they are positively related to to the score of a supplier. If there is a negatively related criterion, transformation of negativity or taking reciprocal can be applied for conversions. The purpose is to aggregate multiple performance scores of a supplier with respect to different criteria into a single score S_i. In the Ng-model, the author firstly transforms all measures to comparable base. Using transformation

$$y_{ij} = \frac{x_{ij} - \min_{i=1,2,\dots,I}\{x_{ij}\}}{\max_{i=1,2,\dots,I}\{x_{ij}\} - \min_{i=1,2,\dots,I}\{x_{ij}\}}, \tag{2.1}$$

Ng converts all measurement in a 0-1 scale for all items. To facilitate the supplier selection under multiple criteria, Ng defines a non-negative weight w_{ij} which is the weight of contribution of performance of the ith supplier under the jth criteria to the score of the supplier. It is assumed the criteria are ranked in a descending order such that $w_{i1} \geq w_{i2} \geq \dots \geq w_{iJ}$ for all supplier i. The purpose is to aggregate multiple performance scores of a supplier with respect to different criteria into a single score. The proposed model by Ng [13] for aggregation purposes is as follows:

$$\begin{aligned} \max \quad & S_i = \sum_{j=1}^{J} y_{ij} w_{ij} \\ s.t. \quad & \sum_{j=1}^{J} w_{ij} = 1, \\ & w_{ij} \geq w_{i(j+1)} \geq 0, \quad j = 1, 2, ..., J-1 \\ & w_{ij} \geq 0, \qquad\qquad j = 1, 2, ..., J \end{aligned} \tag{2.2}$$

Based on the transformations $u_{ij} = w_{ij} - w_{i(j+1)},\ u_{iJ} = w_{iJ}$ and $a_{ij} = \sum_{k=1}^{j} y_{ik}$, model (2.2) is converted to the following for all inventory items:

$$\begin{aligned} \max \quad & S_i = \sum_{j=1}^{J} a_{ij} u_{ij} \\ s.t. \quad & \sum_{j=1}^{J} j u_{ij} = 1, \\ & u_{ij} \geq 0, \qquad j = 1, 2, ..., J \end{aligned} \tag{2.3}$$

Now the the maximal score S_i can be obtained by the dual of (2.3). That is, the score S_i of the ith inventory item can be easily obtained as

$\max_{j=1,2,...,J}(\frac{1}{j}\sum_{k=1}^{j} y_{ik})$.

3 Issues on Ng-model

In this section using a multi-criteria supplier selection problem We show that Ng-model is not appropriate to applications. Three criteria are under consideration by a company. There are 5 suppliers available. The measures of each supplier under the three criteria are listed in Table 1. We take a reciprocal transformation of the second criteria 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. Table 2 shows the transformed and normalized measures of all suppliers.

Table 1: Measures of suppliers under criteria

Supplier	First criteria	Second criteria	Third criteria
1	24	238	90
2	13	643	80
3	34	689	95
4	53	588	100
5	28	241	90

Table 2: Transformed and normalized measures

Supplier	First criteria	Second criteria	Third criteria
1	0.275	0.000	0.500
2	0.000	0.898	0.000
3	0.525	1.000	0.750
4	1.000	0.776	1.000
5	0.375	0.006	0.500

Now using the Ng-model (the model (2.2)) we solve this supplier selection problem. The following table shows the score of each supplier and optimal weight for each criteria.

Table 3: Weights and score of suppliers

Supplier(i)	w_{i1}	w_{i2}	w_{i3}	S_i
1	1.000	0.000	0.000	0.275
2	0.500	0.5000	0.000	0.449
3	0.500	0.500	0.000	0.762
4	1.000	0.000	0.000	1.000
5	1.000	0.000	0.000	0.375

Table 3 shows the obtained results using the Ng-model. As for the third criteria for all suppliers, the weight is 0, which means that the third criteria does not have any meaning. Therefore, we can say that the Ng-model, is not appropriate or applicable.

4 The proposed model

In virtue of its Data Envelopment Analysis (DEA) feature, the Ng-model avoids subjectiveness in determining weights and provides an objective way for supplier selection problem. However, as we see, the Ng-model may ignore the data of a criterion. This may lead to the situation where a supplier is inappropriately ranked, which may not reflect the real position of this supplier. To address this issue, we extend the Ng-model and propose a similar weighted optimization model. Let w_j be the relative importance weight attached to the jth criteria $(j = 1, 2, ..., J)$. The proposed model is as follows:

$$
\begin{aligned}
\max \quad & S_i = \sum_{j=1}^{J} y_{ij} w_j - (w_1 - w_J) \\
s.t. \quad & \sum_{j=1}^{J} w_j = 1, \\
& w_j \geq w_{j+1} \geq 0, \qquad j = 1, 2, ..., J-1 \\
& w_j \geq 0, \qquad j = 1, 2, ..., J
\end{aligned}
\tag{4.1}
$$

The meaning of (4.1) is to maximize $\sum_{j=1}^{J} y_{ij} w_j$ and minimize the gap between the maximum weight w_1 and the minimum weight w_J simultaneously, which amounts to solving a two-objective optimization model with $\sum_{j=1}^{J} y_{ij} w_j$ and $w_1 - w_J$ for maximization and minimization, respectively.

5 Numerical example

We applied our method, to the same multi-criteria supplier selection problem as discussed in the section 3. It can be seen from Table 4 that, due to the extensions made to the Ng-model, our model avoids of of zero weights and consider all criteria.

Table 4: Weights and score of suppliers using proposed model

Supplier(i)	w_{i1}	w_{i2}	w_{i3}	S_i
1	0.395	0.330	0.275	0.258
2	0.554	0.256	0.190	0.299
3	0.443	0.287	0.270	0.758
4	0.333	0.333	0.333	0.925
5	0.550	0.256	0.194	0.293

As we see our model therefore provides a more reasonable and encompassing index for multi-criteria inventory classification as compared to the Ng-model.

6 Conclusion

In this short paper we presented an extended version of the Ng-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, an improvement over the model proposed by Ng. The proposed model could be viewed as providing a more reasonable and encompassing index since it uses weights for each supplier.

References

[1] Davoudabadi, R., Mousavi, S. M., Sharifi, E. (2020). An integrated weighting and ranking model based on entropy, DEA and PCA considering two aggregation approaches for resilient supplier selection problem. Journal of Computational Science, 40, 101074. doi:https://doi.org/10.1016/j.jocs.2019.101074

[2] Dobos, I., Vörösmarty, G. (2019). Inventory-related costs in green supplier selection problems with Data Envelopment Analysis (DEA). International Journal of Production Economics, 209, 374-380. doi:https://doi.org/10.1016/j.ijpe.2018.03.022

[3] Hadi-Vencheh, A. (2011). A new nonlinear model for multiple criteria supplier-selection problem. International Journal of Computer Integrated Manufacturing, 24(1), 32-39. doi:10.1080/0951192X.2010.527372

[4] Hadi-Vencheh, A., Niazi-Motlagh, M. (2011). An improved voting analytic hierarchy process–data envelopment analysis methodology for suppliers selection. International Journal of Computer Integrated Manufacturing, 24(3), 189-197. doi:10.1080/0951192X.2011.552528

[5] Hosseini, Z. S., Flapper, S. D., Pirayesh, M. (2022). Sustainable supplier selection and order allocation under demand, supplier availability and supplier grading uncertainties. Computers Industrial Engineering, 165, 107811. doi:https://doi.org/10.1016/j.cie.2021.107811

[6] Izadikhah, M., Azadi, M., Toloo, M., Hussain, F. K. (2021). Sustainably resilient supply chains evaluation in public transport: A fuzzy chance-constrained two-stage DEA approach. Applied Soft Computing, 113, 107879. doi:https://doi.org/10.1016/j.asoc.2021.107879

[7] Izadikhah, M., Farzipoor Saen, R. (2016). Evaluating sustainability of supply chains by two-stage range directional measure in the presence of negative data. Transportation Research Part D: Transport and Environment, 49, 110-126. doi:https://doi.org/10.1016/j.trd.2016.09.003

[8] Izadikhah, M., Farzipoor Saen, R. Developing a linear stochastic two-stage data envelopment analysis model for evaluating sustainability of supply chains: a case study in welding industry. Ann Oper Res (2021). https://doi.org/10.1007/s10479-021-04160-7

[9] Izadikhah, M., Farzipoor Saen, R. Solving voting system by data envelopment analysis for assessing sustainability of suppliers. Group Decis Negot 28, 641–669 (2019). https://doi.org/10.1007/s10726-019-09616-7

[10] Karsak, E. E., Dursun, M. (2014). An integrated supplier selection methodology incorporating QFD and DEA with imprecise data. Expert Systems with Applications, 41(16), 6995-7004. doi:https://doi.org/10.1016/j.eswa.2014.06.020

[11] Kaur, H., Prakash Singh, S. (2021). Multi-stage hybrid model for supplier selection and order allocation considering disruption risks and disruptive technologies. International Journal of Production Economics, 231, 107830. doi:https://doi.org/10.1016/j.ijpe.2020.107830

[12] L.J. Krajewski and L.P. Ritzman, Operations management strategy and analysis, Addison-Wesley Publishing Co., London (1996).

[13] W.L. Ng, An efficient and simple model for multiple criteria supplier selection problem, *Eur. J. Oper. Res.* 186 (2008) pp. 1059-1067

[14] Saputro, T. E., Figueira, G., Almada-Lobo, B. (2022). A comprehensive framework and literature review of supplier selection under different purchasing strategies. Computers Industrial Engineering, 167, 108010. doi:https://doi.org/10.1016/j.cie.2022.108010

[15] Sivanagaraju Pitchaiah, D., Hussaian, M., Govardhan, D. (2021). A review on multi attribute decision making for evaluation and selection of supplier for materials. Materials Today: Proceedings, 39, 296-300. doi:https://doi.org/10.1016/j.matpr.2020.07.201

[16] Tavassoli, M., Saen, R. F., Zanjirani, D. M. (2020). Assessing sustainability of suppliers: A novel stochastic-fuzzy DEA model. Sustainable Production and Consumption, 21, 78-91. doi:https://doi.org/10.1016/j.spc.2019.11.001

[17] Toloo, M., Nalchigar, S. (2011). A new DEA method for supplier selection in presence of both cardinal and ordinal data. Expert Systems with Applications, 38(12), 14726-14731. doi:https://doi.org/10.1016/j.eswa.2011.05.008

[18] RC.A. Weber, J.R. Current and W.C. Benton, Vendor selection criteria and method, *Eur. J. Oper. Res.* 50 (1991), pp. 2-18

[19] H.T. Willis, R.C. Huston and F. Pohlkamp, Evaluation measures of just in time supplier performance, *Prod. Invent. Manage. J.* 34 (2) (1993), pp. 1-5.

[20] Yazdani, M., Ebadi Torkayesh, A., Stević, Ž., Chatterjee, P., Asgharieh Ahari, S., Doval Hernandez, V. (2021). An interval valued neutrosophic decision-making structure for sustainable supplier selection. Expert Systems with Applications, 183, 115354. doi:https://doi.org/10.1016/j.eswa.2021.115354