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Evaluating the performance of cement producing companies of Tehran Stock market using Data Envelopment Analysis models

M. Shahriari *

Department of Industrial Management, South Tehran Branch, Islamic Azad University, Tehran, Iran,

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Abstract

Nowadays, performance measurement is carried out through two types of methods: parameterized and non-parameterized. This research focuses on non-parametric methods, specifically those that utilize mathematical programming, to assess the performance of cement companies in the Tehran Stock Exchange (TSE) market. The coverage analysis method used in this study provides an advantage over existing methods in that it can evaluate the performance of units with multiple inputs and outputs that are not interchangeable (UMIMO). The evaluation of performance was carried out using two assumptions: "Performance against constant scale" and "performance against variable scale", based on the inputs and outputs of cement companies in the TSE. The study examined 22 cement producing companies, finding 7 efficient units according to the CCR method and 11 efficient units according to the BCC method.

Keywords: Data envelopment analysis (DEA), Performance, Cement industry, Stock exchange market.

* Corresponding author: Email: shahriari.mr@gmail.com

1. Introduction

The cement industry is one of the most important industries in Iran, and it has been experiencing rapid growth in recent years. Cement production is a major contributor to the country's economy, providing employment opportunities and generating revenue. Iran is currently the fourth-largest cement producer in the world after China, India, and the United States.

The Iranian cement industry has a history of over 80 years and has seen significant development since the Islamic Revolution in 1979. The government has played a crucial role in the industry's development, particularly in terms of investment in new facilities, increasing production capacity, and modernizing the industry's equipment. Most of the Iran's cement production comes from modern cement plants, with many companies operating under the management of the Ministry of Industry, Mine, and Trade. The industry is dominated by a few large companies, but there are also numerous smaller firms operating in the market.

Cement production in Iran is mainly used for domestic consumption, although there is also a significant export market. The main export destinations for Iranian cement are Iraq, Afghanistan, and Central Asia.

However, the industry has also faced several challenges, including sanctions imposed by the United States and other countries, which have affected the availability of raw materials and machinery. The high cost of energy and environmental concerns also pose challenges for industry.

Overall, the Iranian cement industry has great potential for growth and development, and it is expected to play an important role in the country's economic development in the future.

One of the useful and effective techniques that can help managers and experts in evaluating the performance of organizations is mathematical programming models. The purpose of these techniques is to make mathematical models based on existing natural conditions in order to determine the best structure for the systems according to the desired goals and the limitations they face [1].

On the other hand, managers are always trying to get the maximum result with the least facilities and production factors, which is called reaching the maximum efficiency. An efficient company is a company that can obtain the maximum output for a certain set of inputs, with the minimum possible cost. Because the result of increasing efficiency is increasing productivity, which is the main goal of every economic enterprise. One of the most appropriate and powerful methods for determining the relative efficiency and evaluation of the Decision-Making Units (DMUs) is Data envelopment analysis (DEA). The use of this technique is expanding rapidly and is used in the evaluation of various organizations and industries such as banks , offices, hospitals, educational centers, power plants, refineries and so on.

The main purpose of linear programming technique is to compare and evaluate the efficiency of a number of similar DCUs that have different used inputs and production outputs.

Data envelopment analysis is a linear programming technique whose main goal is to compare and evaluate the efficiency of a number of similar decision-making units that have different inputs and outputs. This method, which is capable of measuring the relative technical efficiency of different organizational units, was proposed for the first time in Rhodes' doctoral dissertation under Cooper's guidance with the title of “evaluating the academic progress of students in American national schools”, and the results of this dissertation in 1978, led to the publication of an article with the title of “measurement of the efficiency of decision-making units" by Charnes, Cooper and Rhodes, which is called the CCR model (abbreviated from the first letter of the names of these three people) [2]. In the aforementioned article, they used optimization by mathematical programming method to measure the efficiency of systems with multiple inputs and multiple outputs.

Parvizian et al. presented a model to calculate the efficiency of banking information technology units using DEA. In their research, measuring the efficiency of 38 Information Technology Service departments of Bank Mellat (Iran) and its subsidiaries through identification of input and output indicators using Delphi technique and fuzzy logic with the combination of three modified Russell models, evaluating the efficiency of the components and Anderson-Peterson ranking model and adding weight constraints [3]. Shafii Nikabadi and their colleagues determined the inputs and outputs of Iran's regional power companies using artificial neural network and then evaluated the efficiency of those companies using DEA [4]. Pashapour et al presented a model to optimize the performance of industrial units in crisis conditions by considering economic reversibility factors. In their research, a non-deterministic data envelopment analysis model was used to determine efficient units in a petrochemical company [5]. Chavoshi et al presented a model to measure the efficiency of e-commerce in the provinces of Iran during the years 2015-2016 and using data envelopment analysis model. For this, they investigated the factors affecting the growth and use of e-commerce in Iran based on theoretical foundations, and then used the DEA model with outlier data approach to evaluate the efficiency of the provinces of Iran in e-commerce. The results of this research showed the fact that the average efficiency of e-commerce in the country has grown significantly in 1996 compared to 1993 [6]. M. Shahriari uses the data envelopment analysis (DEA) to assess the progress/regression of decision-making units (DMUs) having a two-stage structure. The progress/regression of these DMU can be assessed in the first stage, the second stage, and the whole system. In the first stage, the progress/regression of bank branches in collecting resources and in the second stage their progress/regression in allocating the resources as well as gaining profit are calculated, and the combination of both types of data is ultimately analyzed. The progress/regression is calculated using two separate indices: the The Malmquist indexand the Meta-Malmquist index. This study applied the proposed models to 20 branches of a commercial bank with two-stage structure [7].

The studu of Mansouri A. et al shows that managers often struggle with the task of ranking options, and there are various approaches available, both qualitative and quantitative. However, when it comes to separating and ranking corporations in the stock market, many of these approaches are unreliable and produce invalid results. Using only qualitative or quantitative approaches alone can also ignore certain advantages of integration, leading to questionable efficiency of results. This study addresses these issues by integrating both qualitative and quantitative approaches to improve the precision of input and output indices. Specifically, the study employs the TOPSIS and DEA approaches to rank active companies in the cement industry accepted in the Tehran stock market. The approach was carried out between 2006 and 2011, using a population of 28 accepted companies in the stock market within the cement industry. The results presented a precise ranking of the companies using integrative techniques. [8].

On the other hand, the importance of the housing market in today's urban society, the need of families to become independent and the unwillingness to live in the past, has caused an increasing demand for housing and, as a result, a dramatic increase in its price. In this situation, one of the most important ways to control housing prices can be to increase the production and reduce the price of construction inputs such as materials necessary for the production and construction of residential buildings. One of the most important products in construction is cement, the changes in its price cause changes in the price of the final product, i.e., building. Therefore, investing in this field can lead to the solution of housing problems.

Ozakan and Olutas (2017) studied the possibilities of cement production with regard to unfavorable outputs in Turkey. In their research, 11 cement production centers were considered. DEA models were defined for existing common inputs and outputs and proposed unwanted inputs and outputs. Finally, the conclusion of their work was that there is a significant difference in terms of compatibility for the operation of cement manufacturing facilities when adverse factors are considered and weights are determined [9].

Also, considering that economic prosperity requires large investments that cannot be provided only through short-term financial resources, therefore, creating a strong and efficient capital market can be the foundation of long-term financial infrastructure in a country through which the capital formation process can be speed up. In fact, the prosperity of the stock market is a symbol of a progressing economy, which creates a positive and two-way relationship between economic growth and stock market development indicators in the long run.

Due to the effective role of financial markets in collecting financial resources through small and large savings, as well as the role of these markets in directing financial resources towards investment needs in productive economic sectors, investing in them is very important. Collecting funds and directing them towards economic activities is the main goal of the stock exchange. The stock market is able to provide the capital needed by the businesses and entrepreneurs of the country by offering the shares of those companies to the people. Therefore, investigating the stock market of cement companies can be an interesting topic for researchers due to the great attraction of investing in them and also contributing to the development of the country.

Seyed Hosseini and Darvish Metoli (2015) evaluated the performance of the cement supply chain. By calculating the efficiency of the entire chain, they also evaluated the efficiency of the chain members and obtained the type of efficiency to scale ratio [10].

Valizadeh Oghani et al. (2016) evaluated relative efficiency in cement companies that are members of the Iran Stock Exchange as an index to measure management ability. To do this, they used the data from 2011 to 2015. For this purpose, they first checked the performance of each company with the help of data envelopment analysis and ranked the units through Andersen-Petersen method. Then, through a regression model, they estimated the management index of each unit with a suitable model [11].

Darvish Mutoli et al., taking into account quantitative and qualitative limitations as well as undesirable outputs, tried to present an integrated approach of network data envelopment analysis method and Malikquist's productivity index with the aim of evaluating the sustainable supply chain performance in the cement supplier industry in Tehran Stock Exchange. They showed that their proposed model can not only provide suitable feedback from the performance of supply chains of cement companies present in the stock market, but also can provide a suitable model for other strategic industries present in the capital market.[12]

Khanmohammadi and Heydari ranked cement companies active in the stock market using the improved DEA/AHP method. They showed that the ranking of these companies was influenced by important factors, and in fact, this ranking method took into account influential factors and elements and obtained the results with minimal error [13].

Therefore, according to the importance of cement industries in the development of construction and also considering the impact of improving the capital market on the improvement of the country's business environment, in this research we intend to evaluate the efficiency of the symbols of cement producing companies in the Tehran stock market by using DEA

2. Data envelopment analysis

Data envelopment analysis (DEA) is a powerful mathematical method in which linear programming is used to determine the relative efficiency of a set of homogeneous decision-making units or DMUs. Charness, Cooper and Rhodes, first presented the DEA model under the (CCR) model. In this project, the efficiency of the decision-making units is calculated using data envelopment analysis or DEA. Data envelopment analysis technique is used in relative performance evaluation, the basis and methodology of this technique is described below in parametric form. Suppose that each decision-making unit has several inputs and outputs as shown in the figure below.

The efficiency value is the result of dividing the output by its input. But due to having more than one input and output, the above division is not possible, and therefore, we need weights for the inputs and outputs of the units so that we can convert the inputs and outputs into one input and output with the help of these weights. For this purpose, assume that $V = (v_1, \dots, v_m)$ and $U = (u_1, \dots, u_s)$ are the output and input weight vectors, respectively. In this case, DMU_j has used the input $\sum_{i-1}^{m} v_i x_{ij}$ and produced the output $\sum_{r=1}^{s} u_r y_{rj}$. Therefore, the efficiency of DMU_p is calculated by solving the following problem.

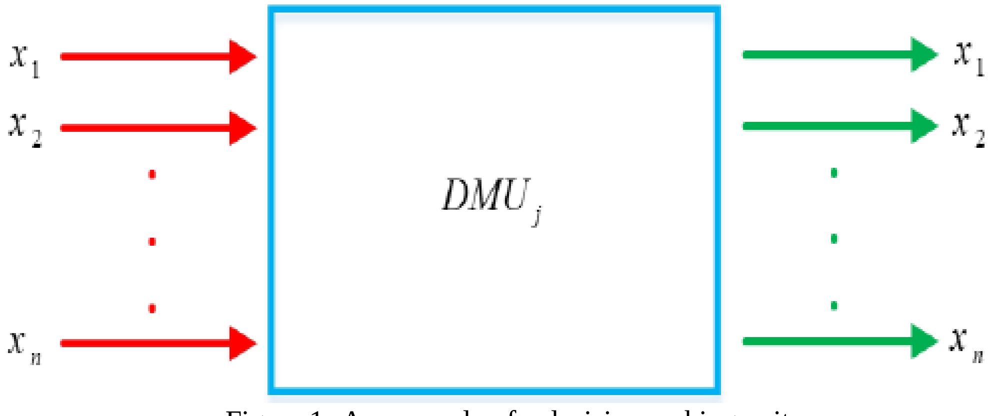

Figure 1- An example of a decision making unit

$$Max \frac{\sum_{r=1}^{s} u_r y_{rp}}{\sum_{i=1}^{m} v_i x_{ip}}$$

$$S.t: \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1, \quad j = 1,\dots,n$$

$$u_r, v_i \geq 0, \quad \mathrm{r} = 1,\dots,s, \quad \mathrm{i} = 1,\dots,m$$

So far, many methods have been proposed to measure efficiency in organizations. However, compared to all model, DEA is a better way to organize and analyze data, because it allows efficiency to change over time and does not require any assumptions about the efficiency frontier. Therefore, it has been used more than other methods in performance evaluation, and it is considered a suitable technique for comparing units in measuring efficiency.

2.1. Classification from the point of view of nature

In this view, DEA models are generally divided into two groups: input-oriented and output-oriented:

- Output-oriented model: In this approach, the argument is that to maximize the value of a fractional expression, it is enough to consider the denominator of the fraction equal to a fixed number and maximize the fraction numerator. These models are used when the goal of the managers is only to increase the outputs for fixed values of the inputs.
- Input-oriented model: There are models that reduce inputs by keeping the outputs constant, and the opposite of this happens in the output-oriented model. Input-oriented models maintain the number of outputs at the given level and reduce the number of inputs proportionally as much as possible.
- Additive model: this model simultaneously considers the reduction of inputs and the increase of outputs and is used more than the other two models.

2.2. Categorization from the point of view of return to scale ration

Before evaluating decision-making units, we must first know the relationship between the ratio of changes in inputs and outputs of decision-making units. This ratio is called efficiency to scale. Determining the model for evaluating the decision-making units of a society depends on the efficiency to scale ratio of that society. Efficiency to scale is the effect of changing the amount of production factors on production. Three types of returns to scale are defined as follows:

- Constant return to scale ratio
- Decreasing return to scale ratio
- Increasing return to scale ratio

In CCR models, constant return to scale ratio, and in BCC models, variable return to scale ratio is considered.

2.3. Classification from a dualistic point of view

DEA models are generally presented in the following two mathematical forms

- Envelopment: which has more computational complexity but has more analytical ability while calculating unit efficiency and can help the decision maker in target setting.
- Multiplicative: It has less computational complexity and calculates the importance (weight) of inputs and outputs.

3. Types of mathematical models for data envelopment analysis

The mathematical form of data envelopment analysis models in the framework of classification is presented in Tables 1-3. Considering that the results obtained from input-oriented and output-oriented CCR models are equal to each other, in this research only the input-oriented CCR model is used, but due to the difference in the efficiency obtained in input-oriented and output-oriented BCC models, both of these models have been used in this research.

3.1. Research variables

It is very important to select the correct variables and check their influence to evaluate the performance through the proposed model. The input variables of this research include the cost price, current liabilities and financial expenses, which current liabilities are used in the calculation of liquidity ratios and the cost price is used in the calculation of activity ratios and profitability ratios. Moreover, the output variables of this research include sales, profit, and current assets, which are used among other factors in financial statements. This information is reported in reference [14], which was published in 1997. Information about the inputs and outputs used in this research can be seen in Table 4.

4. Implementation

To evaluate cement companies according to the mentioned inputs and outputs, these models are written in LINGO 18 software and the evaluation results by four DEA models on cement companies active in the stock market can be seen in Table 5 and Figure 2. As it is clear in Table 5, in input-oriented BCC, output-oriented BCC and additive methods, 11 companies out of the total of 22 active cement companies in the stock market have achieved their maximum efficiency of 1. While according to the CCR method, seven companies have achieved this level of efficiency, which can mean that the CCR method has provided more suitable values for performance evaluation.

5. Results and Conclusion

The cement market plays a significant role in the economic growth and development of the construction industry. With the increasing tendency of people to invest in the stock market, it has become essential to evaluate the performance of companies involved in cement production. In this article, the performance of 22 active cement production companies was examined using different models of data envelopment analysis. By employing four input-oriented BCC, output-oriented BCC, additive method, and CCR method, the performance of these companies was evaluated. The results of this research are significant and can influence the decisions of investors and owners in the cement industry. By evaluating the performance of these companies, investors and owners can make informed decisions and optimize their investments. The presented models of data envelopment analysis can also be applied in the evaluation of the performance of other industries, providing valuable insights for investors and decision-makers.

Table 1- Input-oriented and output-oriented models of CCR in multiplicative and additive forms

Input-oriented model-multiplicative-CCR	Input-oriented model-additive-CCR
$\max \sum_r u_r y_{rp} = \theta_p$ $s.t.$ $\sum_i v_i x_{ip} = 1$ $\sum_r u_r y_{rj} - \sum_i v_i x_{ij} \le 0 \quad \forall j$ $u_r, v_i \ge \varepsilon$	$\min \theta_p - \varepsilon\left[\sum_i s_i^- + \sum_r s_r^+\right]$ $s.t.$ $\sum_j \lambda_j x_{ij} + s_i^- = \theta_p x_{ip} \quad \forall i$ $\sum_j \lambda_j y_{rj} - s_r^+ = y_{rp} \quad \forall r$ $\lambda_j, s_i^-, s_r^+ \ge 0, \theta_p \;\; free$
Output-oriented model-multiplicative-CCR	Output-oriented model-additive-CCR
$\min \sum_i v_i x_{ip} = \phi_p$ $s.t$ $\sum_r u_r y_{rp} = 1$ $\sum_i v_i x_{ij} - \sum_r u_r y_{rj} \ge 0 \quad \forall j$ $u_r, v_i \ge \varepsilon$	$\max \phi_p + \varepsilon\left[\sum_i s_i^- + \sum_r s_r^+\right]$ $s.t.$ $\sum_j \lambda_j x_{ij} + s_i^- = x_{ip} \quad \forall i$ $\sum_j \lambda_j y_{rj} - s_r^+ = \phi_p y_{rp} \quad \forall r$ $\lambda_j, s_i^-, s_r^+ \ge 0, \phi_p \;\; free$

Table 2- Input-oriented and output-oriented models of BCC in multiplicative and additive forms

Input-oriented model-multiplicative-BCC	Input-oriented model-additive-BCC
$\max \sum_r u_r y_{rp} + u'_p = \theta_p$ $s.t$ $\sum_r u_r y_{rj} - \sum_i v_i x_{ij} + u'_p \le 0 \quad \forall j$ $u_r, v_i \ge \varepsilon, u'_p \;\; free \;\; \sum_i v_i x_{ip} = 1$	$\min \theta_p - \varepsilon\left[\sum_i s_i^- + \sum_r s_r^+\right]$ $s.t.$ $\sum_j \lambda_j x_{ij} + s_i^- = \theta_p x_{ip} \quad \forall i$ $\sum_j \lambda_j y_{rj} - s_r^+ = y_{rp} \quad \forall r$ $\sum_j \lambda_j = 1$ $\lambda_j, s_i^-, s_r^+ \ge 0, \theta_p \;\; free$
Output-oriented model-multiplicative-BCC	Output-oriented model-additive-BCC

<table>
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$$\min \sum_i v_i x_{ip} + v'_p = \phi_p$$
$$s.t$$
$$\sum_r u_r y_{rp} = 1$$
$$\sum_i v_i x_{ij} - \sum_r u_r y_{rj} + v'_p \geq 0 \quad \forall j$$
$$u_r, v_i \geq \varepsilon, v'_p \quad free$$

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$$\max \phi_p + \varepsilon \left[\sum_i s_i^- + \sum_r s_r^+ \right]$$
$$s.t.$$
$$\sum_j \lambda_j x_{ij} + s_i^- = x_{ip} \quad \forall i$$
$$\sum_j \lambda_j y_{rj} - s_r^+ = \phi_p y_{rp} \quad \forall r$$
$$\sum_j \lambda_j = 1$$
$$\lambda_j, s_i^-, s_r^+ \geq 0, \phi_p \quad free$$

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Table 3- Additive models in multiplicative and envelopment forms

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<th>- Multiplicative modelAdditive</th>
<th>Additive-Envelopment Model</th>
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$$\max \sum_r u_r y_{rp} - \sum_i v_i x_{ip} + u'_p = w_p$$
$$s.t$$
$$\sum_r u_r y_{rj} - \sum_i v_i x_{ij} + u'_p \leq 0 \quad \forall j$$
$$u_r, v_i \geq 1, u'_p \quad free$$

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$$\min Z_p = -\sum_i s_i^- - \sum_r s_r^+$$
$$s.t.$$
$$\sum_j \lambda_j x_{ij} + s_i^- = x_{ip} \quad \forall i$$
$$\sum_j \lambda_j y_{rj} - s_r^+ = y_{rp} \quad \forall r$$
$$\sum_j \lambda_j = 1$$
$$\lambda_j, s_i^-, s_r^+ \geq 0$$

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Table 4- Input and output variables of listed cement companies in stock exchange

Item No.	Company Name	Close price	Current liabilities	Financial expen diture s	Sales	Net profit	Current Assets
1	Abiek Cement Company	1672322	577732	433447	2683691	452443	1971571
2	Urumieh Cement Company	1052050	760526	72099	1759706	567507	719247
3	Isfahan Cement Company	496884	280373	3334	789525	232498	487757
4	Bojnord Cement Company	908525	923489	95943	1475240	378731	990736
5	Behbahan Cement Company	514061	183148	5417	1086622	510205	421506

6	Tehran Cement Company	2106014	2607008	139226	2901442	1620245	2101924
7	Kash Cement Company	528090	354646	11665	827498	240794	496777
8	Khazar Cement Company	672629	366898	26621	941221	175879	319615
9	Khouzestan Cement Company	1562305	774959	139062	2373906	597224	1413250
10	Darab Cement Company	625843	407718	17340	889429	354314	578604
11	Doroud Cement Company	672833	645746	52931	972748	145968	526259
12	Shahrood Cement Company	847968	668008	65169	1486996	481946	777528
13	Shomal Cement Company	708821	883482	32824	949587	462732	762782
14	Soufi Cement Company	1087826	1205628	135973	1721924	33674	536937
15	Gharb Cement Company	676973	370682	42840	1211377	438969	548417
16	Fars Cement Company	532374	247057	14750	705993	131166	301187
17	Fars-noo Cement Company	643243	267772	18755	1115190	429114	469406
18	Ghaen Cement Company	363770	254429	5156	566976	237491	358278
19	Karoon Cement Company	459349	599355	218	827877	297121	414428
20	Kerman Cement Company	601810	396355	10611	904133	346958	513317
21	Mazandaran Cement Company	1487091	799835	79736	2837297	1044701	1163055
22	Neyriz Cement Company	186689	87858	3262	352271	139432	191109

Table 5- The results of the evaluation of the efficiencies of listed cement companies in the stock market

Item No.	name of organization	Additive	Output oriented BCC	Input oriented BCC	CCR
1	Abiek Cement Company	1	1	1	1
2	Urumieh Cement Company	0.8195	0.8584	0.8479	0.8041
3	Isfahan Cement Company	1	1	1	1
4	Bojnord Cement Company	1	1	1	1
5	Behbahan Cement Company	1	1	1	1
6	Tehran Cement Company	1	1	1	0.9958
7	Kash Cement Company	0.9387	0.9552	0.9531	0.9149
8	Khazar Cement Company	0.57	0.6861	0.6679	0.662
9	Khouzestan Cement Company	1	1	1	0.8454
10	Darab Cement Company	0.9266	0.9403	0.9297	0.8932
11	Doroud Cement Company	0.6457	0.792	0.7875	0.7654
12	Shahrood Cement Company	0.9451	0.9651	0.9615	0.9627
13	Shomal Cement Company	1	1	1	1
14	Soufi Cement Company	0.5894	0.8126	0.7972	0.7488
15	Gharb Cement Company	0.8824	0.9441	0.898	0.8892
16	Fars Cement Company	0.5464	0.6523	0.6469	0.6462
17	Fars-noo Cement Company	0.8309	0.8715	0.8475	0.8412
18	Ghaen Cement Company	1	1	1	0.9756
19	Karoon Cement Company	1	1	1	1
20	Kerman Cement Company	0.9275	0.9318	0.8905	0.8365
21	Mazandaran Cement Company	1	1	1	0.9181
22	Neyriz Cement Company	1	1	1	1

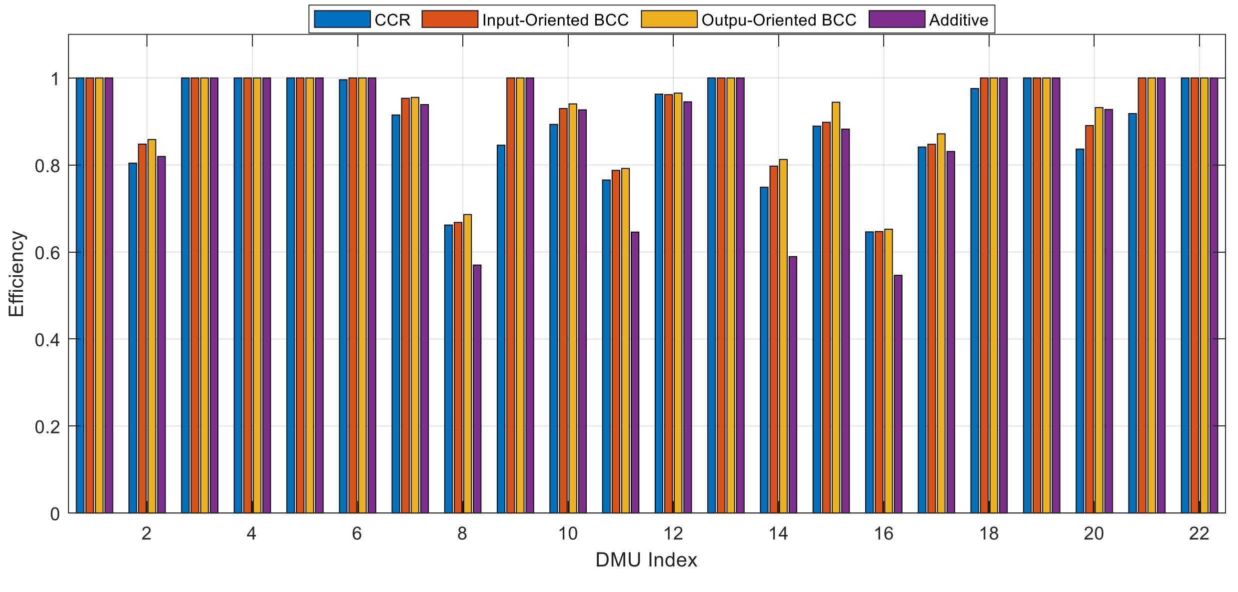

Figure 2. The graphic results of evaluation of the efficiency of cement companies

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