Advances in Environmental Biology, 8(21) October 2014, Pages: 1068-1077

AENSI Journals

Advances in Environmental Biology

ISSN-1995-0756 EISSN-1998-1066

Journal home page: http://www.aensiweb.com/AEB/

Evaluation and Forecasting of suppliers' performance using "Fuzzy Data Envelopment Analysis", a case study: Alfa Company

[1]Alireza Bafandeh Zendeh, [2]Rahil Zandi, [3]Davoud Norouzi

[1]*Department of Management, Tabriz branch, Islamic Azad University, Tabriz, Iran.*
[2]*Higher Education Institution: Ministry of Science, Research and Technology ALGHADIR.*
[3]*Young Researchers and Elite Club, Tabriz Branch, Islamic Azad University،Tabriz. Iran.*

ARTICLE INFO

Article history:
Received 11 June 2014
Received in revised form 21 September 2014
Accepted 25 November 2014
Available online 29 December 2014

Keywords:
Evaluation, Forecasting, supplier, Fuzzy Data Envelopment Analysis

ABSTRACT

Selection of supplier is an important decision involving multiple criteria requires input and output data to be precisely known. This is not always the case in real applications. This paper uses a Fuzzy Data Envelopment Analysis model to decide on supplier selection in Alfa Company. Besides, knowing of suppliers' performance in the future can lead to useful information for management decision making. Due to this case, in this paper we forecast the suppliers' performance in the future by fuzzy linear regression.

To Cite This Article: Alireza Bafandeh Zendeh, Rahil Zandi, Davoud Norouzi., Evaluation and Forecasting of suppliers' performance using "Fuzzy Data Envelopment Analysis", a case study: Alfa Company. ***Adv. Environ. Biol., 8(21),*** *1068-1077, 2014*

INTRODUCTION

The importance of supply chain management, selecting the most qualified suppliers and collaborate with them, the main concern of both organizations. The company also provided the necessary number of components and the services of various or generations, the evaluation of suppliers is important. Here, the need to evaluate the performance of suppliers to determine their status is clear. On the other hand, given the limited number of suppliers in some cases, the evaluation of suppliers in each period, it is necessary to ensure the proper functioning of their future [10,11].

Also according to the preference for domestic suppliers to cooperate with overseas suppliers and local companies need replacement, then assessment of supplier performance in three consecutive periods; we predict their performance in the future [15].

With the advent of supply chain, industrial units and service providers have focused his mind.

A policy is a complex process of supplier selection factors is the price. Other factors may be ordered during the period of time, quality of goods and services, good history of cooperation mentioned. In fact, suppliers of inputs and outputs the same criteria and rating factors those providers can use it to pay selected suppliers [14,13].

But the importance of supplier evaluation process can be reduced to the contractors sought. Contractors can be reduced to the following aspects are important:

Using the best suppliers, reducing the total cost of the product, reduce costs, supplier management, use of all facilities, suppliers, development suppliers can evaluate and select suppliers.

In conclusion, this study expected that the performance of suppliers and their knowledge of future performance to be achieved in the result, in determining the type of cooperation with them, shall adopt appropriate management decisions.

Literature review:

Evaluation of supplier performance:

Evaluation and selection of supplier performance has gained much notice among researchers. Many different approaches for decision making about this problem is proposed [1] presented a paper that reviews the literature of the multi-criteria decision making approaches for supplier evaluation and selection. Related articles appearing in the international journals from 2000 to 2008 are gathered.

Corresponding Author: Alireza Bafandeh Zendeh, Department of Management, Tabriz branch, Islamic Azad University, Tabriz, Iran
E-mail: Bafandeh@iaut.ac.ir

Fourteen out of seventy-eight articles (17.95%) applied DEA in the supplier selection process.

Among 78 journal articles, nine papers (11.54%) formulated the supplier selection problem as various types of mathematical programming models. There are seven (8.97%) out of 78 journal articles proposing AHP to deal with the supplier selection problem. Same as AHP, seven papers (8.97%) used CBR to evaluate and select suppliers. Three papers (3.85%) proposed ANP to tackle the supplier selection problem. Three papers (3.85%) utilized fuzzy set theory in the supplier selection process. Two papers (2.56%) used SMART to solve the supplier selection problem. There is only one paper (1.28%) using GA in the supplier selection process.

Fourteen papers (17.95%) applied integrated AHP approaches to evaluate the performance of suppliers and select the best supplier. Nine papers (11.54%) proposed integrated fuzzy approaches to deal with the supplier evaluation and selection problem. Many other integrated approaches (nine papers or 11.54%) were proposed.

it was observed that price or cost is not the most widely adopted criterion. Instead, the most popular criterion used for evaluating the performance of suppliers is quality, followed by delivery, price or cost, and so on.

In a study that conducted by for choosing appropriate method for supplier selection under certainty, uncertainty and probabilistic conditions, proposed three types of vendor selection models in supply chains and presents a decision making scheme [2]. These models are, Data Envelopment Analysis (DEA), Fuzzy Data Envelopment Analysis (FDEA), and Chance Constraint Data Envelopment Analysis (CCDEA). The case study involves a set of 10 suppliers each with expected costs, quality acceptance level, and on-time delivery distributions.

A comparison of selected vendors resulted from the three approaches was demonstrated. Results from three models are consistent with each other with respect to the worst vendors. All three models demonstrated that same three suppliers are worst vendors.

[8] proposed a fuzzy DEA/AR method that is able to calculate the fuzzy efficiency score when the input and output data are represented as convex fuzzy numbers. To illustrate how the proposed method is applied, the measurement of the efficiency of the university libraries in Taiwan with fuzzy observations is exemplified.

Kao et al., [4] conducted a comprehensive evaluation for the 24 university libraries in Taiwan. There are five criteria, viz., collections, personnel, expenditures, buildings and services. Since the efficiency measures expressed by membership functions rather than by crisp values, more information is provided for management. Qualitative factors are difficult to mathematically manipulate when calculating the efficiency in data envelopment analysis (DEA). Fuzzy efficiencies contain more information for making better decisions [9].

[5] illustrated A performance evaluation of the chemistry departments of 52 UK universities for illustration. In a study to determine the efficiencies for chemistry and physics departments in the UK, Beasley used three inputs: general expenditure, equipment expenditure, and research income and five outputs: number of undergraduates (UGs), number of postgraduates taught (PGs-T), number of research postgraduates (PGs-R), research output in quantity, using research income as a proxy, and research quality, represented by ratings. In a later work, Beasley (1995) further discussed the teaching and research efficiencies of those departments. For calculating the lower bound of the efficiency is nonlinear. For small and medium-size problems, most NLP solvers can find optimal solutions. For large-scale problems, however, this may cause some difficulty in finding the solution.

When some observations are fuzzy, the efficiencies become fuzzy as well. (Chiang et al., 2003), devised a method to rank the fuzzy efficiency scores without knowing the exact form of the membership functions. To illustrate how the proposed method is applied, the ranking of the 24 university libraries in Taiwan with fuzzy observations is exemplified. There are five criteria, viz., collections, personnel, expenditures, buildings, and services. The score of each criterion from each university library is a weighted sum of the standardized scores of several secondary criteria in the range of 0 and 1. One pair of mathematical programs is formulated for each DMU to calculate the total utility. Since the mathematical programs to be solved are nonlinear programs, one needs to rely on a nonlinear programming solver. In this study LINGO (LINDO Systems Inc., 1999) is used to rank the 24 university libraries in Taiwan that have fuzzy observations.

proposed two new fuzzy DEA models constructed from the perspective of fuzzy arithmetic to deal with fuzziness in input and output data in DEA. The new fuzzy DEA models are formulated as linear programming models and can be solved to determine fuzzy efficiencies of a group of decision-making units (DMUs). An analytical fuzzy ranking approach is developed to compare and rank the fuzzy efficiencies of the DMUs. The proposed fuzzy DEA models and ranking approach are applied to evaluate the performances of eight manufacturing enterprises in China.

The eight manufacturing enterprises all manufacture the same type of products but with different qualities. Both the gross output value (GOV) and product quality (PQ) are considered as outputs. Manufacturing cost (MC and the number of employees (NOE) are considered as inputs.

The data about the GOV and MC are uncertain due to the unavailability at the time of assessment and are therefore estimated as fuzzy numbers. Therefore developed two fuzzy DEA models from the perspective of fuzzy arithmetic to tackle fuzziness in input and output data in DEA. The two fuzzy DEA models have been formulated as linear programming models for ease of solution and implementation. An analytical ranking approach based upon degree of preference has been developed for comparing and ranking fuzzy efficiencies of DMUs, which provides not only a full ranking but also the information to what degree a fuzzy efficiency is bigger than another one. Both the fuzzy DEA models and fuzzy ranking approach have been applied to evaluate the performances of eight manufacturing enterprises in China. It is shown that the two fuzzy DEA models are both applicable to fuzzy input and output data, but produce different fuzzy efficiencies, one of which has less fuzziness than the other one.

Numerical example:

An application of the proposed approach in the selection and forecasting suppliers' performance illustrates its implementation. Therefore eight metal part suppliers of Alfa Company were selected. The selection was based on the importance of metal parts for the company.

Investigation of analytical and process it accordingly in Figure 1.

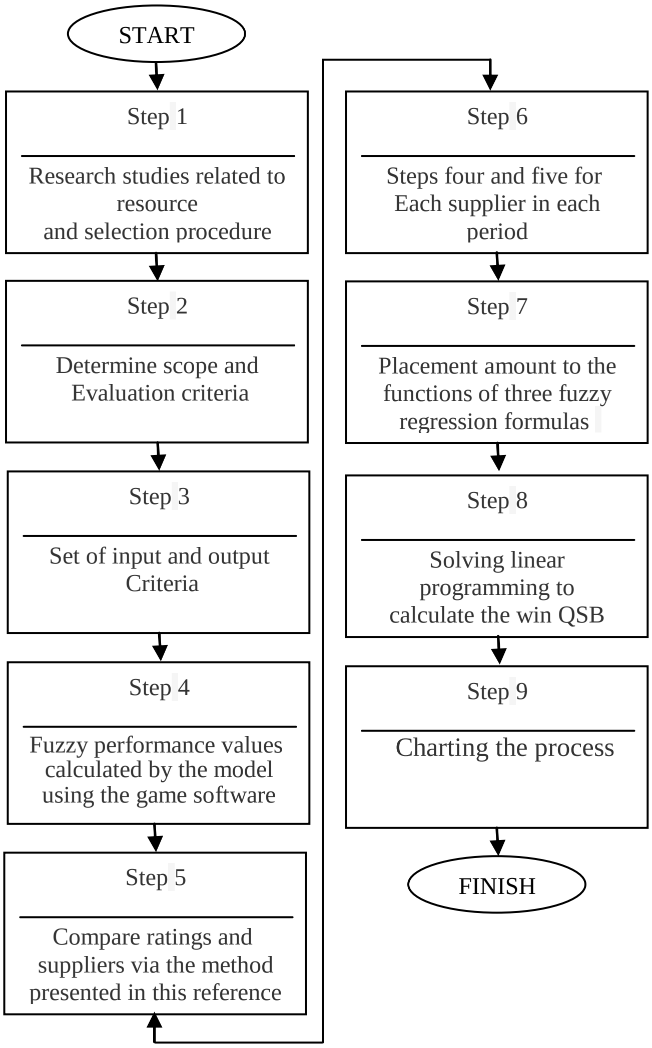


Fig. 1: Methodology work

Evaluation of suppliers performance:

In the first step, it should be identified criteria for evaluation.

Table 1. Shows nine inputs and eight outputs.

Table 1: Criteria for suppliers' evaluation

Row	Criteria	Symbol	Type	
			Input	Output
1	Quality department structure	x_1	*	
2	Inspection and test status	x_2	*	
3	Product warranty and services	y_1		*

Advances in Environmental Biology, 8(21) October 2014, Pages: 1068-1077

4	Customer comments	y_2		*
5	Price	y_3		*
6	Delivery time	y_4		*
7	Flexibility	y_5		*
8	Sufficiency of test equipment	x_3	*	
9	Calibration of inspection and test equipment	x_4	*	
10	Reliability	y_6		*
11	Relationship closeness	y_7		*
12	Personnel qualification	x_5	*	
13	Environmental requirement consideration	x_6	*	
14	Product quality	y_8		*
15	Sufficiency of transportation equipment	x_7	*	
16	Packaging ability	x_8	*	
17	Quality systems	x_9	*	

The performance of suppliers is assessed by company experts using fuzzy linguistic terms such as Very Good, Good, poor and Very Poor, whose membership functions are defined in Fig 2.

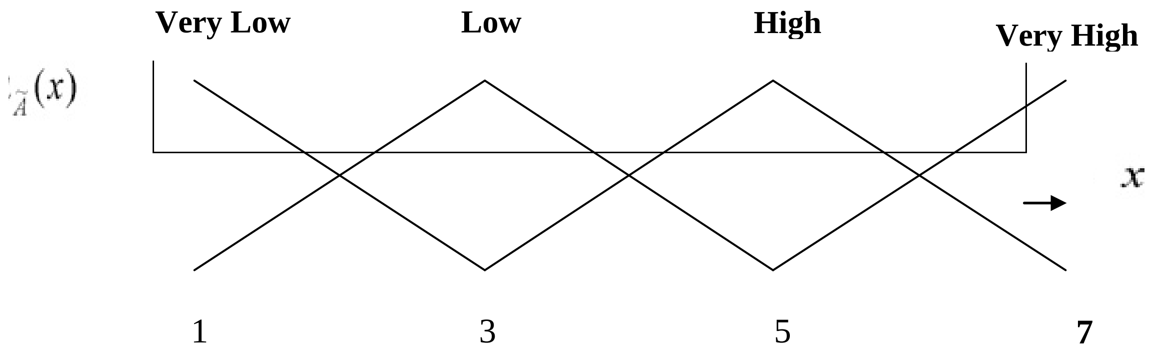


Fig. 2: Fuzzy sets for performance assessment

Linguistic terms are not directly mathematically operable. Each linguistic term is associated with a fuzzy number characterizing the meaning of each generic verbal term. The definitions of a triangular fuzzy number (TFNs) are shown in table 2.

Table 2: The TFNs of linguistic terms

Linguistic terms	TFNs
Very low (VL)	(1, 1, 3)
Low (L)	(1, 3, 5)
High (H)	(3, 5, 7)
Very high (VH)	(5, 7, 7)

Suppliers' efficiency and ranking were calculated using the method mention in (Wang et al., 2009) as follows:

Advances in Environmental Biology, 8(21) October 2014, Pages: 1068-1077

$$\begin{aligned}
&\text{Maximize} \quad \theta_0^L = \sum_{r=1}^{s} u_r y_{r0}^L,\\
&\text{Subject to} \quad \sum_{i=1}^{m} v_i x_{i0}^U = 1,\\
&\qquad \sum_{r=1}^{s} u_r y_{rj}^U - \sum_{i=1}^{m} v_i x_{ij}^L \leqslant 0, \quad j = 1,\dots,n,\\
&\qquad u_r, v_i \geqslant 0, \quad i = 1,\dots,m;\ r = 1,\dots,s,\\
&\text{Maximize} \quad \theta_0^M = \sum_{r=1}^{s} u_r y_{r0}^M,\\
&\text{Subject to} \quad \sum_{i=1}^{m} v_i x_{i0}^M = 1,\\
&\qquad \sum_{r=1}^{s} u_r y_{rj}^U - \sum_{i=1}^{m} v_i x_{ij}^L \leqslant 0, \quad j = 1,\dots,n,\\
&\qquad u_r, v_i \geqslant 0, \quad i = 1,\dots,m;\ r = 1,\dots,s,\\
&\text{Maximize} \quad \theta_0^U = \sum_{r=1}^{s} u_r y_{r0}^U,\\
&\text{Subject to} \quad \sum_{i=1}^{m} v_i x_{i0}^L = 1,\\
&\qquad \sum_{r=1}^{s} u_r y_{rj}^U - \sum_{i=1}^{m} v_i x_{ij}^L \leqslant 0, \quad j = 1,\dots,n,\\
&\qquad u_r, v_i \geqslant 0, \quad i = 1,\dots,m;\ r = 1,\dots,s.
\end{aligned} \tag{1}$$

The problem was solved by linear programming using" GAMS Distribution 23.6.2". Fuzzy efficiency for suppliers related to three periods is in table 3-5.

Table 3: Fuzzy efficiencies of the eight suppliers - period 1

Suppliers (DMUs)	Model (1)				
	Lower bound	Middle bound	Upper bound	Rank	
1	0.1493	0.3689	1	6	
2	0.1744	0.3968	1	4	
3	0.1765	0.7143	1	2	
4	0.1429	0.7143	1	3	
5	0.1475	0.3659	1	7	
6	0.1953	0.7143	1	1	
7	0.1531	0.376	1	5	
8	0.1261	0.3247	1	8	

Table 4. Fuzzy efficiencies of the eight suppliers - period 2

Suppliers (DMUs)	Model (1)				
	Lower bound	Middle bound	Upper bound	Rank	
1	0.1111	0.2941	1		7
2	0.2778	0.5385	1		4
3	0.1749	0.7143	1		2
4	0.1429	0.7143	1		3
5	0.1485	0.3676	1		5
6	0.2	0.7143	1		1
7	0.1111	0.2941	1		7
8	0.0857	0.3333	1		6

Table 5: Fuzzy efficiencies of the eight suppliers - period 5

Suppliers (DMUs)	Model (1)				
	Lower bound	Middle bound	Upper bound	Rank	
1	0.1852	0.4118	1	5	
2	0.2632	1	1	1	
3	0.1579	0.7143	1	3	

Advances in Environmental Biology, 8(21) October 2014, Pages: 1068-1077

4	0.1429	0.7143	1	4	
5	0.1852	0.4118	1	5	
6	0.1765	0.7143	1	2	
7	0.1111	0.2941	1	6	
8	0.0857	0.2381	1	7	

Forecasting:

For estimating suppliers efficiency at fourth period “Fuzzy linear regression” method was used.

$$\min : z = s_0 + \sum_{i=1}^{n}\left[s_i \sum_{j=1}^{m} x_{ij} \right]$$ (۸) تابع هدف

$s.t.$ محدودیت ها:

$$(1-h)s_0 + (1-h)\sum_{i=1}^{n} s_i x_{ji} + \sum_{i=1}^{n} a_i^c x_{ij} + a_0^c \geq y_j$$

$$,\forall_j ; j = 1,2,\ldots m$$

$$(1-h)s_0 + (1-h)\sum_{i=1}^{n} s_i x_{ij} - \sum_{i=1}^{n} a_i^c x_{ij} - a_0^c \geq -y_j$$

$$,\forall_j ; j = 1,2,\ldots m$$

Min C0 + 6C1
:Constraints
y1 ≥ p0 + p1 – (1-h) (c0 + c1)
y1 ≤ p0 + p1 + (1-h) (c0 + c1)
y2 ≥ p0 +2 p1 – (1-h) (c0 + 2c1)
y2 ≤ p0 + 2p1 + (1-h) (c0 + 2c1)
y3 ≥ p0 + 3p1 – (1-h) (c0 + 3c1)
y3 ≤ p0 +3 p1 + (1-h) (c0 +3 c1)

In this linear programming, y1 to y4 are efficiency value for the DMUs calculated by α-cut and “h” is the same as α. In this case α was assumed 0.8.

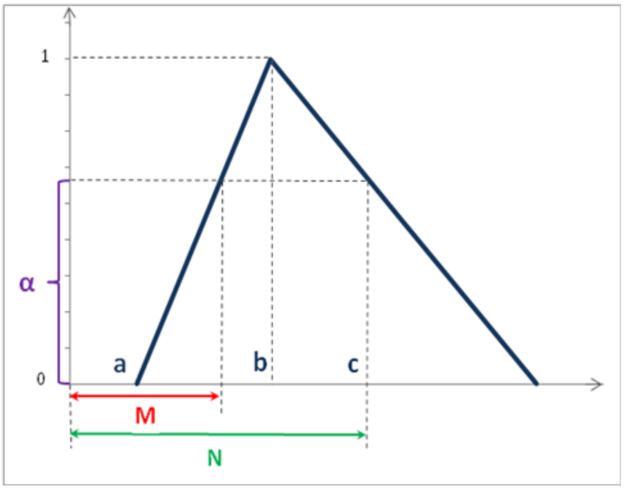


Fig. 2: Calculation of α-cut for up and low limit

For implementation of α in formula the upper and lower limits of α should be considered, “M” and “N” in figure 2.

N = c – α (c – b) (lower limit)
M = α (b – a) + a (upper limit)

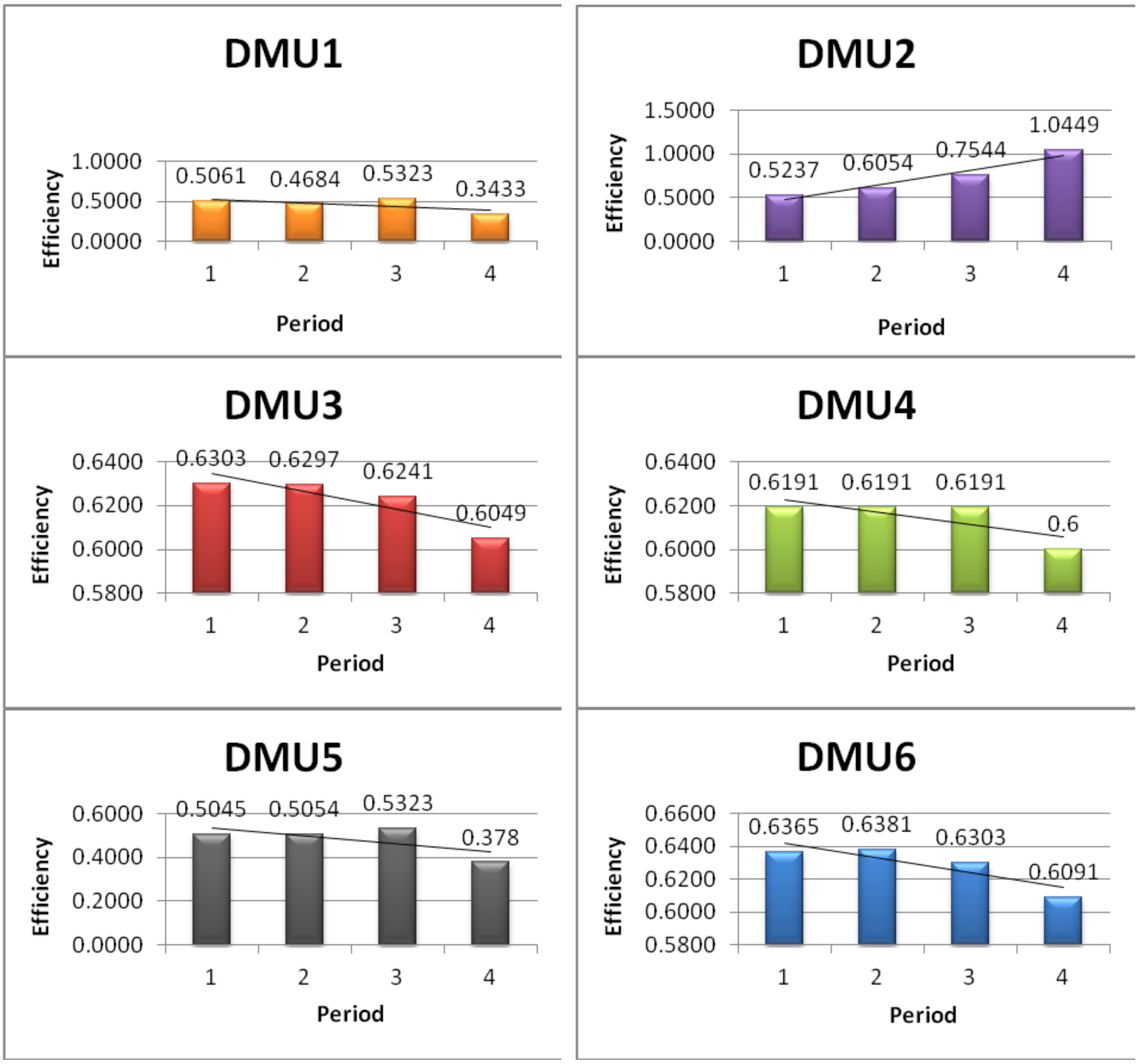
Forecasting the suppliers' efficiency at fourth period considering lower limit of α-cut:

After calculation of the efficiency, trend graphs are drawn as follows:

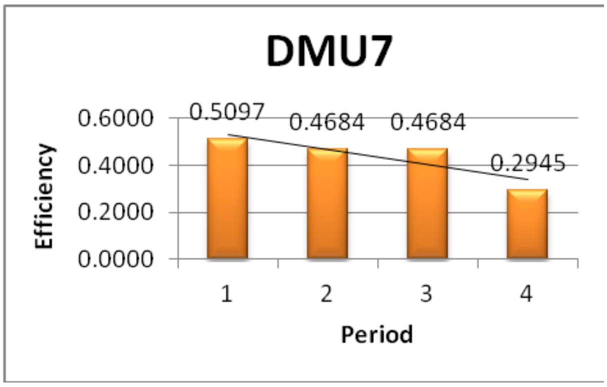
Advances in Environmental Biology, 8(21) October 2014, Pages: 1068-1077

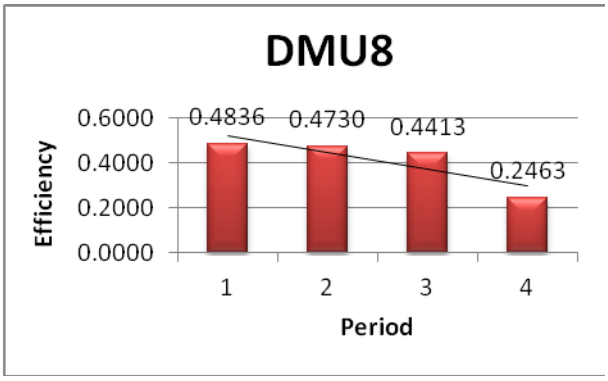
Table 6: Efficiency

Efficiency	Supplier
(0.122, 0.343, 0.563)	DMU-1
(0.754, 1.044, 1.335)	DMU-2
(0.595, 0.604, 0.614)	DMU-3
(0.6, 0.6, 0.6)	DMU-4
(0.327, 0.378, 0.429)	DMU-5
(0.597, 0.609, 0.620)	DMU-6
(0.109, 0.294, 0.479)	DMU-7
(0.052, 0.246, 0.439)	DMU-8



Advances in Environmental Biology, 8(21) October 2014, Pages: 1068-1077



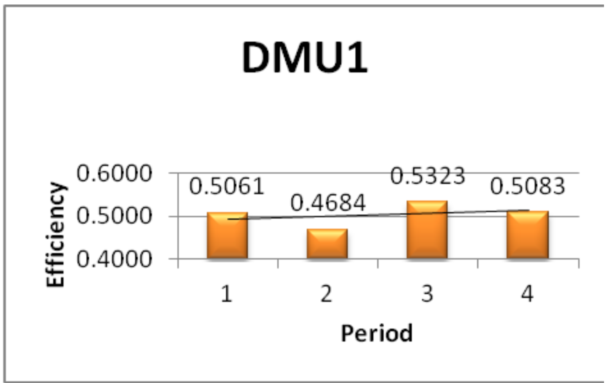


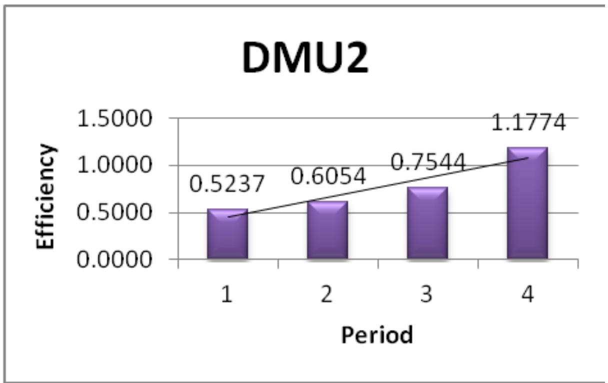
Forecasting the suppliers' efficiency at fourth period considering upper limit of α-cut:

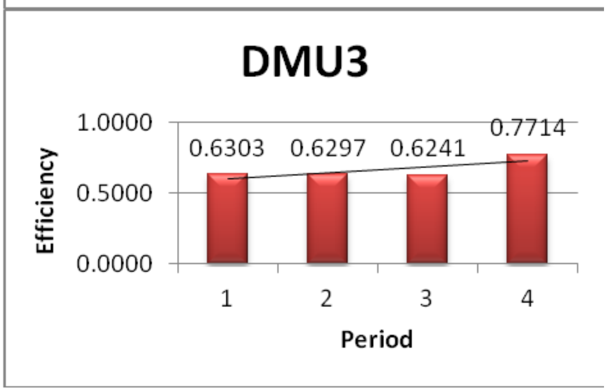
After calculation of the efficiency, trend graphs are drawn as follows:

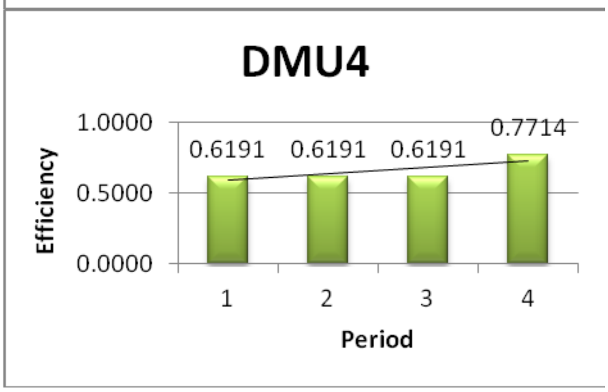
Table 7: Efficiency

Efficiency	Supplier
(0.315, 0.508, 0/700)	DMU-1
(0.857, 1.177, 1.497)	DMU-2
(0.771, 0.771, 0.771)	DMU-3
(0.771, 0.771, 0.771)	DMU-4
(0.497, 0.539, 0.852)	DMU-5
(0.771, 0.771, 0.771)	DMU-6
(0.304, 0.468, 0.631)	DMU-7
(0.238, 0.428, 0.619)	DMU-8

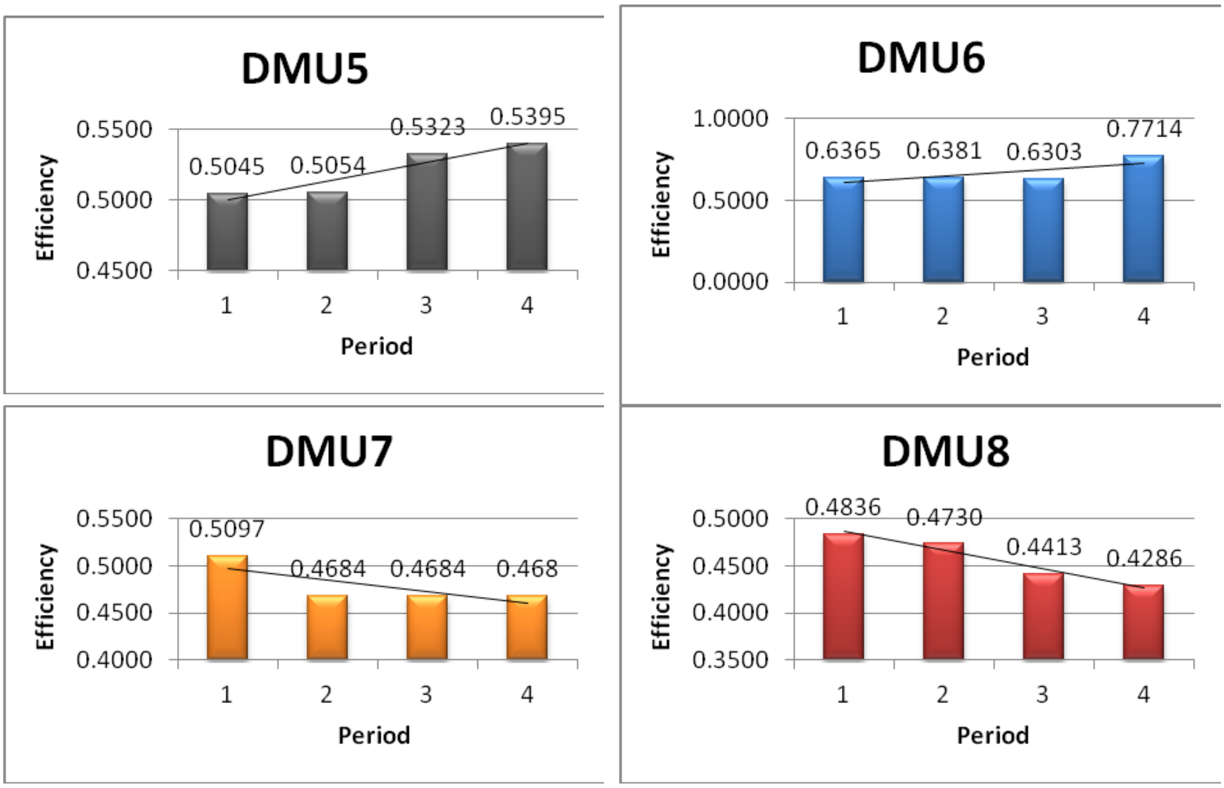








Advances in Environmental Biology, 8(21) October 2014, Pages: 1068-1077



Conclusion:

The following table is obtained by surveying the suppliers' efficiency values and comparing each one using lower and upper limits of α-cut:

Table 8: Comparison between efficiency trend from upper and lower limits of α-cuts

Supplier	Upper α-cut	Lower α-cut
DMU1	Decreasing	Increasing
DMU2	Increasing	Increasing
DMU3	Decreasing	Increasing
DMU4	Decreasing	Increasing
DMU5	Decreasing	Increasing
DMU6	Decreasing	Increasing
DMU7	Decreasing	Decreasing
DMU8	Decreasing	Decreasing

Data in table shows that in lower limit of α-cut, most of suppliers have a decreasing trend in their efficiency and in upper limit of α-cut, most of suppliers have an increasing trend in their efficiency. This result considering the higher amount of the upper limit compared to lower limit, was expectable.

Suppliers 7 and 8 were eliminated due to their decreasing trend in both states. Supplier 2 experienced an increasing trend in both states thus it was considered an appropriate supplier for future associations.

REFERENCES

[1] William Ho, Xiaowei Xu, Prasanta K. Dey, 2010. "Multi-critera decision making approaches for supplier evaluation and selection: A literature review", European Journal of Operational Research, 202: 16-24.

[2] Azadeh, S.M. Alem, 2010. "A flexible deterministic, stochastic and fuzzy Data Envelopment Analysis approach for supply chain risk and vendor selection problem: Simulation analysis", Expert Systems with Applications.

[3] Shiang-Tai Liu a,Mang Chuang, 2009, "Fuzzy efficiency measures in fuzzy DEA/AR with application to university libraries", Expert Systems with Applications, 36: 1105-1113.

[4] Kao, C., Y.C. Lin, L.C. Liang and S.C. Lo, 1998. Ranking university libraries: the Taiwan case. LIBRI, 19: 212-223.

[5] Chiang Kao, Pei-Huang Lin, 2010. "Qualitative factors in data envelopment analysis: A fuzzy number approach", European Journal of Operational Research.

[6] Chiang Kao, Shiang-Tai Liu, 2003. "A mathematical programming approach to fuzzy efficiency ranking", Int. J. Production Economics., 86: 145-154.
[7] Ying-Ming Wang a, Ying Luo b, Liang Liang, 2009, "Fuzzy data envelopment analysis based upon fuzzy arithmetic with an application to performance assessment of manufacturing enterprises", Expert Systems with Applications., 36: 5205-5211.
[8] M. Wena, H. Li, 2009. "Fuzzy data envelopment analysis (DEA): Model and ranking method", Journal of Computational and Applied Mathematics, 223: 872-878.
[9] S.T. Liu, 2008. "A fuzzy DEA/AR approach to the selection of flexible manufacturing systems", Computers & Industrial Engineering, 54: 66-76.
[10] J. Odeck, 2000. "Assessing the relative efficiency and productivity growth of vehicle inspection services: An application of DEA and Malmquist indices", European Journal of Operational Research, 126: 501-514.
[11] Kulshreshtha, M., J.K. Parikh, 2002. "Study of efficiency and productivity growth in opencast and underground coal mining in India: a DEA analysis", Energy Economics, 24: 439-453.
[12] Kuo, R.J., Y.C. Wang, F.C. Tien, 2010. "Integration of artificial neural network and MADA methods for green supplier selection", Journal of Cleaner Production, 23: 123-135.
[13] Baanker, R.D., A. Charnes and W.W. Cooper, 1994."Some Methods for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis," Management Science, 30: 1078-1092.
[14] Amy, H., I. Lee, 2009. "A fuzzy supplier selection, model with the consideration of benefits, opportunities, costs and risks", Expert Systems with Applications, 36(2): 2879-2893.
[15] Samuel, H., H. Keskar, 2007. "Comprehensive and configurable metrics for supplier selection", International Journal of Production Economics, 105(2): 510-523.