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Measuring the units efficiency using an integrated DEA–AHP method: A case study of rivet producer

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A B S T R A C T

The present research purpose is applying a compose method from DEA and AHP for removing this technique deficiency on assessing. For this reason, a compose method on basis of unsubjective double comparisons matrix has been used. At research process, after specifying the input and output variables and also a proper model for DEA, computational research method are dismounted at two stages: At the first stage, DEA model, is dismounted for two-by –two of items (branches), regardless to other items. At the second stage, double items comparisons matrix is provided from first stage results, that is performed total rating by resolving a unit – level AHP model. For this purpose, for dismounting this technique, we have attempted to assess rivet producer units efficiency, at one of the greatest industrial units in Iran. Results indicate unit number 3 with efficiency amount 0.12622 has allocated the highest rate to own and unit number 1 and 2 with efficiency 0.12404 has allocated the least rates to own.

1. Introduction

Resource scarcity is one of the most important issues influencing our nature and lives and it has created so much motivation to measure the efficiency of economic units in an attempt to increase efficiency and productivity. Efficiency is optimal resource allocation and is indicative of maximum using the resources or minimum cost tolerance, with existent technology. During the past few decades, there have been tremendous efforts on developing several methods to measure the efficiency of economic units. Efficiency identification depends on defining and comparing with a desirable and standard limit and basis of such a desirable limit is determined by different methods. Data envelopment analysis (DEA) models are among useful tools at efficiency assessment of several institutions with similar productive structure. Since ever introducing DEA models, numerous applications from them have been proposed at function assessment field (Gergorio & Zao, 2005).

Appling DEA and analytical hierarchy process (AHP) models for first time was extended at assessing the supply chain function (Geo & colleagues, 2006). Designing the facilities place showing at production systems (Yang & Ko, 2003; Ert & colleagues, 2006), selecting the reservoir operator

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(Corpla & colleagues, 2007), improving and refining the railway system (Azadeand et al., 2007) and assessing the bridges risk (Vang et al., 2007) are another application of the implementation of DEA and AHP. Hoo (2008) preformed the extended examinations about DEA compound and its application and used only at four articles from DEA and AHP models. In addition to these applications, Integrated DEA and AHP trend has been used in different methods (Lozano & Vila, 2007, Ramanatan, 2006, Jing et al., 2006). Chen and Chen (2007) applied DEA model with balance score card (BSC) to assess semi–conductor industries function and used AHP for giving weight to four-fold indexes of balance score card. Banit and colleges (2008) attempted to assess research and extension organizations function by composing DEA/AHP technique. Chen et al. (2010) with DEA and AHP methods have analyzed of projects delivery systems in Chinese construction industry. Kang and Lee (2010) provided a new function assessment model from suppliers at cumulative orbital packaging firms by integrating DEA/ AHP technique.

Jalalvand et al. (2010) presented a methodology to compare the supply chain at firms, applying the various DEA models. Maria et al. (2011) implemented DEA/AHP models for some production planning programs. Chen et al (2010) attempted to analysis delivery systems project at Chinese constructional industries, using DEA method. Studies result conducted at efficiency assessment field with DEA techniques approved that by two reasons, applying these techniques alone cannot make available the useful results for decision – makers: 1- not determining the proper weight for input and output variables, 2- not rating perfectly decision- making units. On the other hand, studies record conducted by AHP technique show that this technique structure is on the basis of subjective double comparisons matrix of decision – maker person, which is not a completely scientific method. Therefore, to compensate these deficient, we have used DEA technique on basis of non-subjective double comparison matrix. At this research, main DEA framework is used so that it develops DEAs beyond the efficiency/deficiency classification to a perfect rating. The main advantage at applying this compose method, is perfect rating of decision – maker units based on a through scientific method.

2. Literature review

2.1. Efficiency

At a general glance, efficiency is in four kinds as follow:

- **Technical efficiency:** maximizing the production amount given available production factors and resources or given saving such as machinery and human forces compared with the best possible scenario (Pearse, 1997).
- **Allocative efficiency:** using the least expensive data compound to produce the best produces compounds.
- **Structural efficiency:** The purpose of this efficiency at an industry is to attain average efficiency weight at that industry firms. By using this kind of efficiency, one can examine different industries efficiency with varied produces.
- **Scale Efficiency:** The observed efficiency depends on efficiency at optimal scale, In fact, production purpose is at optimal scale.

Identifying the efficiency for determining a desirable limit is practical by various ways such as ratio analysis method and frontier analysis method. At frontier analysis method, we use efficiency concept, which has a direct relationship with assessment concept, and a frontier is existed as efficiency frontier but at economic theories, there are two important methods of parametric and non–parametric to determine efficiency frontier (production function). At parametric trends, there are different methods such as strike frontier method (SFA), thick frontier method (TFA) and distribution free method (DFA) to determine efficiency frontier. Generally, at all parametric methods we try to estimate a frontier production function in a special form with a compound error sentence, using different assumptions, and by this mean, attribute units' deficiency amount to two classes: strike factors and deficiency factors (Boer & colleeyes, 1998). The most important disadvantage of parametric methods is different assumptions, which assigns for functions and deficiency. So, with considering different assumptions, very different estimations are attained, which make it difficult to compare units practically. On the other hand, non-parametric methods, which were presented by Farrell (1957) to estimate efficiency, do not need to determine a special form of function and strike factors are not also involved. Farrell observed saving instead of guessing the production function and assigned a frontier for units and considered it the operation criteria. Farrell broke economic efficiency (total efficiency) into two parts: technical efficiency and allocative efficiency. Technical efficiency relates to one unit technological structure and allocative efficiency relates to units behavioral objects and it is calculated as follow:

Economic efficiency = allocative efficiency * technical efficiency.

At non-parametric patterns levels, there are different methods to observe deficiency that among the most important and the most elaborate are step–by–step frontier method and linear programming method where both of them are mathematical programming patterns. DEA method, which is a new trend from non-parametric methods to estimate the frontier function is a method that we have used it at this research.

2.2. Data envelopment analysis

DEA is a non- parametric assessment method to measure relative efficiency of decision-maker units (DMUs) on the basis of linear programming. This technique was introduced for the first time by Charnes et al. (1978, 1994). At this method, without considering a special form for functions, form linear programming we took action to perform an optimizing set and unit's efficiency amount, examined on basis of two assumptions of constant to return outputs (CRS) and variable to return output (VRS). Since DEA does not need pre-estimated parameters, it has the advantage of avoiding subjective factors, simplifying calculation, and reducing errors (chen et al., 2010).

Simos and Maroulis (2007) applied DEA to calculate the efficiency of DBB, DB, CM and DBM in road projects. At DEA method, there are different models such as relative form, processor, covering (comprehensive) that in each one of these models, determining unit efficiency examined, has been performed by special method, and for this purpose, different methods such as one-stage, two–stage and multi-stage are used (cooli, 1996). Below, liner programming model used at this research with taking view and with constant output supposition relative to scale has been presented. Let x_{ij} be the inputs for one of decision-making unit with $i=1,\dots,m$ and y_{rj} be the outputs of the same units with $r=1,\dots,s$ and $j=1,\dots,n$ and suppose u_i and v_j are the dual variables associated with x_i and y_j, respectively. The constant return to scale DEA modeling formulation is as follows,

$$\max \quad z = \frac{\sum_{r=1}^{s} u_r y_{r.}}{\sum_{i=1}^{m} v_i x_{i.}}$$

$$\text{subject to} \quad \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1. \tag{1}$$

$$x_{ij}, y_{ij \ge 0}$$

Model (1) is the one of the well known DEA, which can be solved j times to determine the relative efficiencies of various units. However, since model (1) is nonlinear in structure, Charles et al. (1978) proposed a simple modification of the objective function to convert model (1) into a simple linear programming problem as follows,

$$\begin{aligned} \max \quad & z = \sum_{r=1}^{s} u_r y_{r.} \\ \text{subject to} \quad & \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1. \\ & \sum_{i=1}^{m} v_i x_{i.} = 1 \\ & u_r, v_i \ge 0, \qquad j = 1,\dots,n \end{aligned} \tag{2}$$

Problem (2) has been widely used for many water resources management studies. DEA models have been extended when there are uncertainties associated with inputs/outputs called robust DEA.

2.3. Analytic hierarchy process (AHP)

AHP was introduced by Saati(1970) at Warton University. Perhaps, AHP is the most elaborating decision – making Technique in the world, which gets its credit from thousands of real-world applications (Saate, 1994). This method is for complicated analysis occurs in unstructured situations (saati, 1990).

2.4. Rivet

Rivet is a tool for connecting, permanently, two or more segments, which is considered as rapid and cheap connection. By using rivet, we can connect various segments mode of Aluminum, copper, steel, wood, light, plastic and … together. According to rivet properties, no connection can be easier, cheaper and safer than river. We can use river not only as a mechanical connection but also for electrical connecting, pivot, hinge, decorative tool and many other applications.

Special rivet is a kind of rivet which costumer intends to use them in addition to mechanical connection application for other application such as electrical connection or pivoted and decorative characteristic. Producing this kind of rivets usually searches a special method, and some of them have different tolerances to ordinary rivets. Special rivet is produced on the basis of order, according to this fact that order number is one of characteristics determining the rivet price, special rivets are in same extends more expensive than ordinary rivets.

3. Research methodology

The method presented in this paper has advantages of both DEA and AHP methods. Next we explain details of our proposed model.

3.1. Model analysis at rivet – maker firms

3.1.1 Selecting the output and input variables

One of important issues associated with DEA models is the selection of the variables by which we can assess the relative situation of each of decision–maker unit.

Input indexes, including:

- Raw materials number: that is constant and number per year, which is ordered by factory.
- Cost of each rivet: total cost of raw material, parts cost and wage, package cost and all costs relating to rivet production.
- Import: it is calculated as follow:
  {Weight of each rivet * 50% (wastes) * production number per year} + {weight of nail * 20% * production number per year}

Output indexes, including:

- Export
- Income: Growth sales

Information relating to output and input variables relating to rivet – maker firm has been indicated in Table 1:

Table1
Output and input variables

output		input			Rivet code
Income	Export	Import	Cost of each rivet	Raw materials number	
8100000	0	60200	17.50	1000000	5006
12750000	0	94800	17.40	1500000	5008
27300000	0	195600	17.40	3000000	5009
18120000	0	134400	17.41	2000000	5010
19360000	0	142400	17.90	2000000	5012
16440000	0	125250	21.45	1500000	5014
29600000	2500000	217500	21.50	2500000	5016
12060000	1000000	91000	21.80	1000000	5018

In the first stage of the proposed model of this paper, we solve model (2) by comparing the relative efficiency of each pair of units. Therefore, we get some numbers which could be summarized in a Table 2.

Table 2
Matrix efficiency DEA/AHP model

	1	2	3	4	5	6	7	8
1	1	1	0.9640	0.9980	0.9897	1	0.9887	1
2	1	1	0.9636	0.9976	0.9893	1	0.9883	1
3	1	1	1	1	1	1	1	1
4	1	1	0.9956	1	0.9917	1	0.9907	1
5	1	1	1	1	1	1	0.9990	1
6	1	1	1	1	1	1	0.9645	1
7	1	1	1	1	1	1	1	1
8	1	1	1	1	1	1	1	1

In the next stage, we prepare a symmetric matrix based on the information of Table 2 so that we could follow traditional AHP procedure. Table 3 summarizes the details of our computations.

Table 3
The paired comparisons matrix for DEA-AHP model

	1	2	3	4	5	6	7	8
1	1	1	0.9640	0.9980	0.9897	1	0.9887	1
2	1	1	0.9636	0.9976	0.9893	1	0.9883	1
3	1.0373	1.0377	1	1.0044	1	1	1	1
4	1.0020	1.0024	0.9956	1	0.9917	1	0.9907	1
5	1.0104	1.0108	1	1.0083	1	1	0.9990	1
6	1	1	1	1	1	1	0.9645	1
7	1.0114	1.0118	1	1.0093	1.0010	1.0368	1	1
8	1	1	1	1	1	1	1	1

Using traditional normalized procedure used in AHP method yields the ranking of all eight units as follows,

Table 4
The summary of the ranking of eight units

Unit	1	2	3	4	5	6	7	8
Efficiency	0.12404	0.12404	0.12622	0.12473	0.12543	0.12444	0.12607	0.12499

As we can observe from the results of Table 4, unit three represents the highest ranking followed by unit seven, unit five, unit four, unit eight, unit six and unit one and two come in the last.

4. Conclusion

The first step at assessing one organization function, is to select an appropriate assessment model proportional with dimensions in which basis, decision- makers will measure their units, while each one of assessment methods has own special weak and strength points, so, combining of models for developing the assessment process can assist decision makers to examine organizations' functions more accurately. Primary DEA model does not perform perfect rating of units and only classifies items into two classes: efficient and deficient. Each method has its own limitations. Some of limitations are because of subjective data and the other is related to the number of items. This research is an attempt to use DEA concept to rate items perfectly by one of current MCDM methods called AHP. Very important point is that an integrated DEA-AHP method applied in this research has advantages of both DEA and AHP methods and does not suffer of each method's limitations. As seen, a scientific method on the basis of un-subjective double comparison matrix was used to assess units' efficiency. The ranking results show that the interval among different units rating assessed is very insignificant. This research could be extended in different ways and the following summarizes some of future directions,

- Using applied compound models such as BSC and / or FMEA with DEA models,
- Designing hierarchy profiling model that is combining two profile and DEA hierarchy models, innovation is a desired thing that has not been paid much attention to it,
- Using DEAGP model with compound aims to prevent from lack of acceptable area at same of DMU_s,
- Profiling FDEA models because of more conformity of these models to real world.

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