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DETERMINING THE TARGET OUTPUT IN CONTAINER TERMINALS: A METHODOLOGICAL CONTRIBUTION

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ABSTRACT

Due to its capital intensive nature, the efficient management of container terminals is essential in achieving the optimal benefit from the investments made. Albeit the investments in container terminal are made to improve the efficient management of the operations, when the expected handling volumes are not met, there is a risk that said investments can be rendered obsolete. Thereby while the outlook of the decision makers on the cargo potential is important, arrangement of the resources at hand in accordance with this outlook is also crucial. However, there is a need for methodological tools that can help the decision makers set the target output without hampering the efficiency. In this study, through the combined application of super efficiency data envelopment analysis and regression analysis, a model for determining the output level for efficient container terminals was developed. The model was applied to 17 container terminals in Turkey that had over 50000 TEU of container throughput in the year of 2016 and target outputs were evaluated thereafter according to several investment scenarios. Findings of this study reveal that among the selected ports, Marport, TCE Ege and MIP are at the top of the ranking list based on the super efficiency model. The regression analysis applied subsequent to efficiency analysis provides coefficients of the inputs, enabling the calculation of the target outputs after inserting the potential investment values. The regression model that has emerged from efficiency data of 17 container terminals can be used as a tool to evaluate target outputs. It is believed that port managers can validate their investment decisions based on this tool as it would provide the new target output after the changes in inputs.

Keywords: *Target output, efficiency, investment, container terminals.*
Jel Codes*: B23, D24, R42.*

KONTEYNER TERMİNALLERİNDE HEDEF ÇIKTININ BELİRLENMESİ: YÖNTEMSEL BİR KATKI

ÖZ

Sermaye yoğun tabiatından ötürü, konteyner terminallerinin etkin yönetimi, yapılan yatırımlardan optimal faydanın sağlanması açısından oldukça önemlidir. Her ne kadar konteyner terminallerine yapılan yatırımlar operasyonel yönetimin etkinliğini artırmak amacıyla yapılıyorsa da, hedeflenen elleçleme hacimlerine erişilemediği halde, yapılan yatırımların beklenen faydayı sağlamaması riski mevcuttur. Bu sebeple karar vericilerin yük potansiyeli konusundaki görüşleri önemli olsa da, eldeki kaynakların bu görüşlere uygun şekilde değerlendirilmesi de bir o kadar önemlidir. Bu yolda karar vericilere, etkinliği zedelemeden hedef çıktıyı belirleme konusunda yardımcı olacak metodolojik araçlara ihtiyaç vardır. Bu çalışmada, süper etkinlik veri zarflama analizi ve regresyon analizinin birlikte kullanılması ile konteyner terminallerinin etkin olması için çıktı seviyesini tespit eden bir model geliştirilmiştir. Model, Türkiye'de 2016 yılında 50000 TEU üstü konteyner elleçlemesi olan 17 konteyner terminaline uygulanmış ve seçilen terminallerin hedef çıktıları yatırım senaryolarına göre sonraki aşamada hesaplanmıştır. Çalışmanın sonuçlarında, seçilen terminaller arasında Marport, TCE Ege ve MIP terminalleri süper etkinlik modeline göre sıralama listesinin en başında yer bulmuşlardır. Etkinlik analizini takiben uygulanan regresyon analizi girdilerin katsayılarını ortaya koyarak potansiyel yatırım değerlerinin girilmesinden sonra hedef çıktıların hesaplanmasını sağlamaktadır. 17 konteyner terminalinin etkinlik verilerinden oluşturulan bu regresyon modeli hedef çıktıların değerlendirilmesi için kullanılacak bir araç niteliğindedir. Bu araç, girdilerde yapılan değişikliklere bağlı olarak yeni hedef çıktıları sağlayacağından, liman yöneticileri tarafından yatırım kararlarının doğrulanmasında kullanılabilecektir.
Anahtar Kelimeler*: Hedef çıktı, etkinlik, yatırım, konteyner terminalleri.*
Jel Kodu: *B23, D24, R42.*

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INTRODUCTION

Ports are vital nodes for the global trade as they are at the heart of the physical infrastructure chain of maritime transportation. Due to the globalization and the stream of containerization starting from the late 50s to our day, the role that the ports play in supply chains have undergone many changes (Slack, 1985). These changes mainly resulted in the requirement for ports to adapt to the frequently advancing technologies, improving both infrastructure and superstructure and maintaining the operations in efficient levels. Today, ports are more than conventional infrastructures that are solely focused on cargo handling in between shore and land, as they are required to be integrated with the rest of the maritime supply chain actors and to add value through more diverse services (Woo et al., 2011; Schellinck and Brooks, 2016).

Another important point to consider is that the rivalry between ports is increasing consistently and it pushes ports in to a corner, in which they have to find new ways to improve service quality levels in order to attract ship owners, cargo owners and their intermediaries (Ugboma et al., 2007; Yeo et al., 2015; Thai, 2016). One way to achieve differentiation is through investing on physical and technical infrastructures (Lirn et al., 2014). However, the managers should evaluate such investments by considering not only the financial costs and expected financial returns but also its effect on the port operations efficiency. In other words, the managers should examine the investment plans by scrutinizing whether the increased inputs will hamper the operational efficiency level of the port or not. Additionally, port managers should also be aware of the target output (TEU throughput) level that would keep the operational efficiency at a desired level after the investments are carried out. Otherwise, such capital intensive investments can cause idle capacities and eventually increase operational costs instead of generating value for the users as it was aimed to.

Although port efficiency literature is broad in scope covering many studies that calculate and compare relative efficiencies of ports from all around the globe, research focusing on the relation between investments and their efficiency effects is scant. Moreover, these limited research on this particular topic built their research on evaluation of post-investment impacts on the operational efficiency. Therefore, contribution of these studies hardly goes beyond the ports that are subject to said researches. Considering that the existing literature have not focused on investment evaluation before it is carried out, our study aims to fill this gap through a methodological contribution. To address this gap, through the combined application of super efficiency data envelopment analysis and regression analysis, our study develops a model for determining the output level for efficient container terminals. Several investment scenarios are run in the model to show how it works in terms of generating the target output.

This paper is thus organized as follows. The next section reviews the literature on port efficiency including the studies that investigate investment impacts on operational efficiency. Proposed methodology is then described, followed by the analysis and results. Finally, the study is concluded by revealing the managerial implications and further study recommendations.

1. LITERATURE REVIEW

Due to the evolving roles that the ports play and performance related responsibilities that the ports have within the global supply chains, efficiency in port management has become a vital issue for the managers. Consequently, academic research on efficiency measurement in ports attracts appreciable attention, as the outcomes of such research provide fruitful insights for port managers to compare their port with their rivals, to decide on resource purchasing (or reduction), to examine their processes and to evaluate their investment plans.

In the body of literature on port efficiency, seminal work of Roll and Hayuth (1993) is the first study that applies DEA to the port industry. In their study, the authors employ hypothetical data to prove that DEA can be used as a method for efficiency comparison between ports. Thereafter, using real-world data, there have been plethora of research on the subject of port efficiency, covering studies with differing aims, methodological nuances and research samples.

Similar to the work of Roll and Hayuth (1992), in the majority of the studies, DEA has been applied with the aim of ranking and comparing operational efficiency levels of ports within a given sample setting. For instance, Tongzon (2001) compared the efficiency of 4 Australian ports with 12 international ports which are recognized with their high throughputs; Itoh (2002) compared 8 Japanese ports using cross-sectional data covering 9-year period; Barros and Athanassiou (2004) compared the efficiency of 4 Portuguese ports with 2 Greek ports using data covering 12-year period; Schoyen and Odeck (2013) compared 6 Norwegian ports with 18 ports in other Nordic countries and UK; and Ateş et al. (2013) compared 9 ports located in Black Sea. By obtaining the rankings and the operational efficiency scores, these studies have revealed the best practices within their sample and accordingly pointed out improvement recommendations for the inefficient ports. In a similar vein, some scholars applied DEA with the aim of evaluating financial efficiencies of the ports (Ablanedo-Rosas et al.,2010; Güner, 2015) and environmental efficiencies of the port cities (Lee et al., 2014) as well.

Beside the comparison purposes that are based on relative efficiency scores, some scholars aimed to analyze whether the differences in the efficiencies are affected by specific factors. For instance, Cullinane et al. (2005) calculated the relative efficiency scores of 30 top container ports and investigated whether there is a relation between private sector involvement and their efficiencies. The findings of their study revealed no evidence for such a link between private sector involvement and improved efficiency. Similarly, Tongzon and Heng (2005) scrutinized this relation by applying another technique for efficiency measurement (stochastic frontier model) by using data of 25 ports. Their findings revealed that private sector participation to some extent can improve operational efficiency of the ports. The study of Güner (2015), on the other hand, applied DEA to 13 Turkish Ports. Findings showed that all the facets of efficiency (infrastructural, superstructural, operating and financial) are at higher levels for the private ports.

Other than the governance structure-efficiency linkage, another issue that the scholars have investigated was the relation between size of the terminals and the efficiency scores. The findings revealed from this stream of literature are contradictory as well. For instance, in their studies respectively examining Asian ports and Middle Eastern-East African ports, Sohn and Jung (2009) and Al Eraqi et al. (2008) reported that bigger ports efficiency scores are relatively higher. On the other hand, the study of Coto-Millan (2000) which focuses on Spanish ports revealed that smaller ports have higher efficiency scores.

Similar to our study, another important yet relatively scarce research was focused on port investments and its impact on efficiency. In their study, Garcia-Alonso and Martin-Bofarull (2007) aimed to reveal whether port investments lead to higher efficiency. The study focused on Port of Valencia and Port of Bilbao, as both of the ports had recorded high investment expenditures. Their findings showed that the volume of investment expenditure does not necessarily result in higher efficiency levels. The authors concluded that port managers should focus on attracting the international routes to increase ports outputs, along with the investments that increase the level of inputs. The study of Sağlam et al. (2018) evaluated the efficiency levels of Mersin International Port in order to reveal the efficiency effect within 6-year period in which the port have gone through significant increases in the inputs and shift of resources between dry bulk and container terminals. This study adopted berthing time difference as the output variable of DEA model and revealed that although the container terminal have been operated efficiently as a result of the investments, the shift of resources resulted in inefficiency of the dry bulk terminal.

The common ground of these two studies is that both of them carried out post-evaluation of the investment impact. However, what is crucial for the port managers is to be able to foresee these impacts before deciding on whether to invest or not (or to fine-tune the amount of investment). Therefore, our study aims to fill this gap in the literature by proposing a multi-level methodology that enables decision makers to test their investment plans.

2. METHODOLOGY

In this study, it is aimed to reach the results by combining two separate methods which are super efficiency and regression analysis. Super efficiency analysis is applied with the aim of providing the efficiency scores of terminals that are used as dependent variables in the following step, which is the regression model that provides the coefficients to be used in the modeling of the target outputs.

The details regarding the application of these methods are briefly introduced in the following two sections which are followed by the introduction of the data set and the research model.

2.1. DEA Super Efficiency Analysis

The super efficiency method is derived from the conventional data envelopment analysis (DEA) method. The conventional method is based on an efficiency concept originally developed by Farrell (1957) and was first developed by Charnes et al. (1978) as the CCR model. Homogenous decision making units (DMUs) are used to determine the efficiency frontier and the units at that frontier are defined as efficient. The other units are scored according to their position compared to the frontier. The efficient DMUs in the conventional model have a score of 1 and those that are not efficient have scores below 1 according to their position compared to the frontier. In the following years, CCR is modified by Andersen and Petersen (1993) to break the tie of efficient DMUs which does not allow them to exceed the score of 1. This improved model is called as super efficiency model. The analysis is carried out by excluding the evaluated DMU from the reference set, thereby providing the flexibility in the score of the efficiency. On the other hand, efficiency scores of the inefficient DMUs remain same as in the conventional CCR model (Lee et al., 2011). Although it is argued that the standard can not be achieved in the super efficiency scores provided by the model, the differentiation of the scores of the efficient units increases its functionality when compared with the conventional methods (Zhu, 2014:177).

2.2. Regression Analysis

Various methods are used to examine the statistical relationships in between variables, and to model in order to understand the relational mechanisms of variables. One of the most common and the simplest method is the regression analysis. It provides a lenient way to examine functional relationships between discussed variables (Chatterjee and Hadi, 2015:1). Application area of this method is wide and its practices occur in almost every field such as economics, management, social sciences, engineering, physical and chemical sciences, and biological sciences (Montgomery et al., 2012: 21).

Before applying the numerical analysis and obtaining the results, the expected relationship is simply expressed in the form of a model connecting the dependent and one or more explanatory variables Chatterjee and Hadi, 2015:1). The statistical model can be expressed as follows in a theoretical model (1):

$$Y = f(X_1, X_2, X_3, \dots, X_i, \varepsilon) \quad (1)$$

where:

Y = dependent variable,

$X_1, X_2, X_3, \ldots, X_i$=set of explanatory variables,

ε=residuals from the model (the part that model cannot explain)

The regression models can vary according to aim of their usage, and probably the most commonly applied form is the linear one. The linear regression model can be expressed as (2):

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_i X_i + \varepsilon \quad (2)$$

The only difference of the regression model from the previous statistical model are βs. They are the coefficients of the model which quantify the direction and the strength of the statistical relationships between the dependent variable and individual explanatory variables (Esquerdo and Welc, 2018:2). These coefficients perform a crucial task since they are used to understand the direction and the strength of the relationship.

After the model is estimated, various diagnostic tests should be carried out even if the relationships are significant in the model. These usually consist of 4 tests that check the important assumptions for the reliability and validity of the model. These are (i) the conditional mean of ε is zero, (ii) coefficient constancy which reveals that both β and ε are fixed over the sample period, (iii) serial independence in the disturbances of ε, and (iv) a distributional assumption of normality for ε (Pagan and Hall, 1983). Ensuring these assumptions makes the model more reliable. If the previous steps fail, t statistics should be reconfigured by applying other correctional methods and the model should be made practicable.

2.3. Data

The variables of the data set used in the study are presented in Table 1. The ports in the list are composed of ports with container throughput over 50000 TEU in 2016. Ranked by their TEU volumes, ports are listed in the table below. The variables in the table are used for both super efficiency and regression analysis. In the super efficiency analysis container throughput is used as output while berth length, number of quay crane and number of yard equipments are used as inputs. In the regression analysis, all variables are included as independent variables in the model. The dependent variable of the model is comprised of the super efficiency scores obtained from the data envelopment analysis.

Table 1: Port Variables Used in the Analysis

	ÇIKTI	**GİRDİLER**		
Port Name	**Container Throughput**	**Length of the Container Terminal**	**Number of Quay Crane**	**Number of Yard Equipments**
Marport	1846995	1605	15	60
MIP (Mersin)	1453038	2385	18	59
Asya Port	694107	1330	13	43
Evyapport	688496	813	9	32
Kumport	664787	2024	13	37
Yılport	396099	762	8	28
TCE EGE	366845	703	4	13
Gemport	356461	866	7	29
Mardaş	291138	910	11	22
Nemport	271751	820	5	12
Borusan	249466	450	8	19
Limak İskenderun	243745	920	6	21
Port Akdeniz	172036	440	4	8
Assan Port	131051	680	5	7
Rodaport	86322	1200	4	7
Samsunport	54929	776	3	6
DP World Yarımca	51553	922	6	18

Source: Collected from Ports' Websites

2.4. Research Model

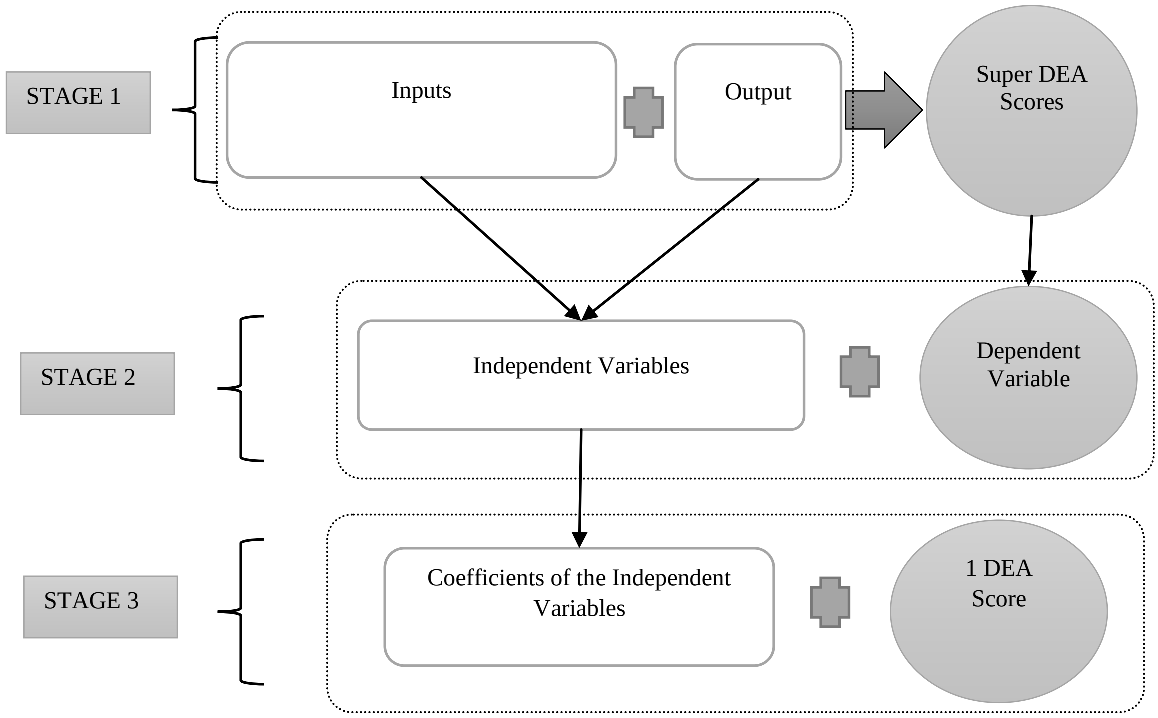
The research model of the study is presented in Figure 1 and is explained stage by stage below.

Stage 1: At this stage, the super-efficiency scores for each container terminal are determined by using the input and output variables. The selected input variables used in the data envelopment analysis are the number of quay cranes, the number of yard equipments and berth length, while the output variable is the quantity of containers handled.

Stage 2: At this stage, all variables (both inputs and output) included in the data envelopment analysis are used as independent variables, while super-efficiency scores are used as the dependent variable in the regression model. Then, the regression model is estimated.

Stage 3: At this stage, the coefficients obtained from the regression equation are separated and the equation is set up. Then the output variable is left alone on one side of the equation to calculate the target output quantity which is the main purpose of the study.

Figure 1: Research Model of the Study



3. FINDINGS

In this section, the results obtained from the applied methods are presented and evaluated over various possible scenarios. Firstly, the results of super efficiency analysis are presented followed by the targeted coefficients that are obtained by estimating the regression model.

3.1. DEA Super Efficiency Results

DEA super efficiency analysis is performed with the variables mentioned in the Table 1 as berth length, number of quay crane and number of yard equipments are inputs, and the amount of handled TEU is output. The results of the analysis are presented in Table 2. Contrary to the traditional data envelopment analysis, in the super efficiency analysis, the results can exceed the score of 1. The results of the analysis reveal that the most efficient port is Marport with a score of 1.55. It is followed by TCE Ege and MIP ports. On the other hand, least efficient ports are DP World and Samsunport. After obtaining the super-efficiency scores for each port, the estimation of the regression equation is explained in the next section.

Table 2: DEA Super Efficiency Results

Rank	DMU Name	Efficiency	Rank	DMU Name	Efficiency
1	Marport	1,55	10	Borusan	0,48
2	TCE EGE	0,92	11	Yılport	0,46
3	MIP (Mersin)	0,80	12	Mardaş	0,43
4	Evyapport	0,74	13	Gemport	0,41
5	Nemport	0,74	14	Rodaport	0,40
6	Port Akdeniz	0,70	15	Limak İskenderun	0,38
7	Assan Port	0,61	16	Samsunport	0,30
8	Kumport	0,58	17	DP World Yarımca	0,09
9	Asyaport	0,52			

3.2. Regression Analysis Results

Theoretically established regression model is as follows. It consists of 1 independent and 4 dependent variables. The efficiency scores obtained by data envelopment analysis in the previous phase are modeled as dependent variables, and all the variables used in the DEA analysis are added to the model as independent variables. Then the model is estimated through an econometric software (Eviews 10) to obtain the coefficients of the variables.

$$Y_p = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon$$

$$Efficiency_p = \beta_0 + \beta_1 Output_p + \beta_2 BerthLength_p + \beta_3 QuayCraneNo_p + \beta_4 YardEquNu_p + \varepsilon$$

The regression model is estimated by the least squares method and the results are presented in Table 3. The model is significant according to the F statistic that shows the significance of the model as a whole. In addition, the changes in the independent variables explain 88% of the changes in the dependent variable according to the adjusted R squared value. This value is very high and is an indication of how well the model is established. When the variables in the model are investigated, it is seen that all variables, except number of quay crane variable, are significant. Significance value, statistically, depends on the degree of contribution. This variable can still be used in the model, but as its coefficient indicates, its contribution is exiguous. The coefficients of the model are obtained. However, certain diagnostic tests should be applied to the model's residuals in terms of reliability and validity of the model.

Table 3: Regression Analysis Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.679025	0.069165	9.817498	0.0000*
Output	1.33E-06	1.46E-07	9.171792	0.0000*
Berth Length	-0.000178	8.65E-05	-2.051389	0.0627**
Number of Quay Crane	0.002587	0.020306	0.127406	0.9007
Number of Yard Equip.	-0.022265	0.006597	-3.375146	0.0055*
C	0.679025	0.069165	9.817498	0.0000*
R-squared	0.915191	**F-statistic**	32.37352	
Adjusted R-squared	0.886921	**Prob(F-statistic)**	0.000002*	

Significance Levels: *1%, **10%

One of the tests applied to the residuals of the model is the autocorrelation test. For a robust model, there should be no autocorrelation relationship between residuals. The test is performed and the results are presented in Table 4. The null hypothesis of this test is that there is not any autocorrelation between residuals, and the null hypothesis cannot be rejected based on the results of all lags.

Table 4: Autocorrelation Test Results

Lags	**AC**	**PAC**	**Q-Stat**	**Prob.**	**Lags**	**AC**	**PAC**	**Q-Stat**	**Prob**
1	0.058	0.058	0.0673	0.795	7	0.015	-0.015	3.0236	0.883
2	0.284	0.282	1.8076	0.405	8	-0.151	-0.016	3.8431	0.871
3	-0.091	-0.130	1.9990	0.573	9	-0.195	-0.276	5.3758	0.800
4	0.002	-0.072	1.9991	0.736	10	-0.113	-0.036	5.9622	0.818
5	0.050	0.131	2.0670	0.840	11	-0.238	-0.110	9.0082	0.621
6	-0.180	-0.208	3.0167	0.807	12	-0.128	-0.232	10.067	0.610

Other tests that should be applied to residues are serial correlation LM test, heteroscedasticity test and normal distribution test. In order for the model to be robust, it requires not having a serial correlation and a changing variance. Also the residuals should have a normal distribution characteristic. The null hypotheses of these tests are respectively, “there is no serial correlation”, “there is no change in variance” and “the residuals are distributed normally”. The null hypothesis for all tests cannot be rejected and the model and the coefficients are considered to be reliable.

Table 5: Autocorrelation Test Results

White Test	F-statistic	0.995101	Prob. F(2,10)	0.4035
	Obs*R-squared	2.821758	Prob. Chi-Square(2)	0.2439
LM Test	F-statistic	0.415214	Prob. F(14,2)	0.8738
	Obs*R-squared	12.64828	Prob. Chi-Square(14)	0.5544
	Scaled explained SS	5.729975	Prob. Chi-Square(14)	0.9728
Normality Test	Skewness	-0.069783	Jarque-Bera	0.037160
	Kurtosis	2.818389	Probability	0.981592

After all these steps are carried out, the new model with the coefficients obtained from the regression equation is formed as below:

$$Efficiency_p = 0{,}679024736 + 0{,}000001335 * Output_p + (-0{,}000177543 * BerthLength_p) + (0.002587 * QuayCraneNu_p) + (-0{,}022265411 * YardEquNu_p) + \varepsilon$$

In this model, the left side of the equation is fixed to 1 to find the values that make the dependent efficiency variable 1:

$$Efficiency_p = 1$$

$$1 = 0{,}679024736 + 0{,}000001335 * Output_p + (-0{,}000177543 * BerthLength_p) + (0.002587 * QuayCraneNu_p) + (-0{,}022265411 * YardEquNu_p) + \varepsilon$$

Then, for the purpose of the study, mathematical operations are carried out to leave the output variable alone on one side of the equation:

$$1 - 0{,}679024736 - (-0{,}000177543 * BerthLength_p) - (0.002587 * QuayCraneNu_p) - (-0{,}022265411 * YardEquNu_p) = 0{,}000001335 * Output_p$$

As a result, the recommended model for the container terminals to determine the most effective output level relative to the inputs is as follows:

$$Output_p = \frac{1 - 0{,}679024736 - (-0{,}000177543 * BerthLength_p) - (0.002587 * QuayCraneNu_p) - (-0{,}022265411 * YardEquNu_p)}{0{,}000001335}$$

In the following section, it is aimed to define how this model can be used in port industry throughout possible scenarios. In this way, it is hoped that the results may be embodied and their comprehension may be facilitated.

3.3. Application of Scenarios

In this section, using the coefficients obtained from the regression analysis, it is presented in several possible scenarios how the target output may be affected by the changes in the input values according to several investment decisions. Investment decisions are evaluated through input variables discussed in the regression model. At this point, number of yard equipments and berth lengths come into prominence among the inputs used. As quay cranes in the ports are not used in large numbers, their impact on the efficiency of the port is very low (0.0025) compared with their high investment costs. Even though, this input variable is included in the calculation of the target output model in the scenario analysis, as its impact on port efficiency is very low, it can not be considered as an investment opportunity. In this context, investment scenarios are applied by using berth length and number of yard equipments inputs. In order to diversify the results, scenarios are applied to two ports which are at the top and mid of the efficiency ranking. In addition, when determining the target outputs after the investment decisions in the scenarios, two possible output targets are calculated: (i) how much the ports should handle to maintain the existing efficiency scores, (ii) how much the ports should handle to reach the standard efficiency score of 1. The scenarios are applied in this direction and the results obtained are presented in the following parts.

Scenario 1 Marport: Sustaining Efficiency

Based on DEA, super efficiency score of Marport is 1,55 and the variables used in efficiency calculation are as follows; TEU throughput is 1846995, berth length is 1605 meters, number of quay cranes is 15 and number of yard equipments is 60. Considering that Marport is placed at the top of the efficiency rankings, the following scenarios are designed in order to maintain their efficient operations after several possible investments are carried out.

1.a. Investment on Berth Length

This scenario assumes that the port has decided to increase the overall berth length by 100 meters. In order to reveal the target output that would not hamper the operational efficiency, our proposed model is applied and the results are shown in Table 6.

Table 6: Target Outputs after Berth Length Increase

Variables	Coefficients	Previous	New
C	0,679024736	-	-
TEU Throughput	0,000001335	1846995	1846995

Berth Length	-0,000177543	1605	1705
Nu. Of Quay Crane	0,002587132	15	15
Nu. Of Yard Equip.	-0,022265411	60	60
Target Outputs After Investment		**To Maintain "1"**	**To Maintain "1.55"**
		1439165 TEU	1851253 TEU

In order to obtain these target output results, two steps are taken. Initially, berth length is increased from 1605 to 1705 and efficiency score is set to 1 as it is the bottom score to be identified as an efficient terminal. Therefore, the target output in said conditions is revealed to be 1439165 TEUs. In the second step, berth length is increased 100 meters again and the efficiency score is set to 1.55, which is the current super efficiency score of the terminal. To keep this efficiency level, the target output is calculated to be 1851253 TEUs. As a result of both steps, it can be concluded that terminal should handle at least 1439165 TEUs to stay as an efficiently operated terminal and should aim to exceed 1851253 TEUs to improve efficiency.

1.b. Investment on Yard Equipment

The assumption behind this scenario is that the port has decided to invest on yard equipment and purchase 10 additional equipment to be used in storage and transport operations at yard side. Table 7 shows the target output results that are revealed after the application of our purposed model.

Table 7: Target Outputs after Yard Equipment Increase

Variables	Coefficients	Previous	New
C	0,679024736	-	-
TEU Throughput	0,000001335	1846995	1846995
Berth Length	-0,000177543	1605	1705
Nu. Of Quay Crane	0,002587132	15	15
Nu. Of Yard Equip.	-0,022265411	60	60
Target Outputs After Investment		**To Maintain "1"**	**To Maintain "1.55"**
		1439165 TEU	1851253 TEU

Similar to the previous scenario, two steps are followed to obtain the results. Initially, number of yard equipment is increased from 60 to 70 and efficiency score is set to 1 as it is the bottom score to be identified as an efficient terminal. Target output in said conditions are calculated to be 1592686 TEUs. In the second step, increase of yard equipment by 10 is inserted again and the efficiency score is set to current super efficiency score of 1.55. To keep this efficiency level, the target output is calculated to be 2004775 TEUs. Overall findings of this scenario is as follows; lowest TEU level to maintain as an efficient terminal is revealed to be 1592686, whereas any additional handling volume that is over 2004775 TEUs should be reached if the terminal aims to improve its current efficiency level after the yard equipment investment.

Scenario 2 Asya Port: Reaching to Efficiency Threshold

Asya Port is ranked at an average position with super efficiency score of 0,52. TEU throughput of the port is 694107 and the inputs consist of 1330 meters of berth, 13 quay cranes and 43 yard equipment. Considering that Asya Port is one of the inefficient ports, the following scenarios are designed in order to determine two target outputs after possible investments are carried out; (i) the target that maintains the current efficiency score (0.52) of the terminal and (ii) the target that reaches the efficiency threshold (1).

2.a. Berth Length Increase

This scenario assumes that the port has decided to increase the overall berth length by 100 meters. Unlike the scenarios on Marport, as this scenario determines the target output of an inefficient terminal, use of the model is twofold. Initially, the aim is to determine the target output after the berth investment is carried out in a way that it does not hamper the current efficiency level (0.52), even though it is far below the efficiency threshold. Then, the model is run again to determine the target output that would enable Asya Port to reach to the efficient level after the berth length is increased by 100 meters. Table 8 presents the target outputs after said investment is made.

Table 8: Target Outputs after Berth Length Increase

Variables	Coefficients	Previous	New
C	0,679024736	-	-
TEU Throughput	0,000001335	694107	694107
Berth Length	-0,000177543	1330	1430
Nu. Of Quay Crane	0,002587132	13	13
Nu. Of Yard Equip.	-0,022265411	43	43
Target Outputs After Investment		**To Maintain "0.52"**	**To Reach "1"**
		766498 TEU	1122859 TEU

In the first calculation, the berth length is increased from 1330 to 1430 meters and efficiency level is set to the current efficiency score of 0,52. Results show that to maintain the current efficiency level, target output should be increased to 766498 TEUs. In the second calculation, the same increase in berth length is inserted and the efficiency level is set to efficiency threshold that is 1. To become an efficiently operated terminal, the target output should be above 1122859 TEUs.

2.b. Yard Equipment Increase

The assumption behind this scenario is that the port has decided to invest on yard equipment and purchase 10 additional equipment to be used in storage and transport operations at yard side. Calculated target outputs are presented in Table 9.

Table 9: Target Outputs after Berth Length Increase

Variables	Coefficients	Previous	New
C	0,679024736	-	-
TEU Throughput	0,000001335	694107	694107
Berth Length	-0,000177543	1330	1330
Nu. Of Quay Crane	0,002587132	13	13
Nu. Of Yard Equip.	-0,022265411	43	53
Target Outputs After Investment		**To Maintain "0.52"**	**To Reach "1"**
		920020 TEU	1276381 TEU

In the first calculation, the number of yard equipment is increased from 43 to 53 and efficiency level is set to the current efficiency score of 0,52. Results show that to save the current efficiency level, target output should be increased to 920020 TEUs. In the second calculation, the same increase in number of yard equipment is inserted and the efficiency score is set to 1. In order to be categorized as an efficiently operated terminal, the minimum handling volume that Asya Port should achieve is calculated to be 1276381 TEUs.

CONCLUSION

Increasing the operational capability of a terminal through investments is one of the most preferred tools in the search of competitive advantage. However, not every investment is a safe bet for success. Especially, considering the cost-intensive nature of port investments, more often than not, these investments result in increased costs instead of achieving the expected benefits (Lirn et al., 2014). From the efficiency perspective, these investments tend to account for additional inputs. Therefore, when these increase in inputs does not deliver the expected level of outputs, the investment actually ends up hampering the efficiency level of the terminal. Such risks require the investment decisions to be made with minimum amount of ambiguity in order to decrease the chance of facing idle capacity, lowered efficiency, increased costs and cash flow related problems.

Although the significance of investment decisions impact on terminal efficiency is apparent, broad port efficiency literature has scarce amounts of researches that focus on this particular issue. The ones that focus on investment impact on port/terminal efficiency are not preemptive and only gauge the impacts of investments that are already made (e.g. Garcia-Alonso and Martin-Bofarull 2007; Sağlam et al., 2018). Even though these studies are valuable contributions, the practical implications that they provide barely goes beyond the ports/terminals that were subject to said researches. Stemming from these gaps, this study develops a preemptive and proactive tool that will enable decision makers to evaluate their investment plans by providing them with a target output level. In the development of this tool, the combined usage of super efficiency DEA method and linear regression analysis was methodologically proposed. Simply put, if the target output levels obtained after using the tool developed are achievable, the investment can be considered feasible in terms of efficiency. If the obtained target output level appears to be an arbitrary number that seems unrealistic to achieve, that investment plan can be destructive for efficiency of operations.

The main limitation of this research is that it employs a narrow data set that consists of 17 Turkish container terminals. By increasing the number of DMUs the accuracy of the results can also be increased in both super efficiency DEA and linear regression models and as a result, in the target efficiency tool that employs these methods. In addition, diversification of the yard equipment can help refine their impact on terminal efficiency, thus the tool would be able to provide more realistic results. Lack of standardized information provided by subject terminals on this matter fettered the authors. Further studies can contribute to the literature by applying the same model in an international setting and/or with a wider sample.

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