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EFFICIENCY MEASUREMENT IN CONSTRUCTION SECTOR USING DATA ENVELOPMENT ANALYSIS METHOD [1]

VERİ ZARFLAMA ANALİZİ YÖNTEMİ KULLANILARAK İNŞAAT SEKTÖRÜNDE ETKİNLİK ÖLÇÜMÜ

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ÖZET

İnsanların açlık susuzluk gibi fizyolojik ihtiyaçlarına ek olarak barınma ihtiyaçları da bulunmaktadır. Yangın, sel, deprem gibi doğal afetler, salgınlar ve savaşlar neticesinde insanlar farklı bölgelere yerleşmektedirler. Dünya genelinde artan nüfus, salgın hastalıklar ve felaketler inşaat sektörünün ne kadar öncelikli ve hayati öneme sahip bir sektör olduğunu göstermektedir. Türkiye'de yaşanan deprem felaketi ve sınır komşularında yaşanan savaşlara bağlı olarak artan göç inşaat sektörünün Türkiye açısından ne kadar önemli ve öncelikli olduğunu bir kez daha gözler önüne sermektedir. Diğer birçok sektörde olduğu gibi inşaat sektöründe de işgücü ve finansal kaynakların etkin bir şekilde kullanılması gerekmektedir. Türkiye'de faaliyet gösteren inşaat firmalarının etkinliklerinin ölçülmesi inşaat sektörünün mevcut durumu açısından oldukça önemlidir. Bu çalışmanın amacı Fortune 500 listesinde bulunan ve Türkiye'de inşaat ve taahhüt alanında faaliyet gösteren on firmanın etkinlik değerlendirmesini gerçekleştirmektir. Etkinlik ölçümünde genellikle Veri Zarflama Analizi (VZA) yöntemi yaygın bir şekilde kullanılmaktadır. Çalışmada etkinlik analizleri için girdi odaklı CCR modeli ve Süper Etkinlik (SE)-CCR modeli kullanılmıştır. Çalışmada etkinliğe etki eden faktörlerin belirlenmesi için Tobit Analizi de yapılmıştır. VZA analizi sonuçlarına göre karar verme birimi (KVB) olarak ele alınan on firma arasından üçünün etkin olduğu tespit edilmiştir. Etkin çıkan firmalar SE CCR modeli sonuçlarına göre kendi aralarında sıralanmıştır.

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ABSTRACT

In addition to physiological needs such as hunger and thirst, people also have shelter needs. As a result of natural disasters such as fire, flood, earthquake, epidemics and wars, people settle in different regions. The world's increasing population, epidemics and disasters show how priority and vital the construction industry is. The earthquake disaster in Turkey and the increasing migration due to wars in the border regions once again reveal how important and priority the construction sector is for Turkey. As in many other sectors, labor and financial resources must be used efficiently in the construction industry. Measuring the efficiency of construction companies operating in Turkey is very important for the current situation of the construction industry. This study aims to evaluate the efficiency of ten companies on the Fortune 500 list operating in the field of construction and contracting in Turkey. The Data Envelopment Analysis (DEA) method is generally widely used in efficiency measurement. In the study, input-oriented CCR model and Super Efficiency (SE)-CCR model were used for efficiency analysis. In the study, Tobit Analysis was also conducted to determine the factors affecting the efficiency. According to the DEA analysis results, three of the ten companies considered as decision-making units (DMU) were efficient. Efficient companies are ranked among themselves according to the results of the SE CCR model.

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The increasing population around the world, the earthquake disaster in Turkey and increasing immigration show that the construction sector is vitally important. The construction sector makes significant contributions to the Turkish economy in terms of both employment and investment. Therefore, as in many sectors, labor and financial resources must be used effectively in the construction sector. Human resources are a vital factor in the development of the construction industry. Differences in construction labor productivity can naturally have major impacts on the national economy and productivity. In most countries, labor cost accounts for 30 to 50% of the overall project cost and is considered a true reflection of the economic success of the business (Prabhu and Ambika, 2013). It is stated that there has been a contraction in the construction sector in Turkey for the last five years, but there has been a gradual increase in employment. There are also fluctuations in employment due to seasonality. In particular, it is stated that the number of paid employees, which was 1.32 million in February 2022, reached its highest level with 1.6 million in December (IMSAD, 2023).

The Turkish Contractors Association states that the construction sector, which plays a very important role in Turkey's economic development, provides employment for approximately 1.5 million people, and its share in the Turkish economy has reached 30%, considering its direct and indirect effects on the sectors (TMB, 2023). Therefore, it can be said that construction efficiency depends on human effort and performance. The construction industry, which contributes to the development and growth of related industries through cooperation between different fields, has a high amount of cash flow. Therefore, to be successful in the sector, high-cost efficiency must also be taken into account (Dzeng and Wu, 2012).

The construction sector has a structure that creates demand for other sectors with its activities in both national and international markets (Şahin and Karacan, 2020). Measuring the efficiency of construction companies in Turkey is very important for the current situation of the construction industry. It has been said that DEA has been successfully applied for productivity and efficiency measurements, which are critical in the construction industry where competition is high (Horta et al., 2010; Hu and Liu, 2018). Additionally, there are studies in the literature using the DEA method in the construction industry (Sueyoshi and Goto, 2009; Lee, 2014; Hu and Lio, 2016; Noorizadeh et al., 2018; Yang et al., 2021; Luo et al., 2022) For this reason, the current study helps to reveal the current situation of the sector by evaluating the effectiveness of ten companies operating in the field of construction and contracting in Turkey on the Fortune 500 list.

The rest of the study is organized as follows. In the second part of the study, the DEA models used in the study are included. The third part of the study contains the analysis results. In the last part of the study, a general evaluation of the study was made.

1. METHOD

1.1. Data Envelopment Analysis

Data Envelopment Analysis (DEA) is a linear programming-based method used to evaluate the performance of decision-making units with similar characteristics (De Leone, 2008; Sarı, 2018; Shureshjani et al., 2022; Selamzade et al., 2023; Dalir et al., 2024). The DEA method is one of the widely used methods for efficiency measurement (Rostamzadeh et al., 2021; Selamzade et al., 2023; Obi et al., 2023; Ersoy and Tehci, 2023).

Efficiency measurement is used to compare the performance of businesses with their competitors and to improve their processes based on performance (Malik et al., 2018; Ersoy and Tehci, 2023). The DEA method has two separate models consisting of the initials of the names Charnes, Cooper and Rhodes (CCR) and Banker, Charnes, and Cooper (BCC) (Charnes et al., 1978; Banker et al., 1984; Ersoy, 2021, Selamzade et al., 2023). Both models have two separate versions, input-oriented and output-oriented (Selamzade et al., 2023; Ersoy and Tehci, 2023).

The DEA method has a very wide application areas such as education, energy, banking, agriculture, health and logistics (Ersoy, 2021; Rostamzadeh et al., 2021; Selamzade and Baghirov, 2022; Narayan et al., 2022; Ersoy and Küsbeci, 2023; Selamzade et al., 2023; Kyrgiakos, et al., 2023). In this paper, efficiency measurements were made with the input-oriented CCR model.

The input-oriented CCR DEA model (Cooper et al., 2011; Xu and Quenniche, 2012; Selamzade et al., 2023; Ersoy and Tehci, 2023) and the Super Efficiency (SE) CCR DEA model of this model (Seiford and Zhu, 1999: 175; Xu and Ouenniche, 2012: 580; Ersoy and Tehci, 2023) are shown in Table 1. According to the CCR model given in Table 1, the efficiency score must be "1" for DMUs to be efficient (Ersoy, 2021; Selamzade et al., 2023).

Table 1. *Input-Oriented CCR Model and SE-CCR Model*

Classic Input-Oriented CCR Model	Input-Oriented SE- CCR Model
$\min \theta_t$ $s.t.$ $\sum_{j=1}^{n} \lambda_j x_{ij} \le \theta_t x_{it}, \quad i = 1,\ldots,m$ (1) $\sum_{j=1}^{n} \lambda_j y_{rj} \ge y_{rt}, \quad r = 1,\ldots,s$ $\lambda_j \ge 0, \quad j = 1,\ldots,n$	$\min \theta_t$ $s.t.$ $\sum_{\substack{j=1 \\ j \ne t}}^{n} \lambda_j x_{ij} \le \theta_t x_{it}, \quad i = 1,\ldots,m$ (2) $\sum_{\substack{j=1 \\ j \ne t}}^{n} \lambda_j y_{rj} \ge y_{rt}, \quad r = 1,\ldots,s$ $\lambda_j \ge 0, \quad j = 1,\ldots,n$

Interviews with experts and based on the literature review in the construction industry, as an input variable; The number of personnel and total assets were determined as output variables, and net sales were determined as the variables to be used in the study. Data regarding the variables that make up the data set of the study were obtained from the Fortune 500 website (www.fortuneturkey.com)

1.2. Tobit Analysis

To obtain consistent estimates in determining the factors affecting the efficiency scores of DMUs as a result of efficiency analyses, the Tobit Analysis, developed by Tobin in 1958, is generally used in the literature. This approach is a special case of the general censored regression model (Henningsen, 2012; Yesilyurt & Salamov, 2017). The Tobit model assumes that the dependent variables (Yj, j = 1...n), which are the efficiency scores obtained by the DEA method in this study, emerge for the censored regression model observations (Bierens, 2014; Yesilyurt & Salamov, 2017):

$$Yj^* = \beta 0 + \beta 1X1 + \ldots + \beta mXm \qquad (3)$$

The following formula is used in the standard Tobit model for constant values (Tobin, 1958; Yesilyurt & Salamov, 2017):

$$xij\ j = 1, \ldots p, \quad (4)$$

$$y^*i \sim N(\theta i\ xi1 + \ldots + \theta p\ xip, \sigma 2)\ , \text{ ve } E(y^*i\ xij, j=1, \ldots, p) = \theta i\ xi1 + \ldots + \theta p\ xip, \quad (5)$$

$$E(y^*i\ xij) = xiT\ \theta$$

Where $xj = (xi1, \ldots, xip)T$ is shown as before; $xj = (\theta 1, \ldots, \theta p)T$

Where, the value of the coefficient θj determines the change in the output variables in the performance evaluation with the vector of indicators xj=(xi1,...,xip)T, one by one, as the value of j increases (Yesilyurt & Salamov, 2017).

In this analysis, the inputs and outputs used in the study were considered independent variables, and the efficiency scores obtained by the CCR method were considered dependent variables. For the analysis results to be consistent, the logarithm of the input and output variables was taken. Tobit analysis was performed by creating the following regression equation (Coelli, 1998; Yesilyurt & Salamov, 2017).

$$TECCR = \beta 1 + \beta 2\ Ln\ Net\ Sales + \beta 3\ Ln\ Number\ of\ Employees + \beta 4\ Ln\ Total\ Assets \quad (6)$$

2. RESULTS AND DISCUSSION

The efficiency of ten different companies in the construction industry and included in the FORTUNE 500 list was evaluated using the DEA method. Two input and one output variables were used in the study. Data envelopment analysis was carried out using the EMS 1.3.0 computer program. Tobit analysis evaluation results were obtained from the Eviews 9 computer program (EViews 9, 2016).

Classic efficiency and super efficiency results of construction companies for 2022 are shown in Table 2.

Table 2. *Efficiency Scores of Companies*

DMU Number	CCR	SE-CCR
F1	0,67	0,67
F2	1,00	1,08
F3	0,64	0,64
F4	0,47	0,47
F5	0,72	0,72
F6	0,92	0,92
F7	0,43	0,43
F8	1,00	1,49
F9	1,00	1,13
F10	0,81	0,81
Mean	**0,76**	**0,83**

As can be seen from Table 2, construction and contracting companies, which are decision-making units (DMUs), are expressed as K1, K2, K3,…., K10, respectively. Table 2 contains decision-making units in the first column, efficiency scores in the second column, and super efficiency results in the third column. When Table 2 is examined, it is seen that K2, K8 and K9 companies with an efficiency score of "1" are efficient. 7 construction and contracting companies with an efficiency score lower than 1 are inefficient.

According to the input-oriented DEA analysis results, the average efficiency score is 0.76 and the company with the lowest efficiency score is K7 company with an efficiency score of 0.43. To rank the efficient companies among themselves, their super efficiency scores must be evaluated. Among the 3 efficient companies, the company with the highest super efficiency score is K8 with an efficiency score of 1.49. K9 company ranks third among efficient companies with an efficiency score of 1.13.

Table 3. *Results of Tobit Analysis*

Method: ML - Censored Normal (TOBIT) (Quadratic hill climbing)
Left censoring (value) at zero
Convergence achieved after 5 iterations
Covariance matrix computed using second derivatives

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-1.644103	0.775361	-2.120437	0.0340
Ln Net Sales	0.656981	0.096423	6.813518	0.0000
Ln Number of Employees	-0.266939	0.037963	-7.031616	0.0000
Ln Total Assets	-0.438883	0.061018	-7.192652	0.0000
Error Distribution				
SCALE:C(5)	0.073327	0.016395	4.472563	0.0000

Mean dependent var	0.764090	S.D. dependent var	0.215790
S.E. of regression	0.094664	Akaike info criterion	-1.387787
Sum squared resid	0.053768	Schwarz criterion	-1.236494
Log likelihood	11.93893	Hannan-Quinn criter.	-1.553754
Avg. log likelihood	1.193893		

$p \leq (0,01)$, $p \leq (0,05)$, $p \leq (0,10)$

As a result of the analysis using the censored normal Tobit method presented in Table 3, it was determined that the output variable, Net sales amount, had a positive effect on the efficiency scores, while the input variables, the number of employees and total assets, had a negative effect. It can be said that an increase in sales amounts by 1% will increase efficiency scores by approximately 0.657%. The fact that existing input variables have a negative effect indicates that the inputs are used idle.

3. CONCLUSION

In this study, the efficiency of ten companies operating in the construction sector and included in the FORTUNE 500 list was evaluated. In the research, efficiency analysis was carried out using the DEA method. For efficiency measurement, the input-oriented CCR model and its super efficiency model were used. Three construction companies were efficient according to the DEA efficiency results using two input variables and one output variable. The ranking of the efficient companies among themselves was made according to the results of the super efficiency CCR model. Since the input-oriented CCR model was used in the study, it may be possible to make inferences about the improvements that can be made for the input variables by keeping the output variable constant.

It is very important for construction enterprises that are not efficient according to the analysis results to reconsider their number of personnel, the working performance of the personnel, the harmony of the personnel within the company, sustainability strategies, competition targets and strategies with competitors, quality policies, business missions and visions, and collaborations with other companies, their marketing and purchasing methods to become efficient.

For businesses that are not efficient to be efficient, they need to take the construction companies that are efficient as their reference. Inefficient businesses need to optimize their personnel numbers or improve their personnel performance. It is recommended that inefficient companies keep their total assets at a similar level to efficient companies.

According to the Tobit analysis results, it was determined that the output variable had a positive effect and the input variables had a negative effect on the efficiency results. It is possible to say that the input variables are used idlely due to the negative impact of the existing input variables.

Since the research results depend on the input and output variables used in the analysis, changes in the input and output variables may affect the analysis results. When evaluated from this perspective, it is useful to remember that the efficiency results obtained with DEA are relative. In future studies, efficiency measurements can be carried out in different sectors by using different input and output variables. Additionally, studies can be carried out using multi-criteria decision making methods or different methods in addition to the DEA method.

AUTHOR DECLARATIONS

Declarations of Research and Publication Ethics: This study has been prepared in accordance with the rules of scientific research and publication ethics.

Ethics Committee Approval: This research does not require ethics committee approval as it does not include analyzes that require ethics committee permission.

Author Contributions: Authors contributed equally to the study.

Conflict of Interest: There are no conflict of interest arising from the study for the authors or third parties.

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