Available online at http://ijdea.srbiau.ac.ir

Int. J. Data Envelopment Analysis (ISSN 2345-458X)

Vol.9, No.1, Year 2021 Article ID IJDEA-00422, pages14
Research Article

International Journal of Data Envelopment Analysis

Science and Research Branch (IAU)

Analysis of the performance of symbols of cement companies in the Tehran Stock Exchange, using data envelopment analysis based on integer indices

M. R. Shahriari[*]
Associate Professor, Department of Industrial Management, South Tehran Branch, Islamic Azad University, Tehran, Iran

Received 21 September 2020, Accepted 14 December 2020

Abstract
Considering the important role of the construction industry in the form of one of the expandable industries for economic growth, increasing GDP and job creation, as well as the great relationship between construction and its required tools, such as machinery, materials Construction, tools, etc., scientific study of each of these sectors, provides the possibility of better development in the construction industry, the results of which can suggest solutions to boost national production. Since cement as an underlying commodity is a widely used material in construction and concreting, and investing in cement companies can play an important role in improving their process, so in this The paper examines the efficiency of symbols of cement companies in the Tehran Stock Exchange using data envelopment analysis. Due to the fact that some of the indicators extracted from the stock market are usually integers, in this study, a data envelopment analysis model in mixed integer programming class (MILP) has been used, which is capable of processing continuous data. And has the integer together. The results presented in this article can be effective on managers' decisions to increase capital or on how to invest in cement companies.

Keywords: Data Envelopment Analysis, Cement, Capital Market, Performance Evaluation

[*] Corresponding author: Email mohammadrezashahriyari75@gmail.com

1. Introduction

Given that in an urban social life, the first need of every family is to have a shelter to live in, so this has led to a significant growth in demand for housing, which results in the prosperity of the construction industry, as one It is an important component of GDP and related industries.

One of the most important and widely used products needed in buildings is cement, which as a basic industry, has a key role in the development of socio-economic infrastructure of any country. So that not only the housing market in the country is mainly affected by the price of this product and the need for proper management in its production is felt, but even in order to implement the policies of the resistance economy, it can be through The development of this industry, in line with non-oil exports, was an important factor in foreign exchange, creating sustainable employment, preventing the sale of raw materials and optimal use of the country's mines. Therefore, the evaluation of cement companies with the aim of increasing the efficiency of this industry, can help those involved in improving their situation. Extensive research has been done in this direction to guide investors and industry experts in the right direction.

Ogioni et al. (2011) Using data envelopment analysis as well as a directional distance performance approach, for models with multiple production inputs and desirable, an environmentally friendly criterion for 21 prototypes of the cement industry in many Presented by countries. To understand the impact of this research on the environment, they analyzed cases in which carbon dioxide emissions could be considered as an undesirable input or output. The results of their research showed that countries where the cement industry operates in high-tech furnaces and adopts alternative fuels and raw materials in their production processes are very economically efficient, which has a comparative advantage. It places countries that are highly motivated to modernize their production processes [1].

Taghizadeh and Pourrabi (2013) Using data envelopment analysis method to evaluate the energy efficiency of companies operating in the cement industry using an average of eight years for input variables including fuel costs (diesel, fuel oil and ... , Natural gas costs, electricity and water costs as well as intended outputs including net sales, increase (decrease) in inventory of manufactured goods, increase (decrease) in inventory of manufactured goods and profit from investment [2] Afshar Kazemi et al. (2015), through data envelopment analysis, evaluated the efficiency of 26 companies active in the production and export of cement. [3] Seyed Hosseini and Darvish Motavi (2016) evaluated the performance of the chain They provided cement and by calculating the efficiency of the whole chain, evaluated the efficiency of the members of the chain and finally, obtained the type of return per scale. [4] Valizadeh Oghani et al. (2017) evaluated the relative efficiency of companies. Cement, a member of the Iran Stock Exchange, used management data as an indicator to measure ability, and they used data from 2011 to 2015. To this end, they initially Using the data envelopment analysis method, they examined the performance of each company and used the Anderson-Petersen method to rank the units. Then, through a regression model, the management index of each unit was estimated with a suitable pattern [5]. Ozakan and Olutas (2017) analyzed the cement production facilities in Turkey with respect to unfavorable outputs. In this study, 11 cement production centers that are members of the Turkish Cement Producers Association have been considered. They defined DEA models for existing common inputs and outputs and proposed unwanted inputs and outputs. There is a significant difference when adverse factors are considered and weights are determined [6].

In the current situation, the most important goal that is among the priorities of all societies is economic growth and development, and in fact, economic growth is the main factor in the development of a country. Under these circumstances, investing in a country's stock market in the right context can improve that country's economic situation. Therefore, studying the parameters and components affecting this market can provide more appropriate solutions for both investors and industry owners to result in economic prosperity. In fact, capital markets play an undeniable role in the creation and movement of capital in global economies and are able to provide the necessary financial capital to companies and factories to design, develop and Ensure the growth of their products.

Khalili and Safaei (2015) presented a hierarchical and multi-criteria model in accordance with the opinions of financial experts and evaluated the financial performance of companies in the automotive production group of the Tehran Stock Exchange. They used fuzzy hierarchical analysis to determine the weight of the criteria and to simultaneously rank the companies based on the best financial performance using the three methods of VIKOR, ARAS and COPRAS [7]. Khajavi et al. (2015) evaluated the financial performance and ranking of pharmaceutical companies, basic metals group and automotive group and manufacturing parts of Tehran Stock Exchange using a combined fuzzy-AHP-VIKOR model [8].

Mahlavat et al. (2018) presented a multi-purpose portfolio selection model with five objective functions: maximizing efficiency, agility, efficiency, minimizing risk and elongation. Their portfolio returns were based on the performance of their assets, which was measured using data envelopment analysis for six criteria. In their study, all objectives, including DEA scores, were modeled using fuzzy numbers with interval values to provide the desired upper and lower bounds for satisfaction [9]. Also, Ms. Mohammadi and Heidari (2015), using the improved method of combining data envelopment analysis and hierarchical analysis process, proceeded to rank the cement companies active in the stock market and consider the influential factors and elements and compare the results with The least error was obtained [10].

Therefore, considering the importance of the cement industry in the development of construction and also considering the improvement of the capital market on improving the business environment of the country, in this study we intend to use the efficiency of symbols of cement companies in the Tehran Stock Exchange using Consider data envelopment analysis.

In this study, our focus is on using data envelopment analysis to evaluate the performance of cement companies in Iran. DEA uses linear programming to determine the relative effects of similar sets of DMUs. A DMU is considered efficient when no other DMU has produced more outputs using equal or less inputs. The DEA extends the usual performance evaluation from the ratio of one input to one output to the ratio of multiple inputs to multiple outputs using the ratio of the weight of the outputs to the weight of the outputs. Score 1 applies to previously efficient DMUs.

Charans et al. [11] generally present the initial DEA model as the Karen, Cooper, and Rods model (CCR).

Lewis and Sexton [12] The DEA does not consider any hypotheses regarding the internal performance of the DMU. Rather, the DEA treats each DMU as a black box that considers only the inputs consumed and the output products produced by each DMU. This view is often appropriate and sufficient. For example, the black box approach would suffice if the purpose of evaluating is to identify inefficient DMUs and evaluate their inefficiency. However, such an approach does not provide a resource-based approach and cannot be a process-based guide for DMU managers to help them improve the performance of DMUs.

Many production systems have a network structure in which the DMU production process has subset processes, so the intermediate products are the output of the subset processes and will be the input of other subset processes.

With this in mind, Farr and Kraskov in [13] and [14] present the DEA framework based on the actual production approach of Sheffard and Farr [15]. This structure is designed to test the performance of the DMU. In recent years, DEA network models have been proposed by many researchers; For example, Sexton and Wolves [16], Lewis and Sexton [12], Farr et al. [17], Cao and Huang [18], Cook et al. [19]. In these studies, efficiencies have been investigated using the radial model.

Cooper et al. [20] The DEA typically assumes that generating more output than less input is a measure of efficiency. Although in the presence of undesirable outputs DMUs have better or better outputs and less undesirable outputs than fewer inputs, they should be considered efficient.

In the case of adverse outputs, progressive work in various fields can be proposed in Pittman [21], Yasavarang and Klein [22], Jahan Shahlu et al. [23] four strategies for dealing with adverse factors in DEA models:

The first strategy is to simply deny the undesirable factors. The second strategy considers undesirable outputs as inputs and undesirable inputs as outputs. The third strategy considers undesirable outputs in the nonlinear DEA model. The fourth strategy is to

use the transfer reduction function for undesirable outputs and to use compatible variables as outputs.
To solve the problem of undesirable outputs, Seyford and Zhou [24] proposed a DEA model to improve performance by increasing the desired outputs and reducing the undesirable outputs.
Amir Teymouri et al. [25] extended the standard CCR model to a similar model to the DEA, which determines relative efficiency by increasing undesirable inputs and decreasing undesirable outputs.
Korhonen and Luptakik used the DEA [26] to measure the environmental performance of twenty-four coal in a European country. They considered direct production emissions as inputs that were used to increase desired outputs and reduce contaminants and inputs. Farzipour Sain presented a model for selecting 3PL providers in the presence of several dual agents.
Cook and Zhou [27] proposed a new model for classifying inputs and outputs in the DEA. Although their model required many variables and constraints.
Tolo [28] presented an edition of Cook and Zhou. The results of their studies increased the dissociation power of Cook and Zhou models.
Farzipour Sain [29] proposed a method for selecting the best supplier in the presence of constraints and dual factors.
Hatefi and Julai [30] proposed a new model based on the performance of the Translag output range for classifying inputs and outputs. They evaluated the performance of DMUs with flexible evaluations.
Farzipour Sain [31] introduced a model for supplier selection (3PL in the presence of inaccurate data and dual factors).

2- Data envelopment analysis based on integer indices

Data envelopment analysis is a powerful mathematical method that uses linear programming to determine the relative efficiency of a set of homogeneous decision units or DMUs. An efficient DMU is considered when no other DMU can produce more efficient output, when it uses the same or even less inputs. Originally the first known DEA model was introduced by Charles, Cooper and Rhodes under the CCR model. The DEA makes no assumptions about the internal performance of a DMU. That is, the DEA treats each DMU as a "black box" that considers only the input and output consumed by each DMU. This view is often appropriate and sufficient. For example, if the purpose of the analysis is to identify inefficient DMUs and assess their degree of inefficiency, then the "black box" is a good approach.
Data Envelopment Analysis (DEA) is a mathematical programming approach to examining the performance of decision units (DMUs) that covers multiple inputs and outputs. Typical DEA models consider real-value inputs and outputs. However, there are many cases in which some inputs or outputs should take only the correct values. Although rounding performance goals to the nearest integer does not necessarily make much of a difference

for large decision-making units, it can be problematic for small decision-making units. Naturally, data envelopment analysis requires contrast to data with the correct value when definitive and sequential data is used, but limiting all indicators can be even when the input and output variables They are defined on a distance or relative scale.

Conventional data envelopment analysis method is based on the assumption that input and output variables are continuous. However, in many real management cases, some inputs or outputs get only the correct values. Simply rounding the optimal points to the nearest integer can lead to misleading answers and performance evaluations. Conventional data envelopment analysis (DEA) models assume inputs and outputs with real value. In many cases, some inputs or outputs can only get the correct values. In some cases, rounding the DEA response to the nearest total can lead to misdiagnosis of performance and performance goals. This article generalizes the basics for DEA in integer data, we present a complex integer linear programming to calculate the efficiency score.

Lozano and Villa (2006) were the first to investigate this issue at a more general level and proposed a DEA model with mixed integer linear programming (MILP) to ensure the need for integer-based computational objectives. [32]. Then Kyuzmanen and Kazemi Matin (2009) by eliminating the weaknesses of the model [33], have presented a more complete model for evaluating the performance of decision-making units based on integer indices, which in this study to evaluate the efficiency of the company We use it in commercial production. The proposed model can be presented in the form of relations (1) [33].

$$
\begin{aligned}
& EFF\left(x_o, y_o\right) = \\
& \min\ \theta - \varepsilon\left(\sum_{r=1}^{s} s_r^{+} + \sum_{i=1}^{m} s_i^{-} + \sum_{r=1}^{p} s_i^{I}\right) \\
& s.t. \\
& y_{ro} + s_r^{+} = \sum_{j=1}^{n} y_{rj}\lambda_j \quad r \in O \\
& \theta x_{io} - s_i^{-} = \sum_{j=1}^{n} x_{ij}\lambda_j \quad i \in I^{NI} \qquad\qquad (1) \\
& \tilde{x}_i - s_i^{-} = \sum_{j=1}^{n} x_{ij}\lambda_j \quad i \in I^{I} \\
& \theta x_{io} - s_i^{I} = \tilde{x}_i \quad i \in I^{I} \\
& \tilde{x}_i \in \text{int}\,eger \quad i \in I^{I} \\
& \lambda_j \geq 0 \quad j \in J \\
& s_r^{+} \geq 0,\ s_i^{-} \geq 0,\ s_j^{I} \geq 0, r \in O, i \in I, j \in I^{I}
\end{aligned}
$$

The above model is an input-driven data envelopment analysis model whose return on scale is considered constant (CRS). Given that in the investment process of cement companies, the decision maker can by applying changes to the inputs, it affects the obtained outputs, so in this research, an input-driven data envelopment analysis model has been used.

2-1 Research variables

In order to evaluate the performance through the proposed model, selecting the appropriate criterion is of great importance, which can be based on the type of industry, market, perspective, organizations, organs, etc. In order to evaluate the efficiency and ranking of companies operating in the stock market, it should be noted that the correct choice of variables and their impact is very important.

2-2 Input variables

In this study, criteria for ranking cement companies have been used, which are the main factors in the financial ratios of those companies, so that the resulting ranking has good results. Therefore, the input variables of this study include cost, current liabilities and financial expenses, which are current liabilities in calculating liquidity ratios and cost in calculating activity ratios and profitability ratios. Have been used [10].

It is noteworthy that in this study, to calculate the amount of current debts, the amount of debts is divided by 100 thousand and the correct component is taken from it. Therefore, this input variable is an integer.

2-3 Output variables

The output variables of this study include sales, profits and current assets, which are used among other factors in the financial statements. Sales are one of the main pillars of calculating the ratio of activity and profit is necessary to calculate the ratio of profitability. In addition, current assets are also used in ratios [10].

Information about the inputs and outputs used in this research can be seen in Table 1.

3- Implementation

To implement the above model to evaluate cement companies in accordance with the above inputs and outputs, this model has been overwritten in LINGO 18 software.

After implementing the proposed model, the results of the ranking of cement companies active in the stock exchange are given in Table 2. As shown in this table, the companies Abik Cement, Isfahan Cement, Behbahan Cement, North Cement, Karun Cement and Neyriz Cement have reached maximum efficiency and, as a result, have higher attractiveness for capital. They will have depositors.

As it is clear from the results, the efficiency of six cement companies is classified as efficient companies and sixteen other companies are considered as inefficient companies. Analyzing the performance of different companies in different fields using data envelopment analysis has the advantage that it is possible to introduce specific work models for inefficient units. For example, according to the information in Table 3, Urmia Cement Company has been identified as an inefficient company. For this company, Behbahan Cement and Neyriz Cement companies have been identified as efficient models. Similarly, for Bojnourd Cement Company, Abek, Shomal and Neyriz Cement companies have been identified as efficient models.

4- Result

Due to the current economic situation in the country, the interest in investing in the stock market as one of the target markets to maintain the value of money and profitability for the audience has reached its maximum. Therefore, in recent years, we have witnessed an unprecedented emission of liquidity entering the stock market. On the other hand, considering the fundamental role of the cement industry as one of the basic industries in the development of socio-economic infrastructure of any country, especially in the current housing crisis in Iran, this market is one of the attractive markets to attract capital. Cash has been exchanged on the stock exchange. Therefore, this article evaluated the performance of 22 companies active in the field of cement production and calculated the efficiency of these companies through a data envelopment analysis model in the mixed integer planning class. Obviously, the results presented in this article can be effective in correcting the decisions of managers or investors in cement companies.

Table 1- Input and output variables of cement companies active in the stock exchange

	name of Company	Cost of	Current liabilities	financial costs	Sale	Net profit	Current assets
1	Abik Cement Company	1672322	5	433447	2683691	452443	1971571
2	Urmia Cement Company	1052050	7	72099	1759706	567507	719247
3	Isfahan Cement Company	496884	2	3334	789525	232498	487757
4	Bojnourd Cement Company	908525	9	95943	1475240	378731	990736
5	Behbahan Cement Company	514061	1	5417	1086622	510205	421506
6	Tehran Cement Company	2106014	26	139226	2901442	1620245	2101924
7	Khash Cement Company	528090	3	11665	827498	240794	496777
8	Cement Company Khazar	672629	3	26621	941221	175879	319615
9	Khuzestan Cement Company	1562305	7	139062	2373906	597224	1413250
10	Darab Cement Company	625843	4	17340	889429	354314	578604
11	Doroud Cement Company	672833	6	52931	972748	145968	526259
12	Shahroud Cement Company	847968	6	65169	1486996	481946	777528
13	Shomal Cement Company	708821	8	32824	949587	462732	762782
14	Sufi Cement Company	1087826	12	135973	1721924	33674	536937
15	Gharb Cement Company	676973	3	42840	1211377	438969	548417
16	Fars Cement Company	532374	2	14750	705993	131166	301187
17	Farsnov Cement Company	643243	2	18755	1115190	429114	469406
18	Ghaen Cement Company	363770	2	5156	566976	237491	358278
19	Karun Cement Company	459349	5	218	827877	297121	414428
20	Kerman Cement Company	601810	3	10611	904133	346958	513317
21	Mazandaran Cement Company	1487091	7	79736	2837297	1044701	1163055
22	Neyriz White Cement Company	186689	0	3262	352271	139432	191109

Table 2 - Results of performance evaluation of cement companies active in the stock market

	name of Company	efficiency
1	Abik Cement Company	1
2	Urmia Cement Company	0.8041134
3	Isfahan Cement Company	1
4	Bojnourd Cement Company	0.9996774
5	Behbahan Cement Company	1
6	Tehran Cement Company	0.9957532
7	Khash Cement Company	0.9114718
8	Khazar Cement Company	0.6619912
9	Khuzestan Cement Company	0.8453919
10	Darab Cement Company	0.8870067
11	Doroud Cement Company	0.7653877
12	Shahroud Cement Company	0.9166767
13	Shomal Cement Company	1
14	Sufi Cement Company	0.7488429
15	Gharb Cement Company	0.8892033
16	Fars Cement Company	0.6462497
17	Farsnov Cement Company	0.8412393
18	Ghaen Cement Company	0.9756110
19	Karun Cement Company	1
20	Kerman Cement Company	0.8329928
21	Mazandaran Cement Company	0.9180673
22	Neyriz White Cement Company	1

Table 3: Results obtained from solving the CRS and input-driven data envelopment analysis model, based on discrete data

	name of Company	λ_1	λ_3	λ_5	λ_{13}	λ_{19}	λ_{22}
1	Abik Cement Company	1	0	0	0	0	0
2	Urmia Cement Company	0	0	1.401273	0	0	0.6729252
3	Isfahan Cement Company	0	1	0	0	0	0
4	Bojnourd Cement Company	0.1778615	0	0	0.3985655	0	1.758425
5	Behbahan Cement Company	0	0	1	0	0	0
6	Tehran Cement Company	0	0	0.4277435	0	0	10.05514
7	Khash Cement Company	0	0	0	0.1087109	0	2.165541
8	Cement Khazar Company	0	0	0.8661899	0	0	0
9	Khuzestan Cement Company	0.2326312	0	0	0.0219506	0	4.907448
10	Darab Cement Company	0	0	0	0.2779519	0	1.918210
11	Doroud Cement Company	0	0	0.0087043	0	0	2.734513
12	Shahroud Cement Company	0	0	0.1736726	0	0	3.685457
13	Shomal Cement Company	0	0	0	1	0	0
14	Sufi Cement Company	0	0	1.584658	0	0	0
15	Gharb Cement Company	0	0	0.6474206	0	0	1.441718
16	Fars Cement Company	0	0	0.4870345	0	0	0.5018027
17	Farsnov Cement Company	0	0	0.8071242	0	0	0.6760451
18	Ghaen Cement Company	0	0.1930303	0	0	0.0177407	1.343599
19	Karun Cement Company	0	0	0	0	1	0
20	Kerman Cement Company	0	0	0	0.0038973	0	2.670435
21	Mazandaran Cement Company	0	0	2.239353	0	0	1.146751
22	Neyriz White Cement Company	0	0	0	0	0	1

References

[1] Mehlawat, Mukesh Kumar, Arun Kumar, Sanjay Yadav, and Wei Chen. "Data envelopment analysis based fuzzy multi-objective portfolio selection model involving higher moments." Information Sciences 460 (2018): 128-150.

[2] Taghizadeh. H, M. Pouree, M. Razavian. “Evaluation of energy efficiency of eligible companies in Tehran Stock Exchange (Case study: Cement industry)”. Monetary Economics Bi-Quarterly, (2014). 20 (6). pp 106-120.

[3] Afshar Kazemi. M.A, A. Fadavi, M.H Razavian. “Evaluating the efficiency of the country's cement industry using data envelopment analysis technique”. Cement Technology Monthly. 2015. 84. 21-26.

[4] Seyed Hosseini. S.M, M.H Darvish Motevally, “Evaluate the performance of the cement industry supply chain using data envelopment analysis.” Journal of Quantitative Studies in Management. 2016. 7 (2). 61-64.

[5] Valizadeh Oghani. A, N. Feghhi Farahmand, M.H Farzin. “Evaluation of management efficiency in Iran's cement industry using data envelopment analysis technique”. Sanandaj Azad University Industrial Management Quarterly. 2017. 42. 119-131.

[6] Ozkan, N. Firat, and Berna Haktanirlar Ulutas. "Efficiency analysis of cement manufacturing facilities in Turkey considering undesirable outputs." Journal of Cleaner Production 156 (2017): 932-938.

[7] Khalili. S, S. Ghadikolaee. “Evaluating the financial performance of companies operating in the Tehran Stock Exchange”. Executive Management Quarterly. 2015. 7 (14). 53-71.

[8] Khajavi. S, H. Fattahi Nafchi, M.H. Ghadiran Arani. “Ranking and evaluation of financial performance of selected industries of Vikor Stock Exchange; Study - AHP - Tehran Stock Exchange Using Case Fuzzy Combined Model: Pharmaceutical, Basic Metals and Automotive Companies and Parts”. Accounting knowledge. 2015. 60(15). 25-46.

[9] Oggioni, G., R. Riccardi, and R. Toninelli. "Eco-efficiency of the world cement industry: a data envelopment analysis." Energy Policy 39, no. 5 (2011): 2842-2854.

[10] Khanmohammadi. M, H. Heidari. “Evaluation of efficiency and ranking of cement companies active in the stock exchange using the improved method of combining data envelopment analysis and hierarchical analysis process”. Journal of Operations Decision Making. 2018. 3(2). 138-150.

[11] Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. European journal of operational research, 2(6), 429-444.

[12] Lewis, H. F., & Sexton, T. R. (2004). Network DEA: efficiency analysis of organizations with complex internal

structure. Computers & Operations Research, 31(9), 1365-1410.

[13] Färe, R., & Grosskopf, S. (2000). Theory and application of directional distance functions. Journal of productivity analysis, 13(2), 93-103.

[14] Färe, R., Grosskopf, S., & Norris, M. (1997). Productivity growth, technical progress, and efficiency change in industrialized countries: reply. The American Economic Review, 87(5), 1040-1044.

[15] Shephard, R. W., & Färe, R. (1980). Dynamic theory of production correspondences (Vol. 50). Verlag Anton Hain.

[16] Sexton, T. R., & Lewis, H. F. (2003). Two-stage DEA: An application to major league baseball. Journal of Productivity Analysis, 19(2), 227-249.

[17] Färe, R., Grosskopf, S., & Whittaker, G. (2007). Network dea. Modeling data irregularities and structural complexities in data envelopment analysis, 209-240.

[18] Kao, C., & Hwang, S. N. (2010). Efficiency measurement for network systems: IT impact on firm performance. Decision Support Systems, 48(3), 437-446.

[19] Cook, W. D., Liang, L., & Zhu, J. (2010). Measuring performance of two-stage network structures by DEA: a review and future perspective. Omega, 38(6), 423-430.

[20] Cooper, W. W., Ruiz, J. L., & Sirvent, I. (2007). Choosing weights from alternative optimal solutions of dual multiplier models in DEA. European Journal of Operational Research, 180(1), 443-458.

[21] Pittman, R. W. (1983). Multilateral productivity comparisons with undesirable outputs. The Economic Journal, 93(372), 883-891.

[22] Yaisawarng, S., & Klein, J. D. (1994). The effects of sulfur dioxide controls on productivity change in the US electric power industry. The Review of Economics and Statistics, 447-460.

[23] Jahanshahloo, G. R., Lotfi, F. H., Shoja, N., Tohidi, G., & Razavyan, S. (2005). Undesirable inputs and outputs in DEA models. Applied Mathematics and Computation, 169(2), 917-925.

[24] Seiford, L. M., & Zhu, J. (2002). Modeling undesirable factors in efficiency evaluation. European journal of operational research, 142(1), 16-20.

[25] Amirteimoori, A., Kordrostami, S., & Sarparast, M. (2006). Modeling undesirable factors in data envelopment analysis. Applied Mathematics and Computation, 180(2), 444-452.

[26] Korhonen, P. J., & Luptacik, M. (2004). Eco-efficiency analysis of power plants: An extension of data envelopment analysis. European journal of operational research, 154(2), 437-446.

[27] Cook, W. D., & Zhu, J. (2007). Classifying inputs and outputs in data envelopment analysis. European Journal of Operational Research, 180(2), 692-699.

[28] Toloo, M. (2009). On classifying inputs and outputs in DEA: a revised model. European Journal of Operational Research, 198(1), 358-360.

[29] Saen, R. F. (2010). Developing a new data envelopment analysis methodology for supplier selection in the presence of both undesirable outputs and imprecise data. The International Journal of Advanced Manufacturing Technology, 51(9-12), 1243-1250.

[30] Hatefi, S. M., & Jolai, F. (2010). A new model for classifying inputs and outputs and evaluating the performance of DMUs based on translog output distance function. Applied Mathematical Modelling, 34(6), 1439-1449.

[31] Farzipoor Saen, R. (2011). A decision model for selecting the best entry modes via data envelopment analysis. International Journal of Applied Decision Sciences, 4(3), 213-229.

[32] Lozano, Sebastián, and Gabriel Villa. "Data envelopment analysis of integer-valued inputs and outputs." Computers & Operations Research 33, no. 10 (2006): 3004-3014.