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From the Strategic Management Perspective Examining Turkish Railways' Performance Considering Railway Accidents

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Abstract

Benchmarking is frequently used in strategic management, while it may not be possible to compare companies such as Turkish Railways (TCDD) with their competitors due to unique structures. In such cases, the dynamic data envelopment analysis method, which is based on the ratio of outputs to inputs with the company's long-term data, can be used. One of the advances in data envelopment analysis in recent years is the ability to include undesired outputs. While determining the best practice, undesirable factors as railway accidents should also be considered for performance evaluation. To my knowledge, there is no study considering accidents in railway performance evaluation. In this context, this study aims to evaluate the performance of railways with 17-year data of TCDD, considering railway accidents, which are undesirable outputs for railways. In this way, it is aimed to contribute to the railway performance evaluation literature by adding undesirable outputs. The total length (km) and the number of personnel are inputs, the total number of passengers and the total freight are desired outputs, and the number of railway accidents is undesired output. The findings show that the best practice example for TCDD is 2013. The findings suggest that practitioners and decision makers should consider undesirable outputs in performance measurement. In addition, suggestions made to the researchers regarding the studies to be carried out within the framework of green management considering undesirable outputs.

Keywords: strategic management, data envelopment analysis with undesirable outputs, dynamic analysis, railway performance

Article Type: Research Article

Stratejik Yönetim Perspektifinden Türk Demiryolları Performansının Demiryolu Kazaları Dikkate Alınarak İncelenmesi

Öz

Kıyaslama (benchmarking) stratejik yönetimde sıklıkla kullanılmasına rağmen, Türkiye Cumhuriyeti Devlet Demiryolları (TCDD) gibi bir ülkedeki tüm demiryolu operasyonlarını yürüten firmaların kendilerine özgü yapıları nedeniyle rakipleri ile kıyaslanmaları pek mümkün olamayabilir. Böyle durumlarda, firmanın uzun dönem verileri ile çıktıların girdilere oranına dayanan dinamik veri zarflama analizi yöntemi kullanılabilir. Veri zarflama analizinde son yıllardaki ilerlemelerden biri de istenmeyen çıktıların analize dahil edilebilmesidir. En iyi uygulamanın belirlenmesinde, demiryollarında meydana gelen kazalar gibi istenmeyen durumların da performans değerlendirmesine dahil edilmesi gerekmektedir. Literatürde demiryolu kazalarının dikkate alındığı bir performans değerlendirme çalışmasına rastlanılmamıştır. Bu kapsamda, bu çalışmada demiryollarından istenmeyen çıktı olan demiryolu kazaları dikkate alınarak, TCDD'nin 17 yıllık (2005-2021 arası) verileri ile demiryolu performansının incelenmesi amaçlanmıştır. Bu şekilde, demiryolu performans değerlendirmesi literatürüne istenmeyen çıktıların eklenmesi ile katkı sağlanması amaçlanmaktadır. Analizde toplam raylı sistem uzunluğu (km) ve insan kaynağı girdi olarak, toplam yolcu sayısı ve toplam taşınan yük miktarı istenen çıktı olarak, demiryolu kazası sayısı ise istenmeyen çıktı olarak alınmıştır. Elde edilen bulgular, TCDD için en iyi uygulama örneğinin 2013 yılı olduğunu göstermektedir. Elde edilen bulgulardan uygulayıcılara ve karar vericilere, performans ölçümünde istenmeyen çıktıların göz önünde bulundurulması önerisinde bulunulmuştur. Ayrıca, araştırmacılara yeşil yönetim çerçevesinde gerçekleştirilecek çalışmalarda istenmeyen çıktıların performans ölçümünde dikkate alınmasına ilişkin önerilerde bulunulmuştur.

Anahtar Kelimler: stratejik yönetim, istenmeyen çıktılı veri zarflama analizi, dinamik analiz, raylı sistem performansı

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1. INTRODUCTION

Benchmarking is used as one of the popular tools of strategic management. The purpose of benchmarking is to seek out best practice and incorporate it into the firm's operations to gain competitive advantage (Cheng, 2004). Best practice is often determined by measuring performance among different companies. However, if a company operates the country's whole railways, it may have no competitors. One of them is TCDD (Turkish State Railways), which is a subsidiary (state economic enterprise) of the Ministry of Transport and Infrastructure and operates the railways in Türkiye. In cases where there is no other competitor that can be included in the comparison, such as in the TCDD example, the company's performance in the past years is evaluated and the best practice is sought in the company's previous year data. Then the strategies for improvement can be determined based on the best practice period.

To determine the best practice, data envelopment analysis (DEA) is the most widely used non-parametric method. Charnes, Cooper and Rhodes (1978) purposed the CCR model for DEA. Banker, Charnes and Cooper developed the BCC model for variable returns to scale DEA. Homogeneous DMUs (decision making units) can be included in the analysis, as well as comparisons can be made with the data of the same DMUs from different years.

Basically, DEA is the ratio of outputs to inputs. There are also some new approaches, undesirable outputs is one of them. Environmental factors such as exhaust emissions, the number of dismissals or the number of accidents are examples for the undesirable outputs. In other words, if two DMUs (or different periods) compared, and they both produce 100 units of output, using 100 units of input. Let the first is completed the production with 2 accidents, and the second with 5 accidents. Certainly, the first DMU (or period) has higher efficiency due to less accidents.

Railway accidents are serious and fatal accidents. While the number of railway accidents in 2016 is 101 on average in the European Union, it is 120 in Türkiye (EUROSTAT, 2017; TCDD, 2022). The effect of railway accidents on railway efficiency should also be considered.

The origin of the railways in Türkiye is started with the 130 km Aydın-İzmir train line constructed between 1856 and 1866. Turkish railways, with a history of more than 150 years, has reached 13,022 km by the end of 2021. TCDD was established in 1953 and still operates as the Railway Infrastructure Operator in the country. As of 2021, TCDD has 125 electric locos and 431 diesel locos, 640 passenger cars and 16476 freight wagons. TCDD has a total of 22813 personnel at the end of 2021, of which 2780 are in general directorates and units, 10496 are regional personnel, and 9588 are affiliated directorates (TCDD, 2022).

Turkish railways have been in operation for over 150 years and has a long way to go. While the European average is 49 km in length per thousand square kilometers, it is 13 km in Türkiye. Frequency of the population traveling by rail the European average is 12.8, but it is 1.8 in Türkiye. In Europe the rate of passenger transport by rail is 8.1% and rate of freight by rail is 16.2%, rates in Türkiye are 4.2% and 4.4%, respectively. Compared to other countries in Europe, Turkish railways need to develop (TCDD, 2022). In this context, Türkiye needs to use existing railway infrastructure more efficiently.

This study aims to evaluate the performance of railways with 17-year data of TCDD, considering railway accidents, which are undesirable outputs for railways. In this way, it is aimed to contribute to the railway performance evaluation literature by adding undesirable outputs. The 17-year (2005-2021) operations of Turkish railways is evaluated, and the best practice is determined.

The rest of the paper is as follows; literature review on railways efficiencies in second section, DEA and its methodology with undesirable outputs in third section, the data set and variables in forth section, the findings in fifth section, discussion and conclusions are in the last section.

2. LIRETATURE REVIEW

There are several studies evaluating the efficiency of railways. Hilmola (2007) used 1980-2003 data to compare Europe and eastern bloc countries in railway efficiency. Total route km, number of locomotive, personnel and freight wagons are used as inputs, total freight and freight ton-km are used as outputs. Using the classical CCR model, Estonia, Latvia and Lithuania are determined the countries that increase their efficiency.

Kabasakal, Kutlar and Sarıkaya (2015) obtained the efficiency scores of thirty-one railway companies operating worldwide, covering the period from 2000 to 2009, using classical DEA models. The effects of outputs on efficiency were estimated via panel regression analysis. In addition, efficiency changes examined with the Malmquist total factor productivity index.

Lawrence and Erwin (2003) examined the performances of 76 railways around the world from 1999 to 2001 with input-oriented CCR and BCC models and hyperbolic DEA. In addition, the efficiency differences between regions were examined by the Kruskal-Wallis method.

Bhanot and Singh (2014) compared before and after the privatization of Indian railways. The study focused only on container transportation by rail, via data covering 1995-2011. The number of terminals, the number of personnel, the number of equipment, the number of wagons and the number of containers are used as inputs, and the freight ton km and net profit are as outputs. Input-oriented both CCR and BCC models used for the study.

Yu and Lin (2008) evaluated the 2002 efficiency of 40 European railways with both classical DEA and network-DEA. Railway line length, number of personnel, number of freight wagons and number of passenger cars are used as input, freight ton-km and passenger-km are used as output. In addition, population density and gross national income per capita were used as environmental variables. By comparing the results of DEA and network-DEA, it was stated that network-DEA allowed more in-depth evaluations.

Doomernik (2015), on the other hand, focused on the efficiency of high-speed railways and examined Asia and Europe by data covering 2007-2012. Using the Malmquist index with the network-DEA, the fleet capacity and railway length are used as input, and the number of passengers and passenger-km are as outputs.

Studies examining the railways efficiencies with DEA models with undesirable output also exists in the literature. In these studies, environmental variables are usually taken as undesirable output. Song et al. (2016) evaluated the 30 Chinese regions railway efficiency by network-DEA. They used carbon dioxide emissions and sulphury emissions as undesirable outputs. Zhou and Hu (2017) used capital and labor as inputs, and dust emission as undesirable output as well as traditional outputs.

Djordjević et al. (2018) used railway accidents as undesirable output, where the level crossings and assets are used as inputs, and freight and passenger volumes as desired outputs. The non-radial DEA method was used in the study, which includes data from 28 European countries covering the years 2010, 2011, 2012 and 2014. The study only prioritizes railways safety, and the efficiency of railways is not discussed by choosing the variables used to cause railways accidents. In the present study, the efficiency of railways is at the forefront and railway accidents are considered as the undesirable output.

Sun, et al. (2020) examined environmental efficiency in high-speed train systems and took sulfur dioxide and industrial wastes as undesirable output. The priority is given to environmental efficiency, instead of railways efficiency. Liu, Qin and Zhang (2016) examined the efficiency of regional railways in China in the context of energy-environment, and carbon dioxide emissions were taken as output. In both studies, emissions and wastes were considered to examine environmental efficiency.

In this study, to examine the efficiency of railways over multi-year data by including undesirable outputs is aimed. By keeping the railways efficiency in the foreground, the data for the years 2005-2021 in Türkiye were used. As far as known, there is no DEA model in the literature that prioritizes the efficiency of railways and includes undesirable outputs. In this sense, it is expected that the study will contribute to the literature.

3. METHODOLOGY

First introduced by Debreu in 1951 and Farrell in 1957, efficiency and resource utilization ratio is based on the ratio of output to input, which is basically a simple ratio analysis (Debreu, 1951; Farrell, 1957). These studies have led to the foundations of the DEA method, which is widely used today in efficiency measurement. The first study to propose the so-called Data Envelopment Analysis (DEA) measure of efficiency is the work of Charnes, Cooper, and Rhodes (1978). Although DEA is the subject of many different applications, it is still the most widely used method to determine the comparative efficiency of decision-making units (DMUs).

When the foundations of DEA were laid, the basic assumption was that efficiency would not change at scale. Constant returns to scale (CRS) was referred to as the CCR model, named by the initials of Charnes, Cooper and Rhodes (1978).

Later studies revealed that efficiency can vary by scale, and a variable returns to scale (VRS) approach was proposed. This model was also referred to as the BCC model, with the initials of its proponents Banker, Charnes and Cooper (1984).

DEA is used to determine the most efficient DMU among the analyzed DMUs or to determine the best practice of the same DMU among different periods. In this study, the best practice year is tried to be determined by comparing the activities of TCDD between 2005 and 2021.

A DEA data domain can be expressed by a data matrix as;

$$P = \begin{bmatrix} Y \\ -X \end{bmatrix} = [P_1, \ldots., P_n]$$

with $s + m$ rows which are s outputs and m inputs, and n columns, each column corresponds to one of the DMUs or a year of a DMU. The j^{th} column can be expressed as;

$$P_j = \begin{bmatrix} Y_j \\ X_j \end{bmatrix}$$

x_{ij} $i = 1,\ldots,m$ is the inputs for the j^{th} year and y_{rj} $(r = 1,\ldots,s)$ is the output for the same year. The output-oriented BCC can be written as (Seiford & Zhu, 2002);

$$\max \eta$$

subject to;

$$\begin{aligned} &\sum_{j=1}^{n} z_j x_j + s^- = x_0, \\ &\sum_{j=1}^{n} z_j y_j - s^+ = \eta y_0, \\ &\sum_{j=1}^{n} z_j = 1, \\ &z_j \geq 0, \quad j = 1, \ldots., n \end{aligned} \tag{1}$$

where the x_0 is the input vector and y_0 is the output vector of DMU_0 under evaluation.

X inputs and Y outputs, which are the subject variables of this classical BCC model, affect efficiency as follows; DMUs that produce the most Y by using at least X considered as efficient, otherwise inefficient. If the outputs are classified as good and bad; it is desired the good outputs (Y^g) to increase and the bad outputs (Y^b) to decrease in order to increase the performance of the DMU.

Seiford and Zhu (2002), purposed to multiply the bad (undesirable) outputs by –1 and find a better translation vector (w) to convert negative undesirable outputs to positive. Then they expressed the data domain as;

$$\begin{bmatrix} Y \\ -X \end{bmatrix} = \begin{bmatrix} Y^g \\ \bar{Y}^b \\ -X \end{bmatrix},$$

for the j^{th} year (column), undesirable output (y^b) is converted as; $\bar{y}_j^b = -y_j^b + w \geq 0$. By this transformation, classical BCC model (1) with undesirable outputs as follows;

$$\max h$$

subject to;

$$\sum_{j=1}^{n} z_j y_j^g \geq \mathrm{h} y_0^g,$$

$$\sum_{j=1}^{n} z_j \bar{y}_j^b \geq \mathrm{h} \bar{y}_0^b, \qquad (2)$$

$$\sum_{j=1}^{n} z_j x_j \leq x_0,$$

$$\sum_{j=1}^{n} z_j = 1,$$

$$z_j \geq 0, \qquad \mathrm{j} = 1, \ldots, n$$

By model (2) desired outputs expands and undesirable outputs shrink to ensure the efficiency. In this way, the efficiency of the railway system can be evaluated by considering undesirable outputs.

4. VARIABLE SELECTION AND DATASET

This study focuses on the railway efficiency of Turkish railways, data collected from TCDD web page annual statistics (TCDD, 2010, 2014, 2018, 2022). Since the data is available online ethics report is not required. Most of the studies evaluating the railway efficiency, use total railway length and number of employees as input. In this study, the same inputs used. For the outputs, total passengers and total freight tonnage taken. Another factor included in the outputs is the number of accidents, hence it is taken as the undesirable output. This study differs from the previous ones in two points, the first is that it deals with the railways efficiency with multi-year data, and the second is that it considers the number of accidents as an undesirable output in the railways efficiency. Railway system DEA model is conceptualized as Figure 1.

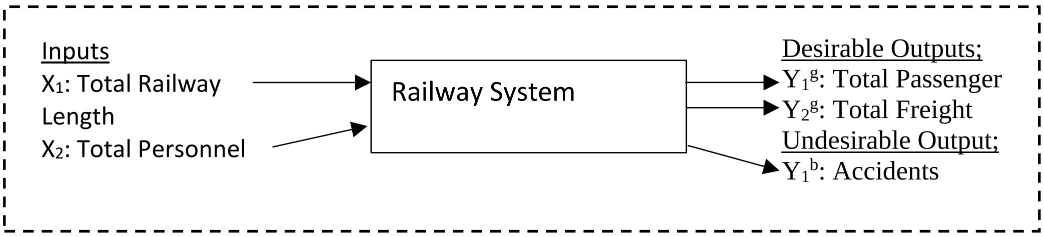

Figure 1. Model for Railway Efficiency with Undesirable Outputs

Descriptive statistics are given in Table 1. First column is the total length of railways, second column is the total personnel, third column is the number of passengers, forth column total freight, fifth column is the number of accidents.

Table 1. Dataset and Descriptive Statistics

Years	Railway Length (km) (X1)	Total Number of Personnel (X2)	Number of Passengers (1000) (Y1g)	Total Freight (1000 Tons) (Y2g)	Number of Accidents (Y1b)
2005	10973	36854	76306	19195	522
2006	10984	35456	77414	20185	455
2007	10991	36110	81260	21404	394
2008	11005	35141	79187	23491	386
2009	11405	33998	80092	21813	299
2010	11940	32642	86820	24355	194
2011	12000	32802	121190	25421	177
2012	12008	31857	120645	25666	147
2013	12097	29901	107646	26597	89
2014	12485	29829	153600	28747	93
2015	12532	29590	182759	25878	101
2016	12532	28146	176631	25886	120
2017	12608	27128	182790	28469	53
2018	12740	27540	185010	31673	71
2019	12803	27260	246144	33535	83
2020	12803	23044	148647	34549	66
2021	13022	22813	191659	38155	73
Minimum	**10973**	**22813**	**76306**	**19195**	**53**
Maximum	**13022**	**36854**	**246144**	**38155**	**522**
Mean	**12054,59**	**30594,76**	**135164,70**	**26765,82**	**195,47**
Std. Dev.	**727,33**	**4288,42**	**52523,42**	**5256,36**	**154,06**

Railway length (km) steadily increases from 2005 to 2021. This can be understandable since the railways can not be dismantled. Railway length increased by 20% from 10.973 km in 2005 to 13.022 km in 2021. Considering that the Turkish railways started to build in 1.855 and reached 10.973 km in 150 years, the 20% increase in 17 years seems quite successful.

The total staff has decreased from 36.854 in 2005 to 22.813 in 2021. To focus on numbers could be misleading. The developments in mechanization and the development of automation-signalling systems in the last 20 years have led to more efficient use of human resources.

The number of passengers, on the other hand, increased almost continuously from 76 million in 2005 to 246 million in 2019. Due to the Covid-19 pandemic restrictions, the number of passengers, which fell to 148,5 million in 2020, increased again in 2021, but could not reach yet the pre-Covid level.

The total freight carried in railways increased regularly from 2005 to 2021, reaching 38 million tons from 19 million tons. Although there was an increase of 100%, the enormous increase in the number of passengers (233%) did not catch up in freight transportation. This is because most of the investments made in railways are high-speed train investments and most of the new lines built for passenger transportation.

The number of accidents occurring in railways is a little more interesting. The number of accidents on train lines, which was 522 in 2005, decreased to 53 in 2017. Although it increased slightly between 2017-2021, it closed the series with 73. The accident data also reveal the importance of this study. Regular changes in other variables may not be sufficient to determine efficiency. Including railway accidents as an undesirable output in the efficiency calculation will allow for more consistent evaluation.

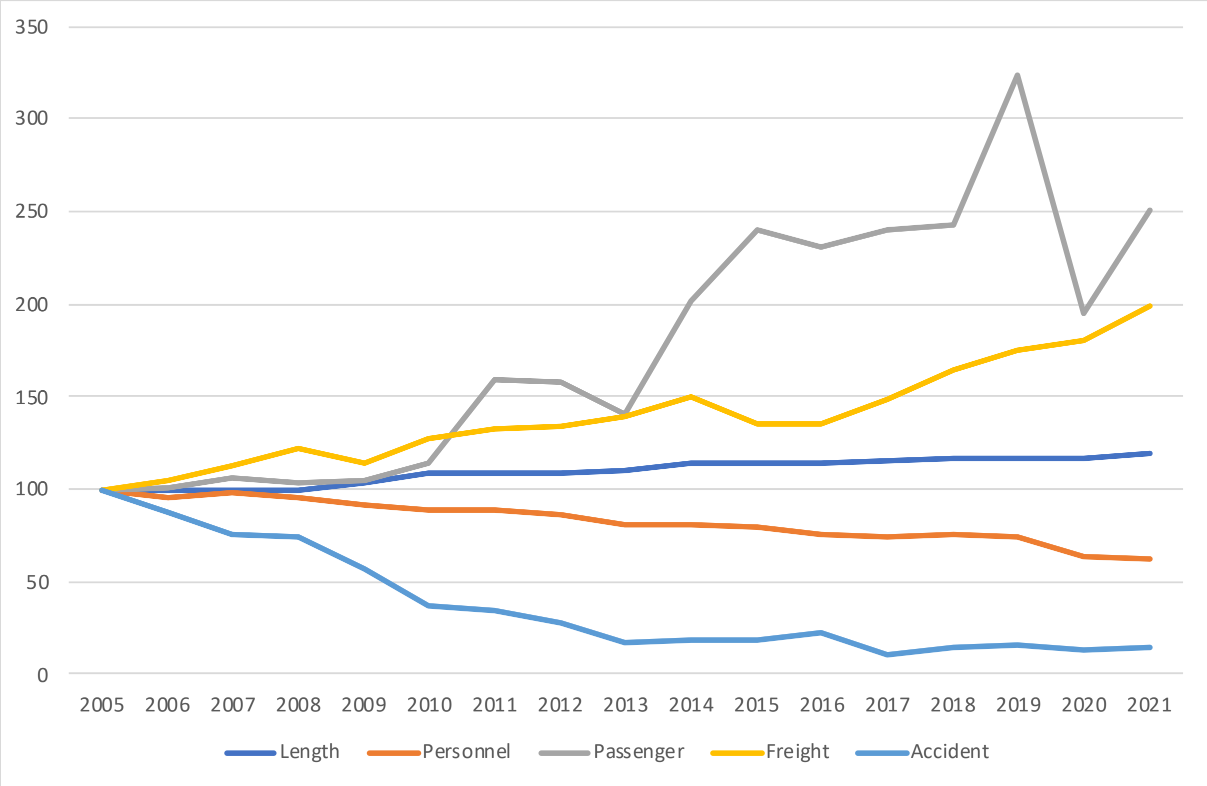

Figure 2. Change of variables by years (2005 data = 100 for all variables)

By fixing the 2005 value of each variable to 100, the trends are given in Figure 2. The change over the years can be clearly seen. The number of passengers (gray line) increased more than 200% and suddenly decreased in 2020 due to the Covid-19. The number of accidents (light blue line) is decreased steadily. Changes of variables by years are as seen in Table 1 and Figure 2.

There are different views in the literature regarding the relationship between the number of input-output factors included in DEA and the number of DMU or period. Golany and Roll (1989) and Dyson et al (2001) state that the number of DMUs or periods should be at least twice the number of variables, while Bowlin (2011) states that it should be at least three times the number of variables. In this study, a total of 17 periods and a total of 5 factors were included in the analysis. The requirements of both views have been met.

5. RESULTS

Output oriented BCC model with undesirable outputs (Seiford & Zhu, 2002) applied to the dataset. The obtained efficiency scores, and targets for inefficient years are given in Table 2. If the efficiency score is 1 for a year, efficiency is achieved, otherwise it is inefficient. 2005, 2006, 2007, 2008, 2013, 2017, 2019, 2020, 2021 are the efficient years, others are inefficient. Targets to ensure full efficiency are given in Table 2. Since all inputs are desirable inputs, inputs must be reduced to increase efficiency. For outputs, increasing the desired outputs (such as the number of passengers and the amount of freight in this study) and decreasing the undesirable outputs (the number of railway accidents) increase efficiency.

Table 2. Efficiency Scores, Input Reductions, Desired Output Improvements and Undesirable Output Reductions

Year	Efficiency Score	Rank	Total Railway Length (km)			Total Personnel			Total Passenger (1000)			Total Freight (1000 tons)			Number of Accidents		
			Input1	Target	Diff.	Input2	Target	Diff.	Output1	Target	Diff.	Output2	Target	Diff.	U.D. Output1	Target	Diff.
2005	1	1	10973	10973	0%	36854	36854	0%	76306	76306	0%	19195	19195	0%	522	522	0%
2006	1	1	10984	10984	0%	35456	35456	0%	77414	77414	0%	20185	20185	0%	455	455	0%
2007	1	1	10991	10991	0%	36110	36110	0%	81260	81260	0%	21404	21404	0%	394	394	0%
2008	1	1	11005	11005	0%	35141	35141	0%	79187	79187	0%	23491	23491	0%	386	386	0%
2009	1,097	8	11405	11405	0%	33998	33221	-2%	80092	89611	12%	21813	24628	13%	299	277	-7%
2010	1,113	9	11940	11940	0%	32642	30371	-7%	86820	109953	27%	24355	27104	11%	194	157	-19%
2011	1,069	6	12000	12000	0%	32802	30518	-7%	121190	129529	7%	25421	27323	7%	177	153	-14%
2012	1,018	3	12008	12008	0%	31857	30436	-4%	120645	122802	2%	25666	27061	5%	147	140	-5%
2013	1	1	12097	12097	0%	29901	29901	0%	107646	107646	0%	26597	26597	0%	89	89	0%
2014	1,041	4	12485	12485	0%	29829	27583	-8%	153600	159933	4%	28747	29932	4%	93	75	-19%
2015	1,044	5	12532	12532	0%	29590	28197	-5%	182759	190766	4%	25878	30593	18%	101	83	-18%
2016	1,087	7	12532	12532	0%	28146	28146	0%	176631	191975	9%	25886	30465	18%	120	85	-29%
2017	1	1	12608	12608	0%	27128	27128	0%	182790	182790	0%	28469	28469	0%	53	53	0%
2018	1,014	2	12740	12740	0%	27540	25817	-6%	185010	187691	1%	31673	32132	1%	71	64	-10%
2019	1	1	12803	12803	0%	27260	27260	0%	246144	246144	0%	33535	33535	0%	83	83	0%
2020	1	1	12803	12803	0%	23044	23044	0%	148647	148647	0%	34549	34549	0%	66	66	0%
2021	1	1	1302	13022	0%	22813	22813	0%	191659	191659	0%	38155	38155	0%	73	73	0%

For 2009 to ensure the efficiency, total personnel (input2) need to reduce 2% from 33.998 to 33.221, total passenger need to improve 12% from 80 million to 89,6 million, total freight need to improve 13% from 21,8 million tons to 24,6 million tons and number of accidents need to reduce 7% from 299 to 277. For 2010 to ensure the efficiency, total personnel (input2) need to reduce 7% from 32642 to 30371, total passenger need to improve 27% from 86 million to 110 million, total freight need to improve 11% from 24,3 million tons to 27,1 million tons and number of accidents need to reduce 19% from 194 to 157. For 2011, total personnel (input2) need to reduce 7% from 32,8 thousand to 30,5 thousand, total passenger need to improve 7% from 121,2 million to 129,5 million, total freight need to improve 7% from 25,4 million tons to 27,3 million tons and number of accidents need to reduce 14% from 177 to 153. For 2012 to ensure the efficiency, total personnel (input2) need to reduce 4% from 31,8 thousand to 30,4 thousand, total passenger need to improve 2% from 120,6 million to 122,8 million, total freight need to improve 5% from 25,6 million tons to 27 million tons and number of accidents need to reduce 5% from 147 to 140. The 2018 is the second closest to full efficiency among inefficient periods. The ranks for the periods are also given in Table 2.

To achieve full efficiency for 2014 and 2015, it is necessary to reduce human resources by 8% and 5%, increase the number of passengers by 4% for both, reduce the amount of freight by 4% and 18%, and reduce the number of accidents by 19% and 18%, respectively. For 2016, only improvements need to be made in the outputs. In this sense, the number of passengers should be increased by 9% and the amount of cargo by 18%, and the number of accidents should be reduced to 85 with a decrease of 29%.

Since 2018 is the closest period to full efficiency, it has the least improvement suggestions. With a 6% reduction in human resources, 1% increase in the number of passengers and freight, 10% reduction in the number of accidents is sufficient for full efficiency for 2018.

The applied model gives us more information about the dataset. For an inefficient year, efficient reference years and coefficients (lambdas) are given in Table 3. First inference from Table 3 is the years which are efficient, but not reference for inefficient years as 2005, 2006, 2007, 2020. These years are efficient but not a good reference for other periods. 2005, 2006 and 2007 are the years with many accidents, so they are not a good example in terms undesirable output. For 2020, the number of passengers is quite low due to Covid-19. That is why it is not a good example for efficiency.

Table 3. Reference sets for Inefficient Years and Lambdas

Year	2008	2013	2017	2019	2021
2005**	0	0	0	0	0
2006**	0	0	0	0	0
2007**	0	0	0	0	0
2008*	1	0	0	0	0
2009	0,6337	0,3663	0	0	0
2010	0,23426	0,65893	0	0	0,10682
2011	0,22024	0,5765	0	0,20326	0
2012	0,17558	0,6789	0	0,14552	0
2013*	0	1	0	0	0
2014	0	0,42457	0,28559	0,11888	0,17096
2015	0	0,35948	0,08823	0,55229	0
2016	0,01786	0,29078	0,17225	0,5191	0
2017*	0	0	1	0	0
2018	0	0,05241	0,51544	0,0919	0,34024
2019*	0	0	0	1	0
2020**	0	0	0	0	0
2021*	0	0	0	0	1
times referenced	**5**	**8**	**4**	**6**	**3**

* efficient and referenced years, ** efficient but not-referenced years

Summary of efficient years and reference sets for inefficient years are visualized in Figure 3. Green coded circles are the efficient years, red ones are the inefficient. Arrows show reference years for inefficient years. The most referenced year is 2013. In addition, although the 2005, 2006, 2007 and 2020 periods are efficient, they are not good examples in terms of railway efficiency. For further studies, the super-efficiency models could be applied to the railways.

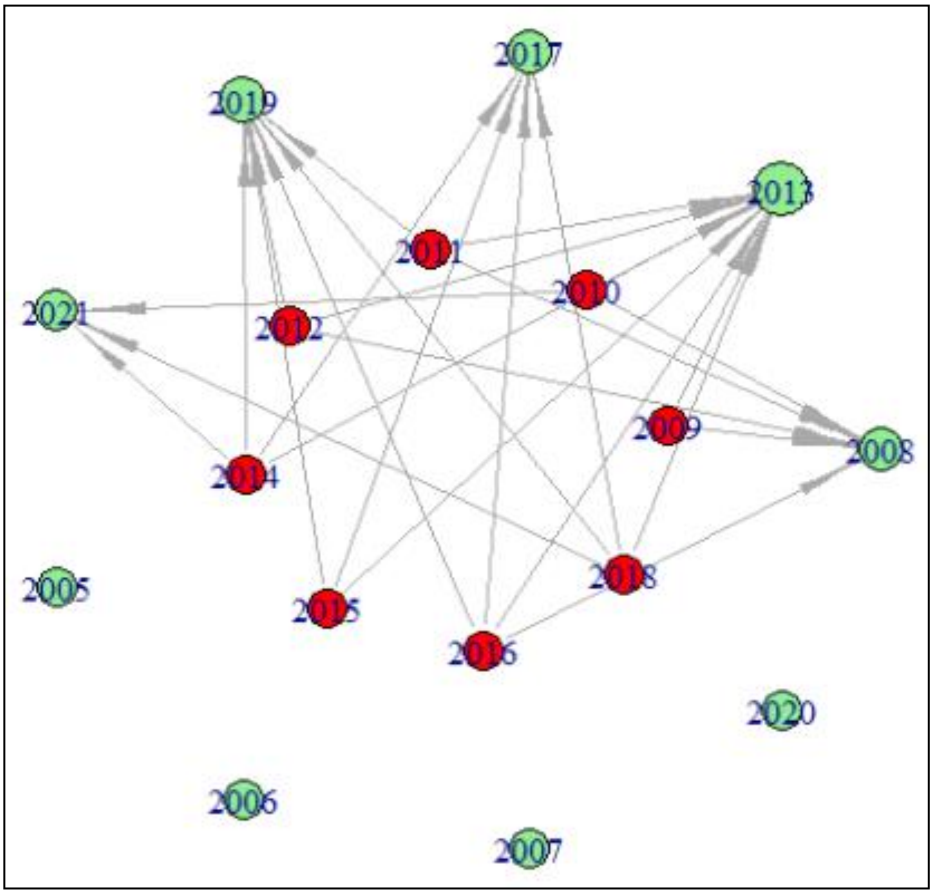

Figure 3. Summary of Efficient Years and Reference Sets for Inefficient Years

6. CONCLUSION AND SUGGESTIONS

The Turkish railways from 2005 to 2021 was examined by DEA with undesirable outputs in this study. Railway accidents were used as undesirable output. Turkish railways, which started in 1856, have been developing in the last decades by allocating serious public resources. As a requirement of strategic management, it is necessary to analyse the efficiency of the railways to determine the best practice and to settle the strategies based on these experiences. In this context, this study is expected to guide railway managers and investors. Since the efficiency of Turkish railways has not been evaluated before, the results have not been adequately discussed. The present study constitutes a reference for future studies on railway efficiency in Türkiye.

The DEA model with undesirable factors, developed by Seiford and Zhu (2002) was used. The findings show that 2005, 2006, 2007, 2008, 2013, 2017, 2019, 2020 and 2021 are efficient years, while the others inefficient. Reference sets, lambda coefficients and targets were examined to make deeper inferences. For reference sets as shown in Figure 3, red circles are inefficient years, while the green circles are the efficient years. The arrows show the reference set for each inefficient year. The years 2005, 2006, 2007 and 2020 are efficient but not reference for inefficient years. This finding show that these years are not good practice in terms of railway efficiency. The rest four years (2008, 2013, 2017, 2019, 2021) are both efficient and reference for inefficient ones.

The 2013, is the most referenced year. This indicates that the 2013 is the best practice period in Türkiye for railway efficiency with undesirable outputs. For both decision makers, investors and practitioners, 2013 is a good reference point for ensuring efficiency and making future projections. Targets for the following years can be determined based on the accident-passenger number and accident-freight ratios in 2013. The purpose of DEA is to determine the best practice frontier within the periods. In this sense, the obtained findings allow to make the necessary inferences.

Another finding is about the targets. Improvements to ensure efficiency for each inefficient year are given in Table 2. The resources of inefficiencies and the improvements which provide efficiency can also be obtained from Table 2. For 2016, efficiency could be achieved with a 9% increase in the number of passengers, an 18% increase in the amount of freight and a 29% decrease in the number of accidents. For the other inefficient periods, suggestions given at Section 5.

The findings about the efficiency of the railways for different periods with undesirable outputs gives more comprehensive implications, the results are consistent with Seiford and Zhu (2002). Moreover, the findings show that undesirable outputs in railway efficiency should be taken into account, which supports Djordjević et al. (2018).

The full efficiency for nine periods may necessitate further analysis. Although the frequency in the reference sets give more information about the best practice, super efficiency analysis should be performed for better rankings among the efficient periods. It is recommended to evaluate the railway efficiency with the super efficiency model in DEA with undesirable outputs. The second suggestion is for practitioners and decision makers. When examining the efficiency of decision-making units, it is necessary to perform analyses with undesirable outputs in order to consider undesirable situations. For railways, railway accidents are used as undesirable output. For airways, the flight delays could be used as undesired outputs.

The final recommendation is for scholars. Green management studies are gaining importance in the near future. For this reason, to carry out studies in which environmental wastes will be considered as undesirable output and to enrich these studies with sectoral practices is recommended.

Ethical Statement

During the writing and publication of this study, the rules of Research and Publication Ethics were complied with, and no falsification was made in the data obtained for the study. Ethics committee approval is not required for the study.

Conflict Statement

This study has not led to any individual or institutional/organizational conflict of interest.

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Extended Abstract

From the Strategic Management Perspective Examining Turkish Railways' Performance Considering Railway Accidents

Benchmarking is frequently used in strategic management, while it may not be possible to compare companies such as Turkish Railways (TCDD) with their competitors due to unique structures. In such cases, the dynamic data envelopment analysis method, which is based on the ratio of outputs to inputs with the company's long-term data, can be used. Then the strategies for improvement can be determined based on the best practice period. To determine the best practice, data envelopment analysis (DEA) is the most widely used non-parametric method. Homogeneous DMUs (decision making units) can be included in the analysis, as well as comparisons can be made with the data of the same DMUs from different years. Basically, DEA is the ratio of outputs to inputs. There are also some new approaches, including undesirable output(s) is one of them. Environmental factors such as exhaust emissions, the number of dismissals or the number of accidents are examples for the undesirable outputs. Railway accidents are serious and fatal accidents. Seiford and Zhu (2002), purposed to multiply the bad (undesirable) outputs by –1 and find a better translation vector (w) to convert negative undesirable outputs to positive. By their model, desired outputs expands and undesirable outputs shrink to ensure the efficiency. In this way, the efficiency of the railway system can be evaluated by considering undesirable outputs.

The data collected from TCDD web page annual statistics. Most of the studies evaluating the railway efficiency, use total railway length and number of employees as input. In this study, the same inputs used. For the outputs, total passengers and total freight tonnage taken. Another factor included in the outputs is the number of accidents, hence it is taken as the undesirable output. This study differs from the previous ones in two points, the first is that it deals with the railways efficiency with multi-year data, and the second is that it considers the number of accidents as an undesirable output in the railways efficiency.

The DEA model with undesirable factors, developed by Seiford and Zhu (2002) was used. The findings show that 2005, 2006, 2007, 2008, 2013, 2017, 2019, 2020 and 2021 are efficient years, while the others inefficient. Reference sets, lambda coefficients and targets were examined to make deeper inferences. For reference sets as shown in Figure 3, red circles are inefficient years, while the green circles are the efficient years. The arrows show the reference set for each inefficient year. The years 2005, 2006, 2007 and 2020 are efficient but not reference for inefficient years. This finding show that these years are not good practice in terms of railway efficiency. The rest four years (2008, 2013, 2017, 2019, 2021) are both efficient and reference for inefficient ones. The 2013, is the most referenced year. This indicates that the 2013 is the best practice period in Türkiye for railway efficiency with undesirable outputs. For both decision makers, investors and practitioners, 2013 is a good reference point for ensuring efficiency and making future projections. Targets for the following years can be determined based on the accident-passenger number and accident-freight ratios in 2013. The purpose of DEA is to determine the best practice frontier within the periods. In this sense, the obtained findings allow to make the necessary inferences. The findings show that undesirable outputs in railway efficiency should be taken into account, which supports Djordjević et al. (2018).

It is recommended to evaluate the railway efficiency with the super efficiency model in DEA with undesirable outputs. The second suggestion is for practitioners and decision makers. When examining the efficiency of decision-making units, it is necessary to perform analyses with undesirable outputs in order to consider undesirable situations.

The final recommendation is for scholars. Green management studies are gaining importance in the near future. For this reason, to carry out studies in which environmental wastes will be considered as undesirable output and to enrich these studies with sectoral practices is recommended.