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PERFORMANCE EVALUATION OPTIMIZATION MODEL WITH A HYBRID APPROACH OF NDEA-BSC AND STACKELBERG GAME THEORY IN THE PRESENCE OF BAD DATA

Abstract. *The evaluation of organisational performance and internal power is of the most significance for any organisation. The purpose of this paper is to present a hybrid approach using Network Data Envelopment Analysis (NDEA), BSC, and Game Theory to evaluate the performance of decision-making units. To evaluate the efficiency of each decision-making unit, the relationship between different departments within an organisation is modeled based on the BSC indicators (growth and learning perspective, internal processes perspective, customer perspective, and financial perspective). Also, the influence of each of the BSC indicators on the efficiency of the decision-making units is examined using Game Theory and Stackelberg Theory. Moreover, the indicators related to each aspect of the BSC are expressed as input/output to determine performance. The proposed model has been implemented in 15 different cement factories based on the information obtained in 2021. The results reveal that the customer perspective has the greatest impact on the performance of the entire organisation and plays a crucial leading role in the organisation. Among the followers, the perspective of internal processes that is influenced by the leader strategy (customer perspective) is ranked first, and the perspectives of growth, learning, and finance are ranked second, third, and fourth, respectively. This research facilitates managerial decision-making for the optimal allocation of resources to increase the performance and profitability of the organisation.*

Keywords*: Data Envelopment Analysis, Balanced Score Card, Game Theory, Stackelberg Theory, Efficiency*

JEL Classification: C44, C67, C72, D61

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1. Introduction

In today's competitive global economy, organisations are constantly evaluating their performance and that of their competitors for survival. With regard to technological advances and rising levels of expectations of customers and stakeholders of organisations, evaluation of performance leads to the growth and development of companies and organisations (Benbarka, 2007). A performance measurement system is defined as a comprehensive set of measures that quantify the effectiveness and efficiency of the activity.

At present, evaluating the efficiency of different sections of any organisation has become one of the major concerns of senior managers of organisations. How to measure efficiency on the one hand, and analysis and their value, on the other hand, have caused various methods to solve this problem to be provided. Efficiency analysis is carried out through a theoretical framework called Data Envelopment Analysis (DEA) (Charnes et al., 1978). This approach is able to measure the efficiency of units with multiple inputs and outputs, but it creates many problems for the decision-making of managers since the model looks at internal activities as a black box (Fare and Grossopf, 2000). To overcome this problem, the combination of DEA with BSC has been exploited. However, the BSC model also faces problems such as the inability to identify inefficient units, how to establish a relationship between different criteria, and so on. These problems can be solved by combining BSC with a Network Data Envelopment Analysis (NDEA) model. On the other hand, some of the units within the organisation affect the efficiency of other units. As the relationship between these units is investigated in the form of a network, some units play the role of leader and influence other units as followers. Therefore, in the hybrid model proposed in this study, three approaches of NDEA, BSC, and Stackelberg Game Theory were employed to evaluate all the goals of the companies and identify strengths and weaknesses. This model forces managers to take into account all operations (primary and secondary) in the organisation.

The cement industry as one of the processing industries in Iran is of particular importance and has been considered in terms of foreign exchange savings in the way of self-reliance. In this sense, the need to measure and make an economic comparison between the active units of this industry in the country is felt more than ever from a managerial point of view and from the perspective of productivity. A look at the indicators and financial statements of these units clearly illustrates the need to conduct research in connection with the evaluation of their efficiency. In this study, the division cement units of Fars and Khuzestan Holding (the greatest cement holding in the country) are examined in terms of efficiency with respect to BSC and the corporate strategy map and Game Theory.

Compared to conventional DEA models that operate using a black-box or a separation approach, network DEA (NDEA) arises due to its competence in evaluating performance without neglecting internal interactions within DMUs (Kao et al., 2017). Since DEA models look at internal processes as a black box and only exploit a model in which a number of inputs are converted into outputs, without taking into account the inputs and outputs in each of the internal processes, providing specific information about resources and inefficiencies within decision-making units (DMUs) would be difficult for managers of units. Hence, the innovation of the current study is that each decision-making unit is initially considered in the form of a BSC model with four networks and the relationships between input and output factors in each internal network are drawn from the view of experts. This relationship between input and output indicators in the BSC model as an NDEA has received less attention from researchers. Then, the influence of each of the BSC criteria on the efficiency of the whole decision-making unit is examined using Stackelberg Game Theory. Network DEA (NDEA), an extension of traditional DEA models, is a multistage architecture that allows for testing the efficiency of decision-making units (DMUs) (Cook et al., 2010).

Performance evaluation increases the efficiency and effectiveness of organisational programs and processes since it reveals the accuracy and correctness of decisions made by managers and how the organisation performs. Therefore, it is necessary for managers to direct their organisations according to organisational goals and evaluate their organisations regularly and continuously. Various performance appraisal models have been proposed so far; however, each of them has some advantages and disadvantages. As the DEA models do not pay attention to the internal processes in an organisation and consider them as a black box, it is difficult for the managers of DMUs to provide information about inefficiencies within the DMUs. Conventional DEA models tend to summarise general calculations for efficiency, which eliminates some important information about the organisation and hides it from the organisation's decision-makers. The same is true for BSC; one of the weaknesses of BSC is the lack of identification of the relationship between the various criteria in performance appraisal. Therefore, the proposed model seeks to mitigate the weakness of each aforementioned method through integrating network DEA, BSC and Game Theory methods to predict organisational performance compared to other organisations.

The proposed model attempts to evaluate all the objectives and functions of the organisation by combining BSC and NDEA, and then the inefficiency of the units within the organisation to be specified. While forcing senior managers to take into consideration all critical operational measures simultaneously, the proposed model also causes the optimisation of sub-functions and exhibits the impact of the inefficiency of each unit on the entire organisation.

2. Literature Review

Data Envelopment Analysis (DEA): The history of the DEA method goes back to the subject of Rhodes' dissertation under the guidance of *Charnes and Cooper*, which evaluated the performance of US public schools. Indeed, DEA is a non-parametric method to evaluate decision-making units that empirically estimate the efficiency boundary based on a set of observations. Rather than using statistical means that may not be applicable to a decision-making unit, DEA obtains the inefficiency of a particular unit by its comparison with similar units that have been identified to be efficient (Charnes et al., 1978).

Balanced Score Card (BSC): The Balanced Score Card (BSC), developed by Kaplan and Norton (1992) at Harvard Business School in 1992, is undoubtedly one of the most well-known and widely used frameworks proposed to measure performance in recent years. This model serves as a conceptual framework to transform the strategic goals of an organisation into a series of performance indicators that are distributed among four perspectives: financial perspective, customer perspective, internal processes perspective, and growth and learning perspective. While helping managers focus on their organisations through the prism of these four main perspectives, this model answers the following questions: How should an organisation appear to shareholders in order to be successful in its financial outputs? What path should the organisation take to reach the position of excellence in the eyes of customers and to meet their satisfaction? How does the organisation set its internal processes to be faced with the consent of shareholders and customers? And finally, how can the organisation strengthen the infrastructure of internal processes, which is the growth and excellence of employees, in order to achieve progress?

Game Theory: Game Theory is an approach to modeling and analysing strategic relationships, situations, and interactions between players to understand the most likely or best possible results (Matsumoto and Szidarovszky, 2016). Game Theory was proposed for the first time in 1921 by a French mathematician named Emile Borel. Game theory is a science that studies people's decisions in terms of interacting with others. In other words, Game Theory is the science for the study of conflicts and cooperation between rational actors. The main goal of Game Theory is to give an attitude and view according to which actors should behave wisely. Game Theory can be divided into two main branches: 1- non-cooperative games and 2- cooperative games (Rouse et al., 2002).

In non-cooperative games, it is assumed that the actors behave rationally and think only of their own interests and that there is no cooperation and agreement between them. However, in collaborative games, actors have the possibility of cooperation and collaboration together, and the main purpose of these games is to provide a way for fair distribution of profits from cooperation (Bauso, 2016).

Table 1 illustrates the classification of studies carried out in conjunction with evaluating the performance of organisations in recent years.

Table 1. A brief review of relevant studies

Author	**Year**	**BSC**	**DEA**		**DM**		**Game Theory**		
			DEA Classic	**Network DEA**	**AHP**	**DEMATEL**	**Non-Cooperative (Stackelberg)**	**Cooperative (Shapley Value)**	**Nash Bargaining**
Chen and Zhu	2020			*					
Omrani et al.	2019		*					*	
Lim and Zhu	2019			*					
An et al.	2019			*				*	
Basso et al.	2018	*		*					
Li et al.	2018			*			*		
Guo et al.	2017			*					
Jahangoshai and Shokry	2017	*		*					*
Rahiminezhad et al.	2016	*			*				
Kwon and Lee	2015			*					
Shafiee et al.	2014	*		*		*			
Kazemkhanlou and Ahadi	2012	*	*						
This Paper		*		*			*		

In addition to the ability to measure efficiency, the evaluation system should be in accordance with the growth and development of the organisation and meet its diverse and multiple dimensions. According to studies, it can be concluded that the BSC is one of the most comprehensive systems for evaluating the performance of organisations. By taking into account the goals, strategy and vision of the organisation, it measures its performance from four important managerial perspectives (financial, customer, internal processes, growth and learning). The DEA technique is also one of the most widely used methods to evaluate the efficiency of a finite number of homogeneous decision-making units in multiple inputs and outputs. Hence, the BSC method as a management tool is primarily employed to determine the key performance indicators of the organisation and has little ability to rank and evaluate the performance of several similar and homogeneous organisations. On the other hand, the strategy, goals, and vision of the organisation are not intended in specifying the input and output parameters of DEA models, and more concentration is on financial factors. Therefore, the combination of these two methods can cover the weaknesses of the two models and offer a comprehensive model. From the third perspective, it is essential to note that some units have a greater impact on the final output in organisations and can play a role as a leader in the organisation.

Examining the models presented by the researchers in connection with the combination of DEA and BSC methods represents that measuring and evaluating the indicators of the two models has not been considered. Besides, there has been no discussion about the inclusion of BSC indicators in these models in the combined models of DEA and Game Theory. Thus, this investigation has summarily exploited three different tools to evaluate the performance of organisations. This combination, as presented in this study, has not been evaluated in the research literature.

3. Methodology and Modeling

The main objective of this study was to evaluate the performance of cement companies under Fars and Khuzestan Holding by the integration of the NDEA, BSC, and Game Theory approaches. This is an applied and descriptive study by purpose and data collection method and quantitative and modeling in terms of nature. In terms of thematic, temporal, and spatial scopes, the present study is thematically in the realm of performance management issues and in the subgroup of performance evaluation. In terms of time, this is a cross-sectional study related to 2021. In terms of location, the scope of this research is the sub-holding companies of Fars and Khuzestan, the largest cement holding in the country. Taking into account that all subsidiary cement companies of Fars and Khuzestan Holding are intended as samples of this research, so the sampling method is not raised. The criteria evaluated in this study were initially obtained through a library study by studying scientific books and articles and interviewing experts in the field of the cement industry. Ultimately, the relevant data was extracted from the audited financial statements for 2021 from the CODAL site. Therefore, the research variables are prepared and set as described in Table 2.

Table 2. Research Variables

Variables	Unit	Calculation formula
Training costs	Hundred dollars	Costs of holding training courses
Direct wages	Hundred dollars	Direct wages of the organisation
Direct consumption materials	Hundred dollars	Direct consumption materials of the organisation
The amount of capital	Hundred dollars	The amount of capital of the organisation
Per capita education	Hundred dollars	Number of training hours / number of employees
Employee Satisfaction Index	Percent	Employee satisfaction survey

Table 2. Research Variables

Variables	Unit	Calculation formula
Production volume	Ton	Production rate during the period
Product quality	Kg/cm2	7-day compressive strength of cement type 2
Environmental pollutants	Mg / cubic meter	The amount of electro-filter outgoing particles and mills
Total market share	Percent	Dollars sales volume / total market size defined in Dollars
Company export share	Percent	Export sales volume / total sales volume
Customer satisfaction level	Percent	Customer satisfaction survey
Sales	Hundred dollars	Net sales during the period
Quality of earnings	Percent	Operating cash flow / operating profit

After data collection for 15 cement companies, the research model is designed on the basis of NDEA and BSC with the opinion of experts in this area.

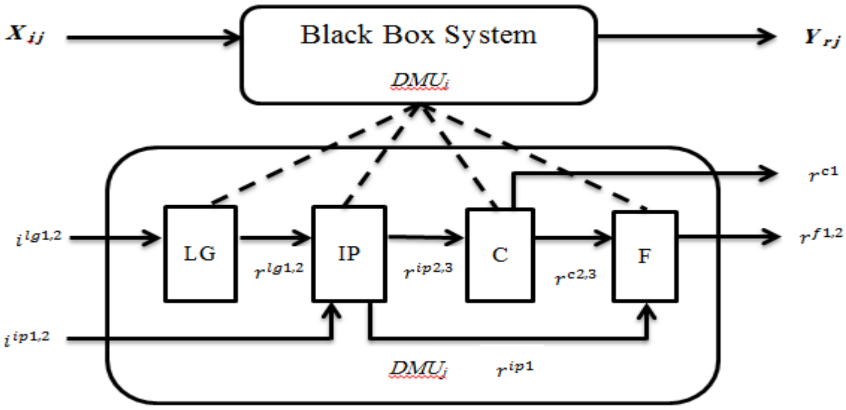

Figure 1. Research model based on Network DEA-BSC

Figure 1 shows the relationships between the input and output variables of the research model. The inputs of the entire system are divided into two categories. Some of the inputs to the model represent the growth and learning perspective and some inputs represent the internal processes perspective. Also, the outputs of the entire system are rendered in terms of customer and financial perspectives. The inputs of internal processes perspective consist of the outputs of growth and learning perspective and the main inputs of the system (excess inputs). In addition, the outputs of the internal processes' perspective enter as the inputs to the customer and financial perspectives. The outputs of customer perspective are also divided into two parts, one of which is the input to the financial perspective and the other part is the output of the entire system. The logic of these relationships is based on the variables of Table 2 and the opinions of experts in the field of cement industry.

In other words, the first contribution of the proposed model is the use of Game Theory and BSC in evaluating the efficiency of decision-making units (DMUs) so that each of the perspectives of BSC is considered as the leader and the other perspectives are considered as the followers, and the efficiency of the DMU is calculated. The second contribution of the proposed model is considering the relationship between key performance indicators in evaluating the performance between the four perspectives of the BSC, which cannot be found in previous studies.

If the system is considered as a black box, the efficiency of decision-making units is modeled as follows (1):

$$
\begin{aligned}
& maz\ \theta_p = \frac{\sum_{r=1}^{s} \quad u_r\, y_{rp}}{\sum_{i=1}^{m} \quad v_i\, x_{ip}} \\
& St: \\
& \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1 \qquad (j=1,2,\ldots,n) \\
& u_r, v_i \geq 0
\end{aligned}
\tag{1}
$$

With regard to the Game Theory and the Stackelberg (leader-follower) model, the leader-follower performance model is formulated, assuming that the financial perspective is considered as the leader and other perspectives in the BSC model as the follower. In order to implement each of the listed models in GAMS software and employ CPLEX for their optimal solving, the mathematical symbols used in the models are defined as follows.

Set and Index	
$\text{DMU} = \{1,2,\ldots,\text{j},\ldots,15\}$	Set of decision making units
$\text{r}^{\text{f}} = \{1,2\}$	Set of outputs from a financial perspective
$\text{r}^{\text{c}} = \{1,2,3\}$	Set of outputs from the customer's perspective
$\text{r}^{\text{ip}} = \{1,2,3\}$	Set of outputs from the internal processes perspective
$\text{r}^{\text{lg}} = \{1,2\}$	Set of outputs from the growth and learning perspective
$\text{i}^{\text{ip}} = \{1,2\}$	Set of system inputs (with direct effect) from the internal processes perspective
$\text{i}^{\text{lg}} = \{1,2\}$	Set of system inputs (with direct effect) from the growth and learning perspective

Parameters	
$Y(j, r^f)$	Outputs from a financial perspective for the decision-making unit j
$W(j, r^c)$	Outputs from the customer perspective for the decision-making unit j
$Z(j, r^{ip})$	Outputs from the internal processes perspective for the decision-making unit j
$F(j, r^{lg})$	Outputs from the employees' growth and learning perspective for the decision-making unit j
$X^{ip}(j, i^{ip})$	System inputs from the internal processes perspective for the decision-making unit j
$X^{lg}(j, i^{lg})$	System inputs from the growth and learning perspective for the decision-making unit j
Outputs	
$u(r^f)$	Coefficient of outputs from a financial perspective for the desired decision-making unit
$k(r^c)$	Coefficient of outputs from the customer perspective for the desired decision-making unit
$t(r^{ip})$	Coefficient of outputs from the internal processes perspective for the desired decision-making unit
$q(r^{lg})$	Coefficient of outputs from the growth and learning perspective for the desired decision-making unit
$v^{ip}(i^{ip})$	Coefficient of system input from the internal processes perspective for the decision-making unit
$v^{lg}(i^{lg})$	Coefficient of system input from the growth and learning perspective for the desired decision-making unit

Based on Stackelberg's game, the efficiency of the decision-making unit p ∈ DMU is determined by taking into consideration the financial perspective as a leader by solving the linear optimisation model (2):

$$\max \phi = \sum_{r^f=1}^{2} Y(p, r^f) u(r^f) \tag{2}$$

$$\sum_{r^c=1}^{2} W(p, r^c) k(r^c) + \sum_{r^{ip}=1}^{1} Z(p, r^{ip}) t(r^{ip}) = 1$$

$$\sum_{r^f=1}^{2} Y(j,r^f)u(r^f) - \left(\sum_{r^c=1}^{2} W(j,r^c)k(r^c) + \sum_{r^{ip}=1}^{1} Z(j,r^{ip})t(r^{ip})\right) \leq 0 \quad ; \quad \forall\, j \in DMU$$

$$\sum_{r^c=1}^{3} W(j,r^c)k(r^c) - \sum_{r^{ip}=2}^{3} Z(j,r^{ip})t(r^{ip}) \leq 0 \quad ; \quad \forall\, j \in DMU$$

$$\sum_{r^{ip}=1}^{1} Z(j,r^{ip})t(r^{ip}) + \sum_{r^{ip}=2}^{3} Z(j,r^{ip})t(r^{ip}) - \left(\sum_{ip=1}^{2} X^{ip}(j,i^{ip})v^{ip}(i^{ip}) + \sum_{lg=1}^{2} F(j,r^{lg})q(r^{lg})\right) \leq 0 \quad ; \quad \forall\, j \in DMU$$

$$\sum_{lg}^{2} F(j,r^{lg})q(r^{lg}) - \sum_{lg=1}^{2} X^{lg}(j,i^{lg})v^{lg}(i^{lg}) \leq 0 \quad ; \quad \forall\, j \in DMU$$

$$u(r^f), k(r^c), t(r^{ip}), q(r^{lg}), v^{ip}(i^{ip}), v^{lg}(i^{lg}) \geq 0$$

Model (2) represents an input-based CCR model. The nature of the DEA models depends on the extent of the management control on system inputs and outputs and its decisions to improve the performance of inefficient units. According to several interviews conducted with the senior managers of the cement industry and the characteristics and features of this industry in the country, cost management and control is more important for the country’s cement industry, therefore, the input-based CCR models were used in this research. It should be noted that the efficiency values obtained based on both input and output based viewpoints are the same in the CCR models; however, this is not the case with the BCC models. Model (2) was developed based on the input-based CCR model and the relationship between the BSC perspectives shown in Figure 1. The objective function represents the output of the financial perspective. The first constraint shows the denominator of the DEA model. This constraint refers to the inputs of the financial perspective that originate from the customer perspective and internal processes. Other constraints for each DMU express the difference between the outputs and inputs of BSC perspectives. The second constraint represents the output of the financial perspective and its inputs coming from the perspectives of the customer and internal processes. The third constraint shows the customer perspective outputs (some of which are the inputs to the financial perspective, and some are the outputs of the entire system) and its inputs from the perspective of internal processes. The fourth constraint represents the outputs of the perspective of internal processes (some of which are inputs to the customer perspective and some are inputs to the financial perspective) and its inputs to the growth and learning perspective that are the main inputs of the system. Finally, the fifth constraint shows the outputs and inputs of the growth and learning perspective.

By the optimal solution of the above model, we will have, for the desired decision-making unit (p):

$\theta_p^{F,Leader} = \phi^*$	Efficiency (Financial perspective)	(3)
$\theta_p^{C} = \frac{\sum_{r^c=1}^{3} W(p,r^c)k^*(r^c)}{\sum_{r^{ip}=2}^{3} Z(p,r^{ip})t^*(r^{ip})}$	Efficiency (Customer perspective)	(4)
$\theta_p^{IP} = \frac{\sum_{r^{ip}=1}^{1} Z(p,r^{ip})t^*(r^{ip})+\sum_{r^{ip}=2}^{3} Z(p,r^{ip})t^*(r^{ip})}{\left(\sum_{i^{p}=1}^{2} X^{ip}(p,i^{ip})v^{ip^*}(i^{ip})+\sum_{lg=1}^{2} F(p,r^{lg})q^*(r^{lg})\right)}$	Efficiency (Internal Process perspective)	(5)
$\theta_p^{LG} = \frac{\sum_{lg}^{2} F(p,r^{lg})q^*(r^{lg})}{\sum_{lg=1}^{2} X^{lg}(p,i^{lg})v^{lg^*}(i^{lg})}$	Efficiency (Learning & Growth perspective)	(6)

Finally, the total efficiency for this decision-making unit is calculated as follows:

$$\theta_p = \left(\theta_p^{F,Leader} \times \theta_p^{C} \times \theta_p^{IP} \times \theta_p^{LG}\right)^{\frac{1}{4}} \quad (7)$$

According to the research model presented in Figure 1, the research variables in each of the four BSC perspectives are separated based on input and output (Table 3).

Table 3. Indices of BSC

BSC	Outputs	Inputs	Input source
Financial perspective	Dollars sales (incremental)	Total market share (incremental)	Customer perspective
	Earnings quality (incremental)	Company export share (incremental)	Customer perspective
		Environmental pollutants (decremental)	Internal processes perspective
Customer perspective	Total market share (incremental)	Production volume (incremental)	Internal processes perspective
	Company export share (incremental)	Product quality (incremental)	Internal processes perspective
	Customer satisfaction rate (incremental)		
Internal processes perspective	Environmental pollutants (decremental)	Direct consumption materials (decremental)	System input
	Production volume (incremental)	Amount of capital (decremental)	System input
	Product quality (incremental)	Per capita education (incremental)	Growth and learning perspective
		Employee Satisfaction Index (incremental)	
Growth and learning perspective	Per capita education (incremental)	Welfare costs of employees (decremental)	System input
	Employee Satisfaction Index (incremental)	Direct wage (decremental)	System input

The variable of environmental pollutants in the financial perspective input is decreasing. In the DEA problems, producing more output with less input is the criterion for the efficiency of a decision-making unit (DMU). However, in some DMUs, in addition to desirable outputs, other undesirable outputs such as environmental pollutants are produced. Therefore, to evaluate the efficiency of each DMU, it is necessary to reduce the undesirable outputs and increase the undesirable inputs in addition to increasing the desirable outputs and reducing the desirable inputs (Liu et al., 2010).

In the proposed model, some inputs and outputs in each of the BSC perspectives are undesirable, as it can be seen in Table 3. For example, environmental pollutants are an undesirable output from the perspective of internal processes, and its reduction is considered for efficiency. Both direct and indirect methods are used to evaluate undesirable data in inputs and outputs. Indirect methods convert the values of undesirable outputs using a uniform descending function so that the undesirable data can be converted into desirable outputs in the production possibility set. This procedure is followed for undesirable inputs as well. In the direct method, the undesirable data enters the main DEA models directly. Hence, the model hypotheses have been changed to be able to examine the undesirable data (Halkos and Petrou, 2019). In this paper, the method proposed by Dyson et al. (2001) has been used. This method was also employed by Amado et al. (2012). Since the undesirable output must be reduced, the data of these outputs are converted by the following function.

$$\widetilde{Y}_{ro} = (\max Y_{rj}) - Y_{ro} + c$$

In this equation, $\widetilde{Y}_{ro}$ denotes the converted output value of r for DMUO, Y_{rj} denotes the main output value of r for DMUj, Y_{ro} denotes the primary output value of r for DMUO and c is a constant value. This conversion is performed in the same way for undesirable inputs.

Table 4 (Appendix) illustrates the problem data of cement companies listed on the Tehran Stock Exchange and Fars and Khuzestan Holdings. Finally, the following table is achieved by solving the model. In this table, the efficiency of each decision-making unit is obtained on the basis of Game Theory (non-cooperative – leader, follower):

Table 5. Results of efficiency using GAMS software (financial perspective)

Efficiency using Game Theory (financial perspective – leader)					
DMU_j	$\theta^{F\text{-}Leader}$	$\theta^{C\text{-}Follow}$	$\theta^{IP\text{-}Follow}$	$\theta^{LG\text{-}Follow}$	θ^{Total}
1	0.357579	0.119252	0.219313	0.007616	0.091865
2	0.502365	0.335370	0.928253	0.005413	0.170575
3	0.365175	0.000017	0.839278	0.001380	0.009236
4	0.390104	0.158255	0.527993	0.002859	0.098250
5	1	0.001462	0.205364	0.002310	0.028858
6	1	0.000011	0.223931	0.001768	0.008079
7	0.574529	0.019297	1	0.001959	0.068268
8	0.343405	0.000018	0.815387	0.003865	0.011828
9	0.585342	0.013163	0.729977	0.003890	0.068392
10	1	0.052675	0.294418	0.000928	0.061586
11	0.836823	0.010389	0.262830	0.002374	0.048260
12	0.627169	0.000011	0.819919	0.005584	0.013452
13	0.775027	0.000016	0.957751	0.003683	0.014398
14	0.677455	0.022351	0.401714	0.003701	0.068883
15	0.490457	0.000016	0.633292	0.006853	0.013665

According to Table 5 and the presented output, if the financial perspective is determined as the leader, the efficiency in the 3 decision-making units is equal to one. From the perspective of the customer, internal processes, and the growth and learning that are regarded as followers, the efficiency of decision-making units in terms of internal processes is higher than other perspectives, and even the efficiency of 60% of decision-making units in financial perspective is higher. Then, for further investigation, each perspective is examined as a leader, and other perspectives as a follower. In the proposed model, the efficiency of each decision-making unit will be different if the perspective of the customer, internal processes, and growth and learning are selected as leaders.

Table 6. Results of efficiency using GAMS software (customer perspective)

Efficiency using Game Theory (customer perspective – leader)					
DMU_j	$\theta^{F\text{-}Follow}$	$\theta^{C\text{- }Leader}$	$\theta^{IP\text{-}Follow}$	$\theta^{LG\text{-}Follow}$	θ^{Total}
1	0.125294	1	0.635368	0.007616	0.156915
2	0.060108	1	0.837145	0.005413	0.128468
3	0.106162	1	0.511707	0.001380	0.093074
4	0.206929	0.689103	0.514327	0.002859	0.120331
5	0.586995	0.789942	0.117995	0.002310	0.106030
6	0.126278	0.965847	0.248192	0.001768	0.085530
7	0.211423	0.776988	0.965803	0.001959	0.132779
8	0.063338	1	0.642308	0.003865	0.111983
9	0.110249	1	0.433657	0.003890	0.116779
10	0.258033	0.869168	0.126893	0.000928	0.071679
11	0.360477	1	0.163492	0.002374	0.109209
12	0.300409	1	0.260712	0.005584	0.144613
13	0.258580	1	0.514166	0.003683	0.148757
14	0.054362	1	0.424041	0.003701	0.096109
15	0.406708	1	0404508	0.006853	0.183240

According to Table 6 and the presented output, if the customer perspective is determined as the leader, the efficiency in 10 decision-making units (about 66%) is equal to one. From the perspective of financial, internal processes, and the growth and learning that are considered as followers, the level of efficiency of most decision-making units in terms of internal processes is higher than in other perspectives.

Table 7. Results of efficiency using GAMS Software (Internal process)

Efficiency using Game Theory (internal process perspective – leader)					
DMU_j	$\theta^{F\text{-}Follow}$	$\theta^{C\text{-}Follow}$	$\theta^{IP\text{-}Ledear}$	$\theta^{LG\text{-}Follow}$	θ^{Total}
1	0.125294	0.000012	0.773760	0.007616	0.009722
2	0.349188	0.000013	1	0.192273	0.030606
3	0.329625	0.000014	1	0.562499	0.040224
4	0.206929	0.000012	0.693491	0.508030	0.030644
5	1	0.000007	0.988658	0.698965	0.046626
6	0.402165	0.000008	0.746211	0.443603	0.032421
7	0.468796	0.000007	1	0.819524	0.041095
8	0.250470	0.000016	1	0.206578	0.030015
9	0.399777	0.000009	1	0.381308	0.034259
10	0.786188	0.000013	1	1	0.056697
11	0.785566	0.000010	0.887587	0.914108	0.050387
12	0.626429	0.000010	1	0.029893	0.021037
13	0.775007	0.000015	1	0.441129	0.047305
14	0.174226	0.000015	0.799955	0.480146	0.031669
15	0.406708	0.000017	0.781431	0.422622	0.039100

Based on Table 7 and the presented output, if the internal processes perspective is determined as the leader, efficiency in 8 decision-making units is equal to one. In the financial, customer, growth, and learning perspectives that are considered as followers, about half of the decision-making units is the efficiency of the financial unit, and the other half is the efficiency of the growth and learning perspective, which is less than the efficiency of internal processes perspective.

Table 8. Results of efficiency using GAMS software (growth and learning)

Efficiency using Game Theory (growth and learning perspective – leader)					
DMU_j	$\theta^{F\text{-}Follow}$	$\theta^{C\text{-}Follow}$	$\theta^{IP\text{-}Follow}$	$\theta^{LG\text{-}Leader}$	θ^{Total}
1	0.125294	0.000043	0.015736	1	0.017025
2	0.349188	0.000039	0.141051	0.804316	0.035180
3	0.329625	0.000036	0.211464	0.642183	0.035722
4	0.206929	0.000027	0.106140	0.722092	0.025606
5	1	0.000019	0.185770	0.860983	0.041712
6	0.402165	0.000025	0.126704	0.640715	0.030200
7	0.468796	0.000022	0.165248	0.891232	0.034938
8	0.250470	0.000063	0.073137	0.986245	0.032616
9	0.399777	0.000031	0.119217	0.762394	0.032636
10	0.786188	0.000031	0.167875	1	0.044985
11	0.785566	0.000036	0.121189	1	0.042966
12	0.626429	0.000029	0.168886	0.998937	0.0411871
13	0.775007	0.000041	0.221963	0.751196	0.047991
14	0.174226	0.000047	0.073469	0.765323	0.026039
15	0.406708	0.000054	0.084626	1	0.036971

According to Table 8 and the presented output, if the growth and learning perspective is determined as a leader, the efficiency in 4 decision-making units is equal to one. In the financial, customer, and internal processes perspectives that are intended as followers, the level of efficiency of decision-making units in the financial perspective is higher than other perspectives.

The ranking of decision-making units using total efficiency in different scenarios in which each perspective is the leader is summarised in Table 9.

Table 9. Ranking of decision-making units

	F-Leader		C-Leader		IP-Leader		LG-Leader	
DMU_j	θ^{Total}	rank	θ^{Total}	rank	θ^{Total}	rank	θ^{Total}	rank
DMU_1	0.091865	3	0.156915	2	0.009722	15	0.017025	15
DMU_2	0.170575	1	0.128468	6	0.030606	12	0.03518	8
DMU_3	0.009236	14	0.093074	13	0.040224	6	0.035722	7
DMU_4	0.09825	2	0.120331	7	0.030644	11	0.025606	14
DMU_5	0.028858	9	0.10603	11	0.046626	4	0.041712	5
DMU_6	0.008079	15	0.08553	14	0.032421	9	0.0302	12
DMU_7	0.068268	6	0.132779	5	0.041095	5	0.034938	9
DMU_8	0.011828	13	0.111983	9	0.030015	13	0.032616	11
DMU_9	0.068392	5	0.116779	8	0.034259	8	0.032636	10
DMU_{10}	0.061586	7	0.071679	15	0.056697	1	0.044985	2
DMU_{11}	0.04826	8	0.109209	10	0.050387	2	0.042966	3
DMU_{12}	0.013452	12	0.144613	4	0.021037	14	0.041871	4
DMU_{13}	0.014398	10	0.148757	3	0.047305	3	0.047991	1
DMU_{14}	0.068883	4	0.096109	12	0.031669	10	0.026039	13
DMU_{15}	0.013665	11	0.18324	1	0.0391	7	0.036971	6

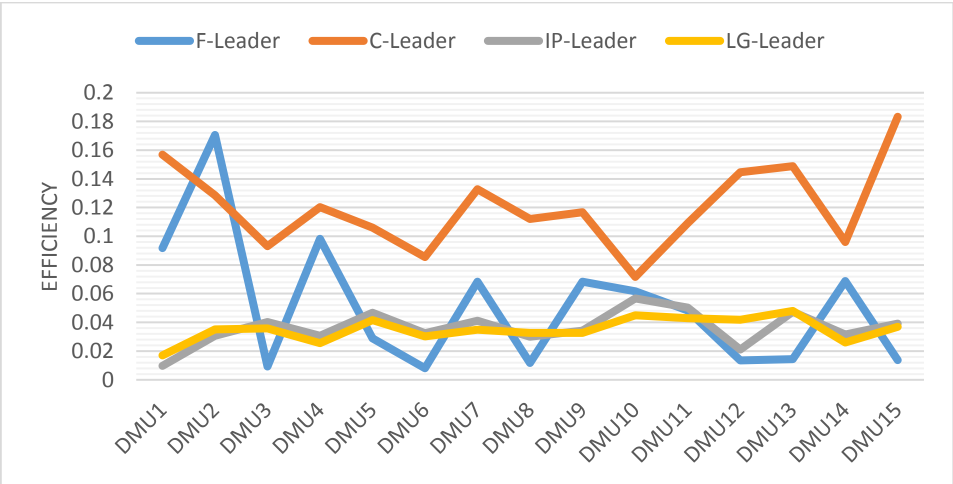

Figure 2. Ranking of decision-making units from BSC perspectives

The Spearman correlation coefficient between the ranks of decision-making units in four different scenarios of BSC perspectives indicated that there is a significant relationship between the perspective of internal processes and the perspective of growth and learning with a correlation coefficient of 0.686 at the error level of 0.01.

4. Conclusions

The discussion of measuring the performance of organisations has found great importance among managers in recent years.

One of the subsets of performance measurement is to measure the efficiency of organisations and companies. The aim of measuring the efficiency of organisations is the better allocation of resources in order to increase profits and minimise costs. In this article, a comprehensive model of combining NDEA models and Game Theory in BSC perspectives was offered in order to rank and analyse the efficiency of cement industry units. As can be seen, the BSC indicators in four perspectives of financial, customer, internal processes, and growth and learning were initially specified and calculated concerning the strategy map. By collecting information about 15 cement units in the holding, the performance evaluation phase of the units began. In the next step, the NDEA model was developed with regard to the relationships between the indices. Then, Stackelberg theory and Game Theory were exploited to examine the leader-follower in the decision-making units (DMUs) based on perspectives of BSC. At this stage, the proposed model was implemented four times so that one perspective of the BSC perspectives in each stage was considered as the leader and the other perspectives as the followers. According to the results obtained from the implementation of the model, the order of the four perspectives in BSC can be represented as follows: C>F>IP>LG

Therefore, the customer perspective plays a decisive role in the efficiency of decision-making units. In other words, one can argue that the customer perspective in the companies studied in this study acts as a leader, and other perspectives will be followers. Then, the efficiency of all decision-making units based on being the leader of financial, internal processes, and ultimately of the growth and learning perspectives would be decisive. After the customer perspective as a leader chooses their strategies, the followers give the best response to choose the strategies that maximise their efficiency. The best answer is based on the decisions made by the leader and the concept of solutions chosen by the followers.

4.1. Practical Implications

Management and evaluation of the performance cause an increase in the efficiency and effectiveness of organisational programs and processes, since it indicates the performance of an organisation and the accuracy of decisions made by managers. It is therefore essential that all institutions and organisations continuously evaluate themselves and always put themselves in the direction of organisational goals. The results achieved from combining the BSC and NDEA models can be very fruitful by covering the weaknesses of each of the models in calculating the efficiency of the organisation's activities with a high and complex volume. One of the most important issues that is currently of great importance is the interaction of units within the organisation that forces senior managers to take into consideration all important operational measures simultaneously. The NDEA model presented in this study analyses the performance of various departments within the organisation in the form of a BSC and a strategy map of the organisation and helps the managers of the organisation to evaluate the performance of different departments and the entire organisation.

Hence, the case study carried out in this study can be a guide for different organisations that generally decide to implement a performance evaluation system in their own organisation.

4.2. Research Limitations/Implications

This study presented a hybrid model of NDEA, BSC, and Game Theory. The results of the model revealed that the combination of these models could eliminate the defects of each one separately. With regard to the research design, which has been conducted in cross-sectional form over a period of one-year, future studies can explore and develop the temporal impact on each of the factors.

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Table 4. Research Data

	i^{lg}		i^{ip}		r^{lg}		r^{ip}			r^{c}			r^{f}	
DMU	Training costs (Hundred Dollars)	Direct wages (Hundred Dollars)	Direct consumption materials (Hundred Dollars)	The amount of capital (Hundred Dollars)	Per capita education	Employee Satisfaction Index	Production volume	Product quality	Environmental pollutants	Total market share	Company export share	Customer satisfaction level	Sales (Hundred Dollars)	Quality of earnings
1	450	14782	51436	50000	37	79	163114	200	120	13	35	80	355860	82
2	725	16086	65885	300000	15	76	1185744	362	140	45	54	75	1157209	133
3	412	58223	99971	392000	9	72	1461796	225	167	101	23	73	1303083	119
4	552	36787	95302	230000	21	86	800684	270	175	40	10	84	857130	157
5	378	40746	448372	650000	14	81	1803266	225	117	1	0.56	85	2769645	153
6	589	60502	197470	233000	28	80	866096	260	98	0.18	0.002	81	932944	80
7	445	59786	82246	450000	33	85	1560408	285	121	2.3	3.2	90	1342746	99.3
8	358	20338	62333	53222	8	72	729464	299	100	83	39	72	592885	95
9	512	22882	89882	55000	17	74	925978	199	117	1.4	44	70	1107918	101
10	258	116174	405430	1802040	28	80	2325577	215	140	86	12	77	2605349	381
11	248	31344	249936	350000	4	71	1284397	198	72	27	2	78	1338909	103
12	617	15500	130848	400000	2	88	1776454	262	120	2.3	39	93	1779496	99
13	623	28157	93545	650000	17	89	1832191	229	114	90	5	91	2091532	110.9
14	489	23016	74271	208833	15	72	582806	271	123	77	2	85	507169	162
15	724	15036	91842	125000	18	90	864412	195	102	60	32	86	981990	121.9