Technical Journal of Engineering and Applied Sciences
Available online at www.tjeas.com
©2013 TJEAS Journal-2013-3-14/1460-1465
ISSN 2051-0853 ©2013 TJEAS

Evaluation of efficiency of supply chain in automobile industry by fuzzy data envelopment analysis (case study: Sazeh Gostar SAIPA company)

Soleyman Iranzadeh, Ardeshir Bazrkar* and Kamal Khalilpour

Department of Management, Mahabad Branch, Islamic Azad University, Mahabad, Iran

****Corresponding author email:*** Ardeshir.13@gmail.com

ABSTRACT: In today industrial world, ever increasing competition and rapid changes in economic scope have led to new context for planning for production and revolution in the world. Concurrent to revolutions, automobile industry has changed significantly. Automobile companies have expanded their supply chains from external resources and they have emphasized on their supply chains as a competitive advantage. One of the key indices is evaluation of efficiency of supply chain. This research tries to identify important criteria in the selection of suppliers and determine the importance of the criteria based on the experts' viewpoints. Thus after selection of the final criteria, for evaluation of the departments of Sazeh Gostar SIPA company, the suppliers of these departments were evaluated by using Fuzzy DEA and Fuzzy CSW methods based on input and output criteria and finally they were graded according to efficiency score.

keywords: Supply chain management, Data envelopment analysis (DEA), Fuzzy logic, Performance evaluation

INTRODUCTION

Supply chain management has been considered due to ever increasing competition and effort to survival by emphasize on information technology progress and communication in the recent years (Mossa Khani, Naebi, 2007). In two recent decades, by employment of supply chain management in industry selection of suppliers, efficiency has gained attention and different methods have been proposed. Since the supplier efficiency affects on success and failure of a chain. So selection of supplier is a strategic duty. As a result inaccurate decision making in selection of suppliers lead to negative and harmful consequences. So, optimal efficiency of supplier chain, in order to have competitive benefits, is considered as a strategic tool for success in all aspects of automobile industry (Mento, 2003). In this relation and according to current status, measuring efficiency and ratio of input and output is an important task for economic policy makers and experts.

Literature review

faroul offered non parametric method of dea for the first time in 1957 then chanes, cooper and rhodes (ccr) used it in 1987; consequemtly, banker, chanes and cooper (bcc) employed it in 1984. sengopeta offered principles of fuzzy set theory in 1992 and belman and zadeh (1970) and vezerman (1976) developed it for data envelopment analysis as fuzzy. weber et al. (2000) used a combinatory optimization approach involving multipurpose planning and dea approach. in this approach at first, multipurpose programming was employed for selection of suppliers and then it was used for evaluation of supplier efficiency based on dea approach and finally in 2007 bank and yung (2007) employed dea model for measuring supplier chain efficiency in singapour. safar khanlu (2005) used fuzzy dea for evaluation of supply chain and identification of efficient and inefficient decision making units. javan rouh (2003) employed balanced score cards and organization progress models for evaluation of efficiency of sapko automobile parts company stuff.

The aim of this article is to offer an appropriate model for evaluation of supply chain and competent and incompetent suppliers' selection based on defined criteria used as input and output in the model.

Questions

What is efficiency of supply chain in Sazeh Gostar SIPA Company?
What are effective factors on supply chain in Sazeh Gostar SIPA Company?

MATERIALS AND METHODS

Theoretical principles

Definition of supply chain management

Supply chain management involves integration of supply chain activities and related information by improvement in chain relations in order to achieve reliable competitive advantage. So, supply chain management consists of integration of supply chain activities and related information by improvement in production and supply chain relations for investigation of a unique company in defined scopes that both suppliers and distribution channels are considered. The proposed definition for supply chain involves information system management, finding resources and arrangement, scheduling of production, processes of orders, inventory management, warehouse and customer service (Zahedi, 2009).

Importance of evaluation and selection of suppliers

Reduction of production cost is an important factor in survival of today competitive world. Selection of appropriate suppliers could reduce purchase cost significantly and increase competition since costs of primary materials and constituents involve the main share of final cost in most industries. In recent years, determination of proper supplier is considered as a strategic factor in supply chain. The nature of these decision makings is complex and without defined structure and most of qualitative and quantitative efficiency criteria like quality, price, flexibility and time of deliver should be considered. In such conditions, suppliers department plays an important role in efficiency of organization and it affects directly on reduction of costs, increase of benefits and flexibility of an organization. Indeed, selection of appropriate supplier is important for success of organizations (Simchi, 2003).

Data envelopment analysis (DEA)

Data envelopment analysis is a mathematical technique that measures relative efficiency of a group of decision making units; in other word, DEA is a mathematical technique for measuring of relative efficiency of organizational units with different input and outputs by difficult comparison and measuring performance (Saati and Memaryani, 2005).

Fuzzy logic

Fuzzy management science by using fuzzy system theories could be a new approach for solving problems and respond to ambiguities in management systems. Fuzzy system theories by using fuzzy logic enter parameters like knowledge, experience, judgment and decision making into model and causes to flexibility in the model and offers vague image from vague world. It is obvious that, such models are exact and practical due to considering real conditions in the model (Momeni, 2012). By utilization of fuzzy systems, scientific methods of classic management are expanded in the fuzzy systems and management systems become more flexible and management of complex and big companies and organization is facilitated (Azar and Faraji, 2002).

Fuzzy data envelopment analysis model

In recent years, theory of fuzzy sets has been offered for quantification of implicit and vague data in fuzzy data envelopment analysis models (Arman, 2009). Suppose we have n decision making units that each of them uses m different fuzzy input for production of s fuzzy output. In formulation of this model $\tilde{x}_{ip}(i=1,...,m)$ $\tilde{y}_{rp}(1,...,s)$ are input and output values in decision making unit (DMU) in the primary model (Arman, 2009).

Input fuzzy CCR model

Input fuzzy CCR model can be considered as follows:

$$\max \quad w = \sum_{r=1}^{s} u_r \tilde{y}_{rp}$$

$$s.t: \quad \sum_{i=1}^{m} V_i \tilde{X}_{ip} = 1$$

$$\sum_{r=1}^{s} u_r \tilde{y}_{rj} - \sum_{i=1}^{m} v_i \tilde{X}_{ij} \le 0 \qquad \forall j,$$

$$u_r, V_i \ge \varepsilon \qquad \forall r, i.$$

where $v_i (i = 1,...,m)$ and $u_r (r = 1,...,s)$ are weights of input i and output r.

Dual input fuzzy CCR model can be written as follows:

$$\min \quad Z = \theta$$

$$s.t \quad \theta \tilde{x}_{ip} - \sum_{j=1}^{n} \lambda_j \tilde{x}_{ij} \ge \qquad \forall i,$$

$$\sum \lambda_j \tilde{y}_{ij} - \tilde{y}_{rp} \ge 0 \qquad \forall r,$$

$$\lambda_j \ge 0 \qquad \forall j,$$

Like CCR model, confinements of $\sum_{i=1}^{m} V_I \tilde{X}_{ip} = 1$ and $\sum_{r=1}^{s} u_r \tilde{y}_{rj} - \sum_{i=1}^{m} v_i \tilde{x}_{ij} \le 0$ are used for normalization of W value in fuzzy CCR model.

Fuzzy CCR models could not be solved by standard linear programming solver since coefficients of fuzzy CCR model are fuzzy set. Fuzzy linear programming problem involves some grading methods for fuzzy systems. The limited subjects published about fuzzy data envelopment analysis problem solving can be classified into 4 separated approaches of tolerance approach, defuzzy approach, level 2x based approach and fuzzy grading approach (Gasiri,2007).

Table 1. Information about the criteria.

DMUs	Inputs			Outputs			
	X_1	X_2	X_3	Y_1	Y_2	Y_3	Y_4
D_1	(15,20,25)	(10,10,10)	(1,1.3,1.5)	(76,81,86)	(5,6,7)	(3,4,5)	(3,4,5)
D_2	(70,75,80)	(6,6,6)	(1.7,19,2)	(74,77,80)	(3,4,5)	(1,2,3)	(0,0,1)
D_3	(95,98,100)	(1,1,1)	(2,2.3,2.6)	(86,88,90)	(5,6,7)	(3,4,5)	(7,8,9)
D_4	(86,91,96)	(2,2,2)	(3,3.5,4)	(75,78,80)	(1,2,3)	(3,4,5)	(1,2,3)
D_5	(95,98,100)	(40,40,40)	(6,6.3,6.6)	(87,89,90)	(7,8,9)	(7,8,9)	(5,6,7)
D_6	(98,99,100)	(4,4,4)	(10,15,20)	(90,92,95)	(3,4,5)	(1,2,3)	(3,4,5)
D_7	(95,100,100)	(18,18,18)	(6,6.3,66)	(90,95,100)	(7,8,9)	(5,6,7)	(5,6,7)
D_8	(71,76,81)	(18,18,18)	(7.2,7.6,8)	(77,78,80)	(5,6,7)	(7,8,9)	(3,4,5)
D_9	(90,95,100)	(2,2,2)	(5.6,5.8,6)	(80,83,85)	(5,6,7)	(1,2,3)	(3,4,5)

Entering data into fuzzy CSW model and solving it

In this research in order to evaluate efficiency of items suppliers Fuzzy DEA was used. It should be pointed that, the number of investigated suppliers was less (9 suppliers) compared to 7 criteria, and since it was not accordance to the condition in which the decision making units' number should be more than 3 times of total

decision making criteria. So, the method offered by Saati et al. which is called CSW is appropriate for this research. In this model common set of weights is used. Finally CSW was used in fuzzy media.

$$\max \quad \phi$$

$$s.t: \quad \sum_{r=1}^{s} \bar{y}_{rj} - \sum_{i=1}^{m} \bar{x}_{ij} \le 0 \quad \forall_j$$

$$V_i(x_{ij}^m - (1-\alpha)x_{ij}^{\alpha}) \le \bar{x}_{ij} \le V_i(x_{ij}^m + (1-\alpha)x_{ij}^{\beta} \quad \forall_{i,j,}$$

$$u_r(y_{rj}^m - (1-\alpha)y_{rj}^{\alpha}) \le \bar{y}_{rj} \le u_r(x_{rj}^m + (1-\alpha)x_{rj}^{\beta} \quad \forall_{i,j,}$$

$$\phi u_r \le u_r \le (1-\phi)u_r \quad \forall_{r,}$$

$$\phi V_i \le V_i \le (1-\phi)V_i \quad \forall_i$$

where, $V_i(i=1,...,m), u_r(r=1,...,s)$ are optimal values for $\alpha \in [0,1]$.Common set of weights is obtained by solving above problem and efficiency of each unit is calculated as follows:

$$e_j = \frac{\sum_{r=1}^{s} u_r^* \tilde{y}_{rj}}{\sum_{i=1}^{m} V_1^* \tilde{x}_{ij}} \quad \forall j,$$

For solving the problem after entering $-\alpha$, the resultant intervals are considered as variables. So, instead of comparison of intervals a different method is used for solving fuzzy programming problem. Table 3 depicts the results after entering $-\alpha$.

Table 2. Results of calculation after entering $-\alpha$

α	Inputs			Outputs			
	X_1	X_2	X_3	Y_1	Y_2	Y_3	Y_4
0.2	0.053	0.125	0.893	0.061	1.667	1.667	1.667
0.5	0.021	0.050	0.294	0.020	0.333	0.333	0.333
0.8	0.013	0.031	0.143	0.006	0.093	0.158	0.145

Then the common set of weights is obtained by fuzzy CSW by following model:

$$\max \quad \phi$$

$$s.t: \quad \sum_{r=1}^{s} \bar{y}_{rj} - \sum_{i=1}^{m} \bar{x}_{ij} \le 0 \quad \forall_j$$

$$V_i(x_{ij}^m - (1-\alpha)x_{ij}^{\alpha}) \le \bar{x}_{ij} \le V_i(x_{ij}^m + (1-\alpha)x_{ij}^{\beta} \quad \forall_{i,j,}$$

$$u_r(y_{rj}^m - (1-\alpha)y_{rj}^{\alpha}) \le \bar{y}_{rj} \le u_r(x_{rj}^m + (1-\alpha)x_{rj}^{\beta} \quad \forall_{i,j,}$$

$$\phi u_r \le u_r \le (1-\phi)u_r \quad \forall_{r,}$$

$$\phi V_i \le V_i \le (1-\phi)V_i \quad \forall_i$$

Common set of weights is achieved by solving above problem. The results depicted in Table 3.

RESULTS AND DISCUSSION

Data analysis methods

In order to offer a fuzzy data envelopment analysis for evaluation of efficiency of suppliers, it is necessary to select input and output variables based on studied company and decision maker goals. for this purpose,

resources in this company related to supply chain as percentage of on time delivery (X_1), diversity of items (X_2), price (X_3) were considered as input variables and main supplier efficiency involving quality (Y_1), management performance (Y_2), innovation and creativity (Y_3) and technical aspect (Y_4) were selected as output variables.

Table 3. Common set of weights

α	Inputs			Outputs			
	X_1	X_2	X_3	Y_1	Y_2	Y_3	Y_4
0.2	0.027	0.062	0.446	0.030	0.833	0.833	0.833
0.5	0.011	0.026	0.0155	0.009	0.157	0.157	0.157
0.8	0.008	0.020	0.089	0.002	0.035	0.059	0.054

By using triangular fuzzy numbers the fuzzy efficacy is calculated as follows:

$$e_j = (e_j^m, e_j^\alpha, e_j^\beta) \forall j,$$

where

$$e_j^m = \frac{\sum_{r=1}^{s} u_r^* y_{rj}^m}{\sum_{i=1}^{m} V_i^* x_{ij}^m},$$

$$e_j^\alpha = \frac{\sum_{r=1}^{s} u_r^* y_{ij}^m \sum_{i=1}^{m} V_i^* x_{ij}^\beta + \sum_{r=1}^{s} u_r^* y_{ij}^\alpha \sum_{i=1}^{m} V_i^* x_{ij}^m}{(\sum_{i=1}^{m} V_i^* x_{ij}^m)^2}$$

$$e_j^\beta = \frac{\sum_{r=1}^{s} u_r^* y_{ij}^m \sum_{i=1}^{m} V_i^* x_{ij}^\alpha + \sum_{r=1}^{s} u_r^* y_{ij}^\beta \sum_{i=1}^{m} V_i^* x_{ij}^m}{(\sum_{i=1}^{m} V_i^* x_{ij}^m)^2}$$

where in $e_p^m + e_p^\beta$ all input and output weights are changed minimum for $l \le p \le n, p$ or for all DMUs that $e_p^m + e_p^\beta < 1$ is used for measuring efficiency in (0,1). For doing so, among options an option could be replaced as follows:

$$M_r = \frac{u_r^*}{e}, Ni = V_i^* \forall r, i,$$

where,

$$e = \max_{1 \le j \le n} \{e_j^m + e_j^\beta\}$$

The resultant weights of $Ni = (i,...,m)$ و $M_r (r = 1,...,s)$ are common set of mentioned weights. After determination of common set of weights efficiency of decision making units can be calculated (Saati and Memaryani, 2005).

According to this fact that, fuzzy data are symmetrical, so α and β values of high and low limits of mean are equal. As a result, by considering mean high and low limits supply chain efficiency is obtained as follows. Table 4 depicts Sazeh Gostar SIPA supply chain efficiency.

Table 4. Sazeh Gostar SIPA supply chain efficiency.

DMU	0.2	0.5	0.8
D_1	(0.0508,0.211,0.206)	(0.289,0.480,0.528)	(0.542,0.789,0.905)
D_2	(0.0120,0.141,0.140)	(0.075,0.217,0.239)	0.125,0.262,0.319)
D_3	(0.0281,0.421,0.408)	(0.157,0.515,0.525)	(0.313,0.682,0.722)
D_4	(0.0111,0.205,0.194)	(0.070,0.269,0.278)	(0.139,0.352,0.391)
D_5	(0.0156,1.008,0.990)	(0.087,0.928,0.921)	(0.175,1.002,1.011)
D_6	(0.0076,0.676,0.551)	(0.048,0.633,0.541)	0.961,0.573,0.526)
D_7	(0.174,0.771,0.761)	(0.100,0.742,0.754)	(0.199,0.808,0.852)
D_8	(0.0152,0.702,0.674)	(0.087,0.665,0.654)	(0.187,0.749,0.757)
D_9	(0.0128,0.374,0.363)	(0.077,0.405,0.410)	(0.147,0.442,0.472)

According to the results of measuring supply chain efficiency, it was found that supplier 5 is efficient and others are inefficient. These suppliers could change into efficient suppliers by change in input and output.

CONCLUSIONS

The aim of this research was to use Fuzzy DEA to measure efficiency of supply chain in Sazeh Gostar SIPA Company. It was conducted after investigation of supply chain and selection of evaluation unit (polymer) and identification of selected suppliers for evaluation by considering view points of experts of this company. According to number of suppliers involving nine suppliers that supply homogenous items and seven criteria FCSW was used for evaluation based on number of inputs and outputs relative to number of criteria. For doing so, the data were analyzed by software GAMS and LINGO after collection of quantitative and qualitative data. So, efficient and inefficient units were introduced. Unit 5 was efficient. According to results of fuzzy DEA it can be set goals in supply chain so that level of improvement in any viable could be introduced as a goal for each inefficient supply chain. By annual evaluation of supply chain by using fuzzy DEA models efficiency could be identified during a year according to changes in efficiency for each year.

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