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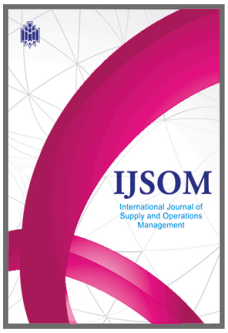

Supply Chain Performance Evaluation Using Data Envelopment Analysis

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Abstract
The competition in crescent urgency in the global economy causes many organizations focus more on novel management ideas in parallel structures, delivery services and their productions. In current conditions, supply chain and a suitable performance evaluating system in order to understand the current condition and programming for its improvement, has a very special importance in creating added value for clients. This study considered the performance of 7 active supply chains in tile industry which have similar supply chain construction, including supplier, producers, distributors and customers. Also producers evaluating who perform a key role in chains by using data envelopment analysis method are considered. With attention to obtained results it can be seen that for evaluating industries, especially tile industries, supply chain criteria's have better results that other criteria's.

Keywords: Supply chain; performance evaluation; efficiency; data envelopment analysis.

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1. Introduction

Goods production and providing services in current conditions need a basic understanding of clients' demands includes the adoption of product properties, products availability in appropriate time and suitable place for clients. These proceedings will not be possible by an separate attitude on different components of preparation of raw materials, product manufacturing or service, distribution and delivery. Access to the considered portion of market will be formed by a consequence of an integrated look at effective rings in business, from the raw and essential material preparation stage to product delivery or customer service and after sales service. Continuity between these rings constructs a chain which has been a beginning of an expression of a new concept entitled "supply chain". Supply chain management is a method for improving business environment and increasing capabilities of competitiveness. The potential benefits of supply chain management will not be achieved automatically. In order to achieve the improvement of the supply chain performance and moving to its considered goals, performance evaluation and attempting for its improvement is very much important. A performance evaluation program for supply chain should cover all important aspects of performance and meet all different needs of entities of supply chain. Constructing a suitable performance evaluation system in order to promote the agreement between supply entities for improving the performance can have a special importance in producing added value for clients and producing finally competitive advantage economic enterprise. Performance evaluation is a quantitative activity or more accurately quantitative process in order to analyze the performance and effectiveness. Effectiveness and supply chain performance are terms of use of resources for obtaining specific objectives in the entire supply chain. Among different methods of evaluation, data covering analysis as a nonparametric method which computes boundary production function based on linear programming technique and because it doesn't need computing the accurate production function and model specification decrease has been extensively used for evaluating the relative performance of a set of decision maker units. In this research, the performance of 7 active supply chain in tile industry which have similar supply chain construction, including providers, producers, Distributors and clients, by evaluating producers who perform a key role in chains and by using data envelopment analysis method are considered. According to effectiveness of inputs on outputs of organizations, outputs are considered as functions of inputs. For performing the desired analysis in this article $DEAP_{1,2}$ has been used.

2. Advantages of data envelopment analysis method

Data envelopment analysis method has so many advantages which some of them are as follows:

1. In this method there is no need to assign weights to criteria's. Data envelopment analysis automatically makes the related weights for analyzing. Eliminating the assigned part of the weights accelerate more the ranking process.

2. Despite parametric methods which need a mathematical function and based on it by using independent variables, the dependent variable has been estimated, data envelopment analysis

doesn't need estimating the production function and its accompanied assumptions.

3. Despite parametric methods which by averaging in units comparison obtain the best performance which exists among the set of units, data envelopment analysis investigates each one of observations in comparison to the produced optimized efficient border and uses for measuring efficiency.

4. Data envelopment analysis is a simple and easy approach and in order to its special capabilities, this method can lead to making a proper decision based on reliance.

5. Using the data and occurred information is performed. Despite famous methods like Logistic regression analysis, Neural Networks and multiple audit analysis which needs predicted data for ranking, this approach (data envelopment analysis) uses real and practical data sets of decision maker units.

6. Possibility of simultaneous usage of different inputs and different outputs with different measuring criteria's.

7. Presenting the optimized solution of Pareto

3. Statement of the problem

Supply chain access to Competitive and developing advantages needs monitoring and evaluating of activities and systematic performed proceedings of chain. Performance evaluation is performance quantification process and the effectiveness of activities. In another words, performance evaluation systems are a set of performance measurement criterions and effectiveness of activities. Briefly, performance evaluation results in supply chain management reveals the effect of production strategies and existing potential opportunities and the facility of merging the cooperation of chain members is obtained through increasing their inner understanding of ongoing processes.

A large portion of available studies on evaluating the performance of supply chain principally focus on frameworks of systems of evaluation indices. Most of these models need human judgments for computing the weights of available indices in evaluation process.

In order to increase the accuracy of the weights of indices which are influenced by the judgments of decision makers, data envelopment analysis has been used a lot as a nonparametric method for evaluating the performance of supply chain. The main property of data envelopment analysis is its capability for computing the performance when there are several inputs and outputs but there are not acceptable weights for aggregation of inputs and outputs. In this research, 7 supply chain of active tile production in Yazd province has been performed using data envelopment analysis and defining the outputs as functions of inputs.

Tile and ceramic are among the oldest productions made by human hands. Abundance of Raw

materials and the facility of manufacturing caused Ceramic objects to be among the oldest finding of primitive humans. In recent years, the rank of our country among top manufacturers of ceramic tile in the world is developing and in 2010 also Iran's tile production by 14.3% increase of the production volume in comparison to 2009, became the fourth major tile producer after China, Brazil and India. On the other hand, Iran's tile consumption by 13.6% increase reached to 335 million Square meters and became the fourth major consumer in the world after China, Brazil and India.

Yazd province with its approximately 40 percent share of tile production in the country is considered to be one of the main poles of this industry in Iran. In this research, the evaluation of 7 active supply chains in tile industry and ceramic of Yazd province which produces approximately 25% of the province production and about 10% of the country's tile has been considered. The considered Supply networks have many similarities. In these 7 supply chain networks, 7 plant of tile manufacturing are the key companies and suppliers and clients constitute other component of the network. Therefore supply chain covers a set of companies including key companies, suppliers, distributers and clients.

The objective of this research is to help the performance evaluation of operatings of these 7 supply chains which in a similar industry and with different key companies and relatively similar suppliers and distributers by using data envelopment analysis.

3.1. Performance evaluation indices (research variables)

Generally, different attempts have been performed in the event of explaining performance evaluation indices in supply chains that each one of them has a different view and approach regarding grouping and classification of the forenamed indices. Sample of some of these researches are as follows:

- Concentration of Qualitative and Quantitative of indices that have been considered in Beeman studies.
- That they measure something: This subject has been concentrated in different researches of Goonaskaran and also Toni (2001) on cost and or non-costing indices, in Eshoncible studie (2004) on quality, cost, flexibility and delivery; in Chan studies (2003) on cost, quality, Exploitation of resources, flexibility, Transparency, Trust and innovation; in Beeman studies on resources, output and flexibility; in Hiber studies in the form of efficiency in supply chain, combination and Efficiency Coordination and in Pan studies (2003) on input, output and processing.
- Attention to Strategic, Operating and or technical Focus of indices that studies of Goonascaran (2001) was focused on them.

Available processes in supply chain that these indices are related to them have been considered in studies of Chan and Key (2003), Hang et al (2004) Lakami and MC Carmack (2004) and Stephens (2001).

Based on the performed studies on system of indices and principles of data envelopment method, evaluation indices of evaluation problem of supply chain performance have been selected. According to the construction of data envelopment analysis which was explained in chapter 2 in details, the selected indices are defined in the forms of conductor indices or input variable and functional indices or output variables.

The considered indices that constitute inputs and outputs of the model are performed based on Organizational Diagnosis studies in tile companies of Tazd province, supply chain key companies, in the year of 90 have been extracted and selected. The used Diagnosis model is from the transcendence of foundation of Europe quality management model that was used with some amendment in order to diagnose the forenamed companies.

3.2. Input variables

Input variables are effective factors on outputs of a decision maker unit that generally are under control of the organization. The available fluctuation in variables leads to producing a change in outputs of the decision maker unit and depending on the effectiveness, will produce different results.

Generally the required input variables of performance evaluation can be incorporated into 3 fields of capital, time and human resources. According to the available constraints in computing the criteria's time area and base on the performed studies, in this research the input variables in the field of tile industry has been defined as follows:

Table1. Problem Inputs

Row	Input title	Sign
1	Intermediate costs	X_1
2	Human resources cost	X_2
3	Depreciation cost	X_3
4	Output value (Sales)	X_4
5	The total value of data (Total Costs)	X_5

3.3. Output variables

Output variables are as effective factors of one or several input related to the decision maker unit that expresses the obtained results of effective factors or input variables.

Output variables or indices of the function constitute the information of management dashboard of the decision maker unit as the result of input variables change. In this research outputs are defined as a function of inputs and in continue they have been pointed out.

Table2. Problem Outputs

Row	Output Titles	Sign	Equation
1	Total Factors Efficiency	Y_1	$\frac{X_4 - X_1}{X_2 + X_3}$
2	Competitiveness	Y_2	$\frac{X_4 - X_1}{X_5}$

Inputs and outputs of the data envelopment analysis of this research can be shown as follows:

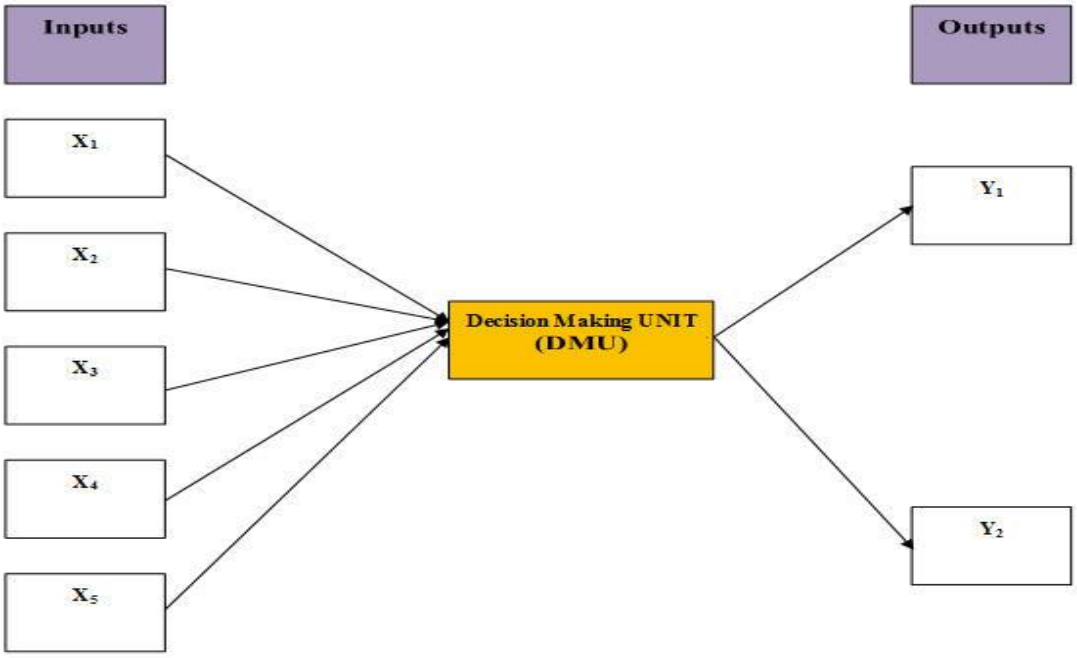

Figure1. Inputs and outputs of the data envelopment analysis model

4. Data and information analysis method (data envelopment analysis model)

Among many methods of performance evaluation, data envelopment analysis has been used extensively for evaluating the performance of a set of decision maker units since this method doesn't need to estimate the accurate production function and also it is possible to note simultaneously to several inputs and outputs regardless of their measurement units.

If we assume that the number of decision maker units are equal to *n* and each decision maker unit has *m* inputs and s outputs, then the input and output vectors are defined as follows:

Table3. Indexes

Title	Sign	Interval
Input	i	1,2,3,4,5
Output	r	1,2
Decision Making Unit	j	1,2,3,4,5,6,7

$$X_i = (X_{1i}, ..., X_{mi})^T \geq 0$$

$$Y_j = (Y_{1j}, ..., Y_{sj})^T \geq 0$$

Where X_{ij} is an indicator of the value of i-th input of j-th decision maker unit and Y_{ij} is the value of r-th output of the j-th decision maker unit. Input and output vectors of the desired decision maker unit for evaluation are as X_0 and Y_0.

In this research the decision maker units are considered to be 7 key companies of tile industry supply chain network and they have been evaluated by using input based CCR and BCC models and comparing the results of models with each other.

Due to the fact that output variables are a function model of input variables therefore input based model has been used. In other words, since decision maker units may affect on inputs, this model has been used.

4.1. Input based CCR modified model

In the divisible CCR model, μ and w variables are nonnegative (Greater than or equal to zero). If each of these variables become zero then each of these inputs or outputs will be eliminated. For example when in the optimized solution of a CCR model $\mu_1=0$, then the first output will be omitted from the performance determination computations.

Kups, Charnz and Roodrs in 1979 proposed that it's better to consider the decision variables of the model (w_i,μ_r) less than a small value like ε and called it modified model.

According to the defined inputs and outputs of, we can define this model as follows:

$$\begin{aligned}
&\max\ z = \mu_1 y_{10} + \mu_2 y_{20} \\
&s.t \\
&. \\
&\mu_1 y_{11} + \mu_2 y_{21} - (w_1 x_{11} + \ldots + w_5 x_{51}) \le 0 \\
&. \\
&\mu_1 y_{17} + \mu_2 y_{27} - (w_1 x_{17} + \ldots + w_5 x_{57}) \le 0 \\
&w_1 x_{10} + \ldots + w_5 x_{50} = 1 \\
&\mu, w \ge \varepsilon
\end{aligned}$$

It should be noted that the zero unit is the investigated decision maker unit. For example when our purpose is to evaluate unit 7, then equation will be formed as follows:

$$\begin{aligned}
&\max\ z = \mu_1 y_{17} + \mu_2 y_{17} \\
&w_1 x_{17} + \ldots + w_5 x_{57} = 1 \\
&\mu_1 y_{11} + \mu_2 y_{21} - (w_1 x_{11} + \ldots + w_5 x_{51}) \le 0 \\
&. \\
&\mu_1 y_{17} + \mu_2 y_{27} - (w_1 x_{17} + \ldots + w_5 x_{57}) \le 0 \\
&\mu, w \ge 0
\end{aligned}$$

4.2. Input based BCC modified model

When there is a constant efficiency with respect to the criterion, CCR model is used. In another word, performance evaluation in these conditions can be considered for a long-term period. BCC model is a type of data envelopment analysis models that evaluates the performance of decision maker units with variable efficiency relative to the criterion that can be used for short-term analysis of efficiency.

According to the defined inputs and outputs, we can express the model of this condition as follows, Where in this model the variable of w is free in mark:

$$\begin{aligned}
&\max\ z = u_1 y_{10} + u_2 y_{20} + w \\
&\qquad s.t \\
&u_1 y_{11} + u_2 y_{21} - (v_1 x_{11} + \ldots + v_5 x_{51}) + w \le 0 \\
&\qquad\qquad . \\
&u_1 y_{17} + u_2 y_{27} - (v_1 x_{17} + \ldots + v_5 x_{57}) + w \le 0 \\
&\qquad v_1 x_{10} + \ldots + v_5 x_{50} = 1 \\
&\qquad u, v \ge \varepsilon
\end{aligned}$$

It should be noted that the zero unit is the investigated decision maker unit. For example when the evaluation of unit 6 is desired, then the equation are formed as follows:

$$\begin{aligned}
&\max\ z = u_1 y_{16} + u_2 y_{26} + w \\
&\qquad s.t \\
&v_1 x_{16} + \ldots\ldots + v_5 x_{56} = 1 \\
&u_1 y_{11} + u_2 y_{21} - (v_1 x_{11} + \ldots + v_5 x_{51}) + w \le 0 \\
&\qquad\qquad . \\
&u_1 y_{17} + u_2 y_{27} - (v_1 x_{17} + \ldots + v_5 x_{57}) + w \le 0 \\
&\qquad u, v \ge \varepsilon \\
&\qquad w \ \textit{is free in sign}
\end{aligned}$$

5. Conclusion and Computational results

In this research, the data envelopment analysis method, due to its capability on evaluating the performance by using different inputs and outputs, has been used. This method has different models that are used based on the required analysis and results. Input based CCR modified model by assuming a constant efficiency relative to the criterion and input based BCC modified model by assuming a constant efficiency relative to the criterion with optimized inputs findings objective for evaluating the performance of active key companies in supply chain and defining reference units for patterning of companies with relatively lesser efficiency have been used and the following results are obtained by using specialized software of data envelopment analysis method, DEAP.

a. The evaluation of supply chain key companies assuming a constant efficiency relative to the criterion

In this case supply chain 1, 3 and 5 have the relative efficiency of 1 and in ineffective supply chains the amount of efficiency were 2, 4, 7 and 6 respectively. The average efficiency of 7 supply chains was equal to 0.766.

Supply chains 1 and 3 were defined as combination of virtual unit or pattern unit of 6 and 7 supplies.

b. The evaluation of supply chain key companies assuming variable efficiency relative to the criterion

Due to the fact that the variable efficiency relative to the criterion case is closer to the environmental conditions of decision maker units, the results of this assumption are more trustable. In this case supply chains 1, 3 and 5 have the relative average of 1 and in the ineffective supply chains the average were 2, 4, 7 and 6 respectively. In this case the management efficiency of supply chain 7 was 1. The average efficiency of the seven supply chains was equal to 0.835.

All of the ineffective units have additive efficiency relative to the criterion. This means that there is the capability of obtaining an input-output ratio more than 1 for them.

Supply chains 1 and 3 were defined as combinations of virtual unit or pattern units of chains 2 and 4. Supply chains 1 and 7 were selected as virtual unit or pattern units of chain 6.

In order to make ineffective units work in higher levels of efficiency, the value of change in the inputs of key companies supply chain has been computed. By these changes, the ineffective units obtain the possibility of achieving the relative efficiency.

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