EFFICIENCY ANALYSIS OF TURKEY'S ROAD TRANSPORTATION SYSTEM USING DATA ENVELOPMENT METHOD

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ABSTRACT

This study investigates whether Turkey utilizes its road transportation indicators efficiently or not within the framework of the European Union (EU) accession process. In addition, it aims to demonstrate Turkey's current position compared to other EU countries by performing relative efficiency analysis on road transportation indicators. Data Envelopment Analysis, which is among efficiency measuring methods and used in this research, is a non-parametric method that is based on linear programming principles. In the analysis, three different models were formed in order to determine the dimensions of different road transportation parameters with the aim of minimizing the number of accidents and the number of casualties in accidents. As a candidate for the EU membership, Turkey's road transportation performance was demonstrated in this study using Data Envelopment Analysis in comparison to members (27 countries whose data were fully accessed) of the EU, which requires its members of fulfilling certain criteria and targets.

Keywords: Transportation, Efficiency, Road, Performance, DEA

VERİ ZARFLAMA METODU KULLANILARAK TURKİYE'NİN KARAYOLU ULAŞIM SİSTEMİNİN ETKİNLİK ANALİZİ

ÖZET

Bu çalışmada Avrupa Birliği'ne katılım sürecinde Türkiye'nin karayolu ulaşım göstergelerini etkin olarak kullanıp kullanmadığı araştırılmıştır. Buna ilaveten karayolu ulaşım göstergelerinin bağıl performansıyla Avrupa Birliği ülkeleri arasındaki konumu gösterilmiştir. Çalışmada parametrik olmayan lineer programlama özellikleri olan Veri Zarflama Analizi kullanılmıştır. Analizde, üç farklı model oluşturulmuştur: farklı yol taşımacılığı parametrelerinin boyutlarını belirlemek, kazaların sayısını en aza indirmek ve kazalarda yaralıların sayısını minimize etmek.

AB için bir aday olarak Türkiye'nin karayolu taşımacılığı performansı 25 Avrupa Ülkesine göre karşılaştırılmıştır.

Anahtar Kelimeler: Ulaştırma, Etkinlik, Karayolu, Performans, Veri Zarflama

1. INTRODUCTION

Traffic is among the prioritized issues for not only Turkey but also other countries. According to the European Transport Safety Council (ETSC), traffic accidents are the main cause of death in all EU countries for those aged 45 and below. It is indicated in various reports published by World Bank that Turkey loses around 2% of its Gross National Product (GNP) every year in traffic accidents, which suggests that the annual socioeconomic cost of traffic accidents in Turkey is nearly 10 billion dollars [1,2].

Number of vehicles per capita, which is among the indicators of economic welfare and development, has reached its peak density especially in cities in recent years. This situation has unsurprisingly increased traffic problems in and out of towns. Given the fact that the volume of road transportation in Turkey is high, Turkey is among the countries with the highest number of traffic accidents. Statistics indicate that over 4000 people are killed and over 200,000 people are injured in traffic accidents every year in Turkey on average.

In order to attain a stable performance in preventing accidents and establishing road safety; the characteristics of vehicles, drivers and roads, which are the three main components of the transportation system, need to be addressed as a whole. More than one factor have an impact on the frequency and violence of traffic accidents such as driver behaviors, characteristics of vehicles and roads, environmental factors and traffic characteristics.

The causes of traffic accidents in Turkey are distributed as follows: 96,82% drivers, 2,38% pedestrians, 0,16% passengers, 0,32% vehicles, and 0,32% roads. These statistics suggest that the human factor is responsible for traffic accidents by 99,36% [3]. Traffic safety is among the issues prioritized by Turkey and other countries in the world.

In the EU summit held in Helsinki on 10-11 December 1999, Turkey was admitted to candidacy having equal rights with other candidate countries. Thus began Turkey’s accession process to the EU. With this development, Turkey would be required to make extensive adjustments in numerous areas including the transportation industry for a long period. The transportation sector is among the areas on which the creation and implementation of a common policy was put as an obligation in the Rome Treaty. Since the Rome Treaty, which is the foundation of the EU, the primary policy that has been pursued by members is the free circulation of individuals and products. These countries make significant efforts to alleviate the obstacles in their borders. The main components of the common transportation policy addressed within this framework were defined as reducing employment, protecting the environment, being open to competition and providing the best service to the customer with the largest perspective. The main purpose of transportation is to provide the service necessitated by the economic and social targets of national development; with the most convenient qualities demanded by the user; in a way to satisfy national security requirements; in a safe and environmentally-friendly manner; for the cheapest price; using contemporary technologies; and in harmony with international regulations and EU policies; continuously and without any interruption [4].

It is aimed in this study to determine Turkey's position among EU member countries and to define its pros and cons in terms of road transportation indicators. This way, it is believed that this study will contribute to the efforts towards harmonization. Therefore, a relative efficiency analysis was conducted using the method of Data Envelopment Analysis (DEA) for 27 EU member countries and Turkey by considering their transportation and traffic structures. Thus, Turkey's position among EU member countries with respect to traffic indicators was determined. Based on the concrete findings, the policies that Turkey should develop in order to increase harmonization with the transportation and traffic structures of EU member countries were discussed.

1.1. TRAFFIC IN TURKEY

As in all other countries, traffic accidents in Turkey are among the top problems. According to a research by the World Bank, the socioeconomic cost of traffic accidents in Turkey constitutes 2,2% of the entire GNP [5].

Traffic indicators by years based on the data provided by Turkish Statistics Institute (TUIK) are given in Figure 1 and Table 1. In recent years, numbers of drivers and vehicles as well as the number of accidents are on the rise. However, deaths caused by accidents slightly declined; which might have stemmed from the fact that most new vehicles are automobiles whose equipments have been designed with an increased focus on safety (Table 2).

Table 1. Traffic Indicators

Year	Number of Motor Vehicles	Increase (%)	Population	Increase (%)	Number of Vehicles per 1000 people	Number of Driver's Licences	Increase (%)	Number of Accidents	Increase (%)
2005	11145826	8,88	72065000	1,28	155	16604724	2,81	621183	15,59
2006	12227393	9,70	72987400	1,28	168	17962895	8,17	728756	17,31
2007	13022945	6,51	70586256	-3,29	184	18877354	5,09	825583	13,29
2008	13765395	5,70	71517100	1,32	192	19924442	5,55	942105	14,11
2009	14316700	3,85	72561312	1,46	197	20460739	2,69	1050011	11,44

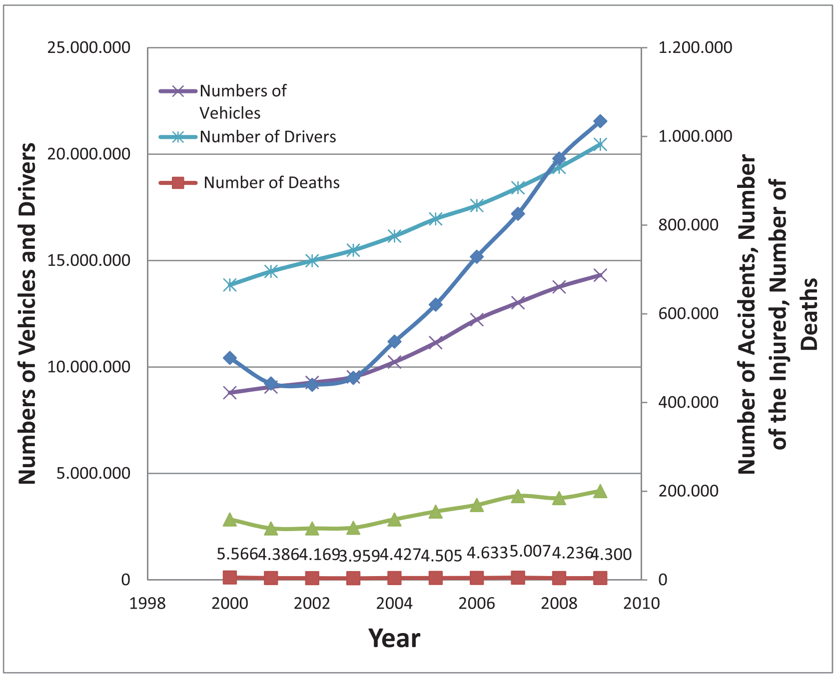

Figure 1. Traffic indicators in Turkey

Table 2. Distribution of Vehicles on Roads

	Motorbike	Automobile	Minibus	Bus	Light-duty truck	Truck	Tractor	Special-Purpose Vehicle	Total
2008	2181383	6796629	383548	199934	2066007	744217	1358577	35100	13765395
2009	2303261	7093964	384053	201033	2204951	727302	1368032	34104	14316700
Increase (%)	5,29	4,19	0,13	0,54	6,30	-2,27	0,69	-0,69	3,85

Table 3 shows the distributions of both passengers and cargo on roads in Turkey. Figure 2 demonstrates the distribution of passengers and cargo with respect to the system of transportation in Turkey. As Figure 2 suggests, both passenger and cargo transportation in Turkey are performed on roads, and thus, researches should primarily focus on the road transportation industry.

Table 3. Road cargo and passenger statistics

Year	Vehicle x Km (Millions)			Ton x Km (Millions)			Passenger x Km (Millions)		
	Motorway	State Highway	Provincial Road	Motorway	State Highway	Provincial Road	Motorway	State Highway	Provincial Road
2005	9466	45818	5845	28504	128343	9964	31606	134681	15865
2006	11528	47055	5994	32926	134361	9265	37994	133608	15991
2007	12727	50459	6423	34452	136967	9911	43873	147694	17548
2008	13131	50255	8385	36925	135607	9403	44394	144378	17326
2009	13908	51932	6592	40515	127211	6729	47481	147253	17730

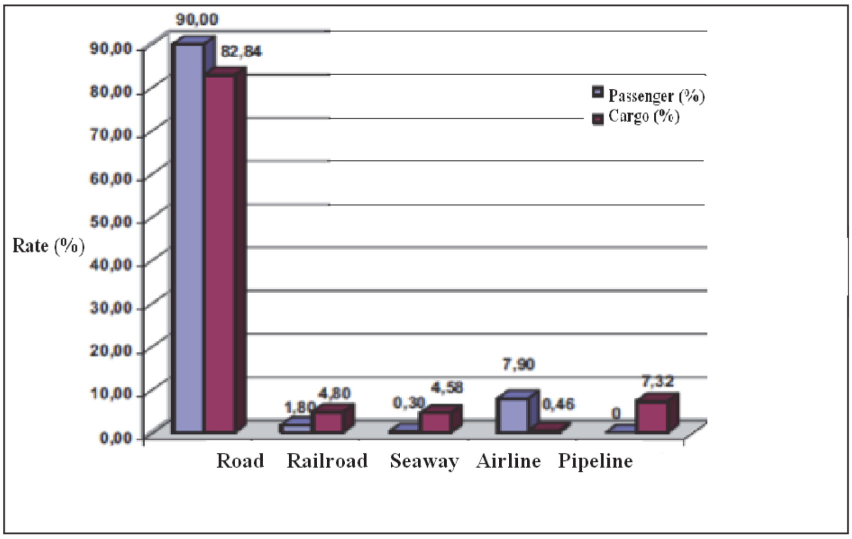

Figure 2. Distribution of transportation sectors

The transportation sector constitutes 7% of the EU's Gross Product, 7% of employment, 40% of member countries' investments and 30% of energy consumption. Across the EU, in the last twenty years, an annual demand of 2,3% for goods and of 3,1% for passengers emerged on average. Steps towards the liberalization of the EU's economy such as the elimination of boundaries between countries and the liberalization of maritime transportation have rendered inevitable the creation of a Common Transportation Policy. These steps are of importance in terms of maintaining growth and overcoming problems such as deadlock and market saturation.

2. EFFICIENCY ANALYSIS

2.1. MATERİAL

In this study, DEA, which is a method used in many studies to evaluate performance, was employed in order to determine Turkey's performance in traffic indicators in comparison with EU member countries. Using the DEA models of CRS (CCR) and VRS (BCC), a section (cross-section) analysis was performed and efficiency scores were ranked. In the study; the main road traffic indicators were used as variables whereas Turkey and 27 EU member countries were regarded as decision making units (DMU) [6]. To determine Turkey's efficiency, three different efficiency models were formulated taking into consideration nine input and various output variables. These models were analyzed according to their input and output values, as presented in Table 4.

Table 4. Input-output variables used in the analysis

Main Road Traffic Indicators	**MODEL 1 (Input/ Output)**	**MODEL 2 (Input/ Output)**	**MODEL 3 (Input/ Output)**
Length of Motorways	I	I	I
Length of Road Network-Main or National Roads	I	I	I
Length of Road Network-Secondary or Regional Roads	I	I	I
Motorization	I	I	I
Passenger Cars-Stock of Registered Vehicles	I	I	I
Buses and Coaches-Stock of Registered Vehicles	I	I	I
Goods Vehicles-Stock of Registered Vehicles	I	I	I
Road share of inland freight transport	I	I	I
Passenger Cars- New Vehicle Registrations	I	I	I
Road Fatalities		O	
Road Fatalities Country Rankings-Fatalities per Million Inhabitants			
Road Fatalities Country Rankings-Fatalities per 10 Billion pkm			O
Road Fatalities Country Rankings-Fatalities per Million Passenger Cars			O
Number of Accidents Involving Personal Injury	O		
Injuries-Numbers		O	

The aim here is;

Model 1: Determining the efficiency that takes the number of accidents as the output and the main road indicators as the input

Model 2: Determining the efficiency that takes the number of casualties on road as the output and the main road indicators as the input

Model 3: Determining the efficiency that takes the number of deaths per vehicle and per kilometer as the output and the main road indicators as the input

DEA analyses are performed in two directions:

- Input-oriented efficiency measures the rate of inputs (main road indicators) that should be used less by decision making units (countries) that are not 100% efficient in order to attain 100% efficiency; when a constant output level is given.
- Output-oriented efficiency measures the rate of outputs that should be produced more by decision making units that are not 100% efficient in order to attain 100% efficiency; when a constant input level is given.
- In the input-oriented approach, if it is not possible to decrease the amount of any input belonging to a DMU without increasing the amount of another input and/or decreasing the amount of an output, this DMU is regarded aspareto-efficient.

In the output-oriented approach, if it is not possible to decrease the amount of any output belonging to a DMU without decreasing the amount of another output and/or increasing the amount of an input, this DMU is regarded aspareto-efficient.

Figure 3 illustrates the efficiency values calculated oriented towards input and output.

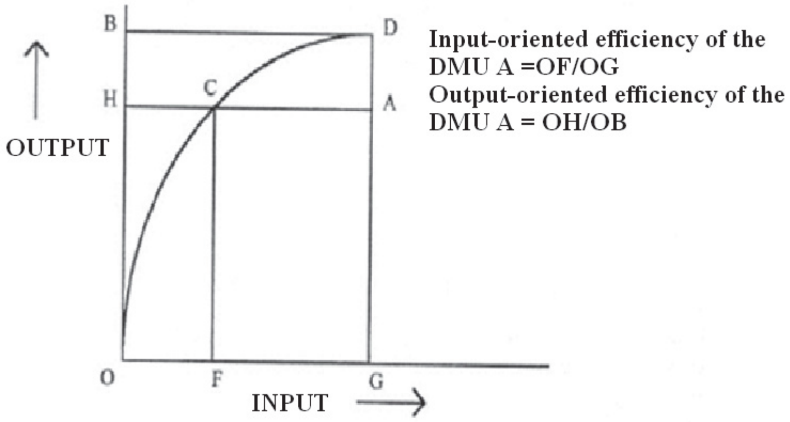

Figure 3. Input- and output-oriented efficiency

Here, in measuring the input-oriented efficiency, both CRS (constant returns to scale) and VRS (variable returns to scale) models were employed.

Constant Returns to Scale (CRS)

- Here, any radial increase in the input vector creates a radial increase in the output vector at the same rate.
- Radial increase: means the increase of all input components at the same rate.

Variable/Decreasing/Increasing Returns to Scale (VRS, DRS, IRS)

- Variable Returns to Scale
    - It means that increasing, decreasing and constant returns are possible.
- Decreasing Returns to Scale
    - Any radial increase in the input vector creates a radial increase in the output vector at a lower rate.
- Increasing Returns to Scale

Any radial increase in the input vector creates a radial increase in the output vector at a higher rate (Figure4).

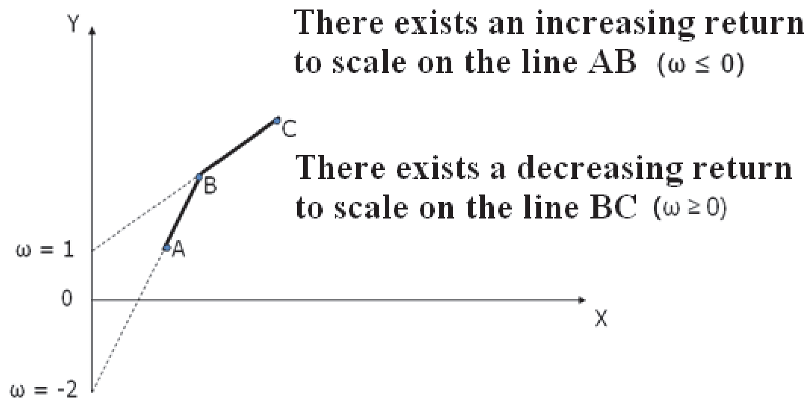

Figure4. Variable to scale model

Scale efficiency measures the difference between the CRS and VRS efficiency scores. The scale efficiency of a DMU is calculated by dividing VRS to CRS efficiency score. A scale efficiency score smaller than 1 point to scale inefficiency; while a DMU is regarded as scale-efficient if it is equal to 1 (100%) and at the same time CRS and VRS efficiency scores are equal to 1. Thus, it is understood that the above DMUs B and D are technically efficient whereas they are not scale-efficient. Only the DMU C is scale-efficient [7]. Constraint on the weights of decision units equates to 1 linear programming model, boundary event "the best observation", and the relative efficiency of the formation of multiple linear combinations allows defining a less strict. For, increasing and decreasing returns to scale are also included in the scale, that is, within the efficiency limits. In general, a comparison of efficiency in the case of constant returns to scale displays a picture with a lower performance; because a DMU needs to have both technical and scale efficiency in order to reach to the efficiency value of "1". In the case of variable returns to scale, on the other hand, if a unit that is not scale efficient has technical efficiency, it can be located over the frontier as the “best observation” [8]. Therefore, it can be stated that the technical efficiency measure for the same DMU is lower in the case of constant returns to scale than in the case of variable returns to scale.

3. RESULTS

3.1. ACCIDENT PERFORMANCE (MODEL 1) ANALYSIS RESULTS

It measures the number of accidents in an outcome-oriented and the efficiency in an input-oriented way; that is, it is the method that focuses on the degree that those inputs that minimize output should be decreased. Moreover, both CRS and VRS efficiency scores were calculated for each model. That is, it is determined in the CRS model whether increasing the amount of input influences the output at the same rate or not. In the VRS model, inputs and outputs are considered as variables.

DMUs' (countries') both CRS and VRS efficiencies according to the Model 1 analysis results conducted for determining accident performance are presented in Figure 5.

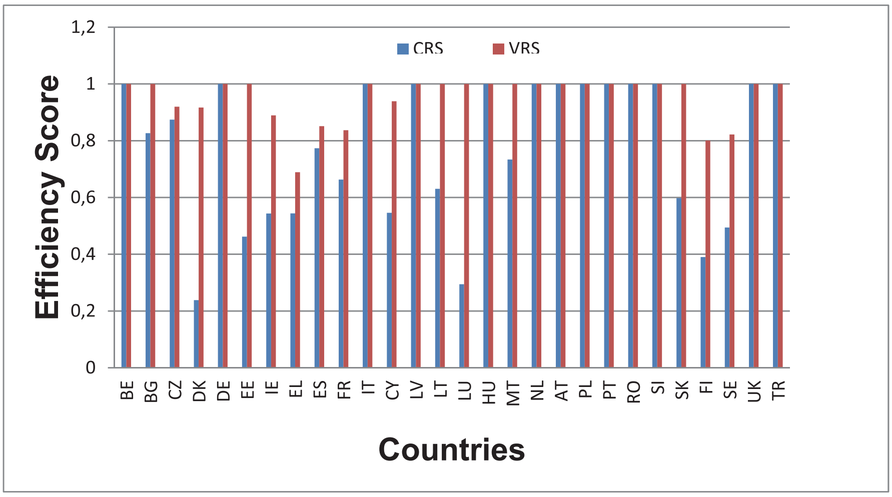

Figure 5. Model 1 analysis results

By performing input-oriented DEA for Model 1; the DMU that ensures minimum number of accidents with its existing inputs was determined. If the efficiency score found through input-oriented model is 1 or 100% and if the inputs or outputs of this DMU do not have mixed inefficiency, this country is deemed efficient. Countries with efficiency scores of higher or lower than 100 are not efficient. Yet another meaning of the efficiency score of an inefficient country is the following: this unit can become efficient if it decreases its inputs as much as its efficiency score. According to the Model 1 CRS analysis results, 13 countries including Belgium, Germany, Italy and Turkey have an efficiency score of 100%. According to the Model 1 VRS analysis results, on the other hand, 19 countries are efficient such as Romania, Denmark and France. These countries were ranked using super efficiency analysis. This ranking is presented in Table 5. The table ranks the countries that produce the highest amount of outputs using the lowest amount of inputs. In the ranking of countries' efficiencies based on CRS analysis, Belgium ranked first whereas Turkey ranked fourth. Romania, on the other hand, ranked first based on VRS analysis. Countries that are not found efficient in neither of the analyses need to decrease their inputs as much as the weights of the input values of their reference countries presented in Table 6 (for CRS) and Table 7 (for VRS).

Table 5. Super-efficiency ranking

	DMU	CRS	DMU	VRS
1	BE	374,88%	RO	800%
2	LV	249,45%	MT	757,79%
3	DE	246,04%	BE	474,81%
4	TR	206,49%	DK	298,31%
5	RO	196,04%	NL	252,15%
6	PT	174,81%	EL	202,77%
7	IT	143,49%	PT	181,56%
8	HU	141,35%	CY	178,23%
9	UK	131,50%	ES	146,88%
10	SI	124,50%	AT	144,19%
11	AT	113,94%	BG	142,83%
12	PL	112,87%	LU	139,29%
13	NL	103,92%	IE	134,50%
14			FR	125,17%
15			SE	124,98%
16			SK	118,89%
17			LT	117,54%
18			LV	112,71%
19			CZ	109,15%

Table 6. Weights of inefficient countries based on CRS analysis results compared to efficient countries and the number of efficient countries' being references

	DMU	Number for efficient countries to be references (dark) Name and weight of reference country for inefficient countries (light)
1	BE	0
2	BG	LV (0,53) HU (0,13) TR (0,01)
3	CZ	DE (0,01) IT (0,05) LV (0,34) RO (0,22)
4	DK	DE(0,00) PT (0,05) SI (0,13) TR (0,00)
5	DE	3
6	EE	LV (0,11) AT (0,01) RO (0,02)
7	IE	IT (0,02) PL (0,00) PT (0,04) RO (0,05) TR (0,00)
8	EL	20 (0,02) PT (0,20) RO (0,23) TR (0,00)
9	ES	IT (0,34) PT (0,39) TR (0,01)
10	FR	IT(0,34)
11	IT	6
12	CY	LV (0,04) HU (0,03) PT (0,03) TR (0,00)
13	LV	7
14	LT	LV (0,43) HU (0,05) TR (0,00)
15	LU	AT (0,02) TR (0,00)
16	HU	4
17	MT	LV (0,02) HU (0,00) PT (0,01) TR (0,00)
18	NL	0
19	AT	5
20	PL	2
21	PT	9
22	RO	7
23	SI	1
24	SK	IT (0,01) LV(0,07) AT (0,02) PT (0,04) RO (0,08)
25	FI	IT(0,01) AT (0,02) PT (0,07) RO (0,05) TR(0,00)
26	SE	DE (0,00) AT (0,37) PT (0,06) RO (0,05) TR(0,00)
27	UK	0
28	TR	11

Table 7. Weights of inefficient countries based on VRS analysis results compared to efficient countries and the number of efficient countries' being references

	DMU	Number for efficient countries to be references (dark) Name and weight of reference country for inefficient countries (light)
1	BE	3
2	BG	0
3	CZ	EE (0,28) IT (0,06) LV (0,52) RO(0,13) UK (0,01)
4	DK	LV (0,53) SK (0,47)
5	DE	4
6	EE	5
7	IE	BE (0,06) EE (0,20) MT (0,21) PL (0,01) SK (0,53)
8	EL	DE (0,01) LV (0,19) HU (0,16) RO (0,04) SK (0,58) TR (0,01)
9	ES	DE (0,03) IT (0,34) SK (0,62)
10	FR	DE (0,02) IT (0,29) LV (0,29) SK (0,40)
11	IT	3
12	CY	BE (0,01) EE (0,11) MT(0,83) PL (0,00) PT (0,01) SK(0,04) TR(0,00)
13	LV	5
14	LT	0
15	LU	0
16	HU	1
17	MT	2
18	NL	0
19	AT	0
20	PL	2
21	PT	2
22	RO	2
23	SI	0
24	SK	8
25	FI	BE (0,12) EE (0,83) PT (0,04) SK (0,01)
26	SE	DE (0,04) EE(0,24) LV (0,45) SK(0,27)
27	UK	1
28	TR	2

Table 6 and Table 7 also illustrate the times efficient countries became references for inefficient ones (shaded in grey). For example, based on CRS analysis results (for Model 1), Turkey became a reference as an efficient country for 11 inefficient countries (Table 6). These countries, including Bulgaria, Denmark and Spain, need to decrease their inputs as much as the multiplication of Turkey's input values by their weights given in brackets.

Based on VRS analysis results, similarly, Turkey became a reference for Cyprus and Greece. In other words, inefficient countries should take the capacity of efficient countries to convert their inputs into outputs as a reference. They should decrease their inputs as much as the values given in blankets nearby the references in both tables.

3.2. RESULTS OF EFFICIENCY ANALYSIS FOR CASUALTIES IN ACCIDENTS (MODEL 2)

According to the performance analysis results of Model 2, which takes the number of casualties in accidents as output and road transportation indicators as input, both CRS and VRS efficiencies of DMUs are presented in Figure 6.

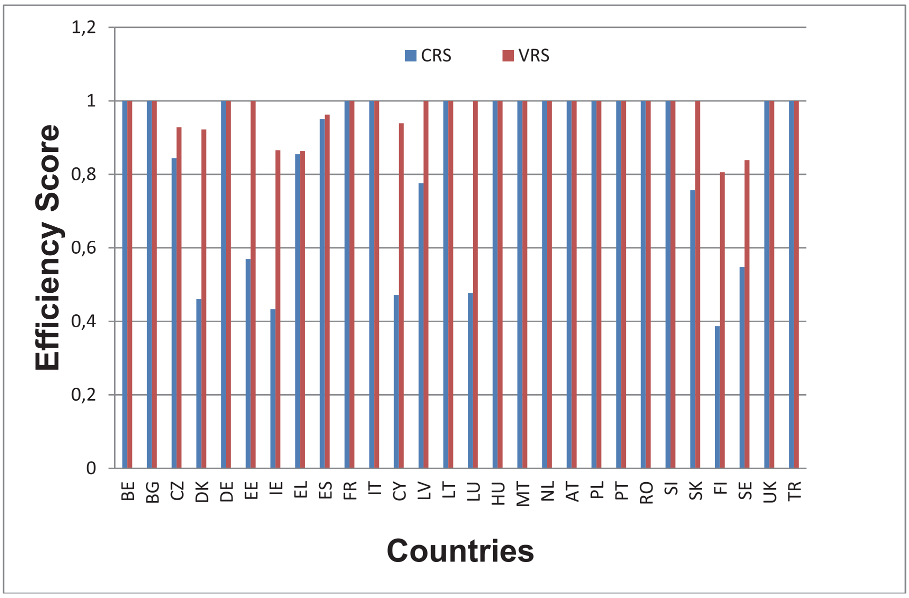

Figure 6. Model 2 analysis results

By performing input-oriented DEA for Model 2; the DMU that ensures minimum number of casualties with its existing inputs was determined. If the efficiency score found through input-oriented model is 1 or 100% and if the inputs or outputs of this DMU do not have mixed inefficiency, this country is deemed efficient. Countries with efficiency scores of higher or lower than 100 are not efficient. Yet another meaning of the efficiency score of an inefficient country is the following: this unit can become efficient if it decreases its inputs as much as its efficiency scores. According to the Model 2 CRS analysis results, 16 countries including Belgium, Germany, France, Italy and Turkey have an efficiency score of 100%. According to the Model 2 VRS analysis results, on the other hand, 20 countries are efficient such as Romania, Poland, Hungary and France. These countries were ranked using super efficiency analysis. This ranking is presented in Table 8. The table ranks the countries that produce the highest amount of outputs using the lowest amount of inputs. In the ranking of countries' efficiencies based on CRS analysis, Belgium ranked first whereas Turkey ranked second. Based on VRS analysis, on the other hand, Poland ranked first whereas Turkey ranked fifth. Countries that are not found efficient in neither of the analyses need to decrease their inputs as much as the weights of the input values of their reference countries presented in Table 9 (for CRS) and Table 10 (for VRS).

Table 8. Super-efficiency ranking for Model 2

	DMU	CRS	DMU	VRS
1	BE	471,04%	PL	800,00%
2	TR	399,71%	DE	800%
3	PL	251,88%	MT	757,79%
4	RO	233,55%	BE	602,05%
5	DE	226,23%	TR	451,72%
6	BG	185,26%	RO	241,35%
7	HU	173,55%	BG	185,77%
8	FR	167,97%	EE	182,39%
9	IT	165,10%	LV	174,47%
10	PT	142,96%	HU	173,97%
11	SI	136,09%	FR	173,54%
12	LT	126,10%	IT	167,89%
13	NL	123,12%	SI	157,19%
14	UK	122,21%	LU	154,33%
15	AT	112,22%	LT	152,96%
16	MT	101,68%	PT	144,38%
17			NL	132,31%
18			SK	126,74%
19			UK	126,15%
20			AT	120,24%

Table 9 and Table 10 also illustrate the times efficient countries became references for inefficient ones (shaded in grey). For example, based on CRS analysis results (for Model 2), Turkey became a reference as an efficient country for 5 inefficient countries (Table 9). These countries, including Czech Republic and Cyprus, need to decrease their inputs as much as the multiplication of Turkey's input values by their weights given in brackets.

Table 9. Weights of inefficient countries based on CRS analysis results compared to efficient countries and the number of efficient countries' being references

	DMU	Number for efficient countries to be references (dark) Name and weight of reference country for inefficient countries (light)
1	BE	2
2	BG	2
3	CZ	IT (0,06) HU (0,11) RO (0,20) TR (0,00)
4	DK	BG (0,14) PL (0,02) RO (0,02) SI (0,20)
5	DE	1
6	EE	HU (0,04) RO (0,04) TR (0,00)
7	IE	BE (0,03) IT (0,00) AT (0,03) PT (0,02) RO (0,06)
8	EL	PL (0,03) PT (0,31) RO (0,37)
9	ES	FR (0,08) IT (0,35) PL (0,16) RO (0,05) SI (0,24)
10	FR	1
11	IT	5
12	CY	HU (0,02) PL (0,00) PT (0,02) RO (0,01) TR (0,00)
13	LV	BG (0,28) RO (0,00)
14	LT	0
15	LU	BE(0,01) RO (0,01) SI (0,01)
16	HU	6
17	MT	0
18	NL	0
19	AT	3
20	PL	5
21	PT	5
22	RO	11
23	SI	5
24	SK	IT(0,01) HU(0,06) AT(0,02) RO(0,10) SI (0,11) TR(0,00)
25	FI	IT(0,01) HU(0,01) PL (0,02) PT(0,03) RO(0,04) SI (0,16)
26	SE	DE(0,00) HU(0,06) AT (0,39) PT(0,06) TR (0,00)
27	UK	0
28	TR	5

Table 10. Weights of inefficient countries based on VRS analysis results compared to efficient countries and the number of efficient countries' being references

	DMU	Number for efficient countries to be references (dark) Name and weight of reference country for inefficient countries (light)
1	BE	4
2	BG	4
3	CZ	BG (0,06) EE(0,25) IT (0,06) LV (0,08) MT (0,19) PL (0,01) RO(0,14) SK (0,20)
4	DK	LV (0,47) SI (0,04) SK (0,49)
5	DE	1
6	EE	4
7	IE	BE(0,02) MT (0,28) SK (0,70)
8	EL	BE (0,00) MT (0,19) PL (0,04) PT (0,26) RO (0,36) RO (0,14)
9	ES	BG (0,25) 10 (0,09) IT (0,35) PL (0,06) RO(0,11) SI (0,14)
10	FR	1
11	IT	2
12	CY	BE (0,01) BG (0,01) EE (0,10) MT (0,83) PT (0,01) SK (0,04)
13	LV	3
14	LT	1
15	LU	0
16	HU	0
17	MT	5
18	NL	0
19	AT	0
20	PL	3
21	PT	2
22	RO	3
23	SI	3
24	SK	5
25	FI	BE (0,14) BG(0,07) EE (0,74) LT (0,02) MT (0,03)
26	SE	DE (0,06) EE (0,38) LV (0,34) SK (0,22)
27	UK	0
28	TR	0

Based on VRS analysis results, similarly, Turkey did not become a reference for other countries although it was an efficient country. In other words, inefficient countries should take the capacity of efficient countries to convert their inputs into outputs as a reference. They should decrease their inputs as much as the values given in blankets nearby the references in both tables.

By performing input-oriented CRS and VRS analyses with Model 2; it was aimed to minimize the number of deaths and the injured. If the efficiency score found through input-oriented model is 1 or 100% and if the inputs or outputs of this DMU do not have mixed inefficiency, it is concluded that the main road traffic indicators of this country cause less casualties in accidents than those of other countries, and this country is deemed efficient. Countries with efficiency scores of higher or lower than 100 are not efficient. Yet another meaning of the efficiency score of an inefficient country is the following: this unit can become efficient if it decreases its inputs, that is its main road traffic indicators, as much as its efficiency score. For this reason, the input-oriented inefficiency score is called contraction coefficient. For example, Czech Republic is not efficient for Model 2 according to CRS analysis with the efficiency score of 84,41%. In order to become efficient, this country needs to reduce its inputs (e.g. number of passengers/vehicles or rate of motorization) by 15.59%.

Table 11. Model 3 super-efficiency analysis results

1	DMU	CRS	DMU	VRS
2	MT	720,66%	RO	800,00%
3	RO	306,80%	MT	757,79%
4	LU	204,30%	BE	307,39%
5	LV	196,36%	LU	226,79%
6	TR	186,19%	TR	205,69%
7	BE	180,90%	EE	202,22%
8	EE	162,11%	LV	198,48%
9	BG	152,36%	CY	184,25%
10	CY	120,54%	BG	182,30%
11	SI	118,72%	SK	125,03%
12	SK	116,83%	SI	119,35%
13	HU	105,09%	NL	111,77%
14	PT	100,93%	PT	110,16%
15			LT	109,15%
16			HU	105,18%

3.3. RESULTS OF EFFICIENCY ANALYSIS FOR LOSSES PER ROAD TRANSPORTATION INDICATOR (MODEL 3)

According to the performance analysis results of Model 3, which takes the number of deaths on roads per one million vehicles for passenger transportation and the number of deaths on roads per one billion passengers-km as outputs and road transportation indicators as input, both CRS and VRS efficiencies of DMUs are presented in Figure 7.

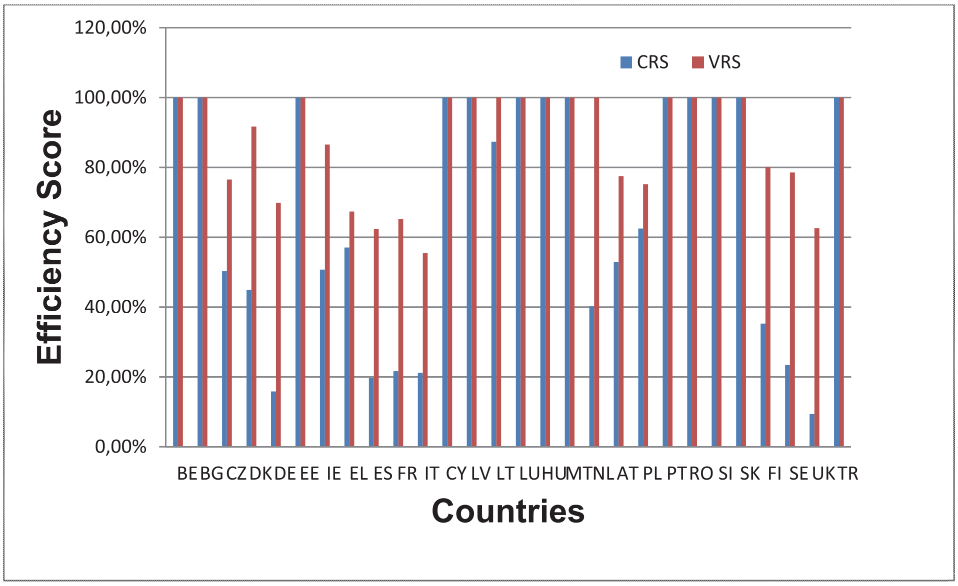

Figure 7. Model 3 analysis results

By performing input-oriented DEA for Model 3; the DMU that ensures minimum number of deaths on roads with its existing inputs was determined. If the efficiency score found through input-oriented model is 1 or 100% and if the inputs or outputs of this DMU do not have mixed inefficiency, this country is deemed efficient. Countries with efficiency scores of higher or lower than 100 are not efficient. Yet another meaning of the efficiency score of an inefficient country is the following: this unit can become efficient if it decreases its inputs as much as its efficiency score. According to the Model 3 CRS analysis results, 14 countries including Belgium, Hungary, Lithuania, Bulgaria and Turkey have an efficiency score of 100%. According to the Model 3 VRS analysis results, on the other hand, 16 countries are efficient such as Romania, Belgium and Turkey. These countries were ranked using super efficiency analysis. This ranking is presented in Table 11. The table ranks the countries that produce the highest amount of outputs using the lowest amount of inputs. In the ranking of countries' efficiencies based on CRS and VRS analyses, Turkey ranked sixth. Countries that are not found efficient in neither of the analyses need to decrease their inputs as much as the weights of the input values of their reference countries presented in Table 12 (for CRS) and Table 13 (for VRS).

Table 12. Weights of inefficient countries based on CRS analysis results compared to efficient countries and the number of efficient countries' being references

	DMU	Number for efficient countries to be references (dark) Name and weight of reference country for inefficient countries (light)
1	BE	2
2	BG	10
3	CZ	BG (0,03) LV (0,26) RO (0,10) SK (0,26)
4	DK	BG (0,09) LV (0,34) RO (0,02)
5	DE	RO (0,15)
6	EE	0
7	IE	BG (0,02) CY (0,15) SI (0,05) SK (0,35)
8	EL	BG (0,30) LV (0,11) RO (0,09) SK (0,34)
9	ES	BG (0,11) LV (0,08) RO (0,11)
10	FR	BG (0,05) LV (0,18) RO(0,10)
11	IT	LV (0,04) RO(0,25)
12	CY	1
13	LV	12
14	LT	BG (0,20) LV (0,51) LU(0,00) MT(0,03)
15	LU	2
16	HU	0
17	MT	2
18	NL	BE(0,03) BG (0,15) LV (0,02) LU (0,10) SI (0,01)
19	AT	LV (0,51) MT(0,11)
20	PL	BG (0,48) LV (0,23) RO (0,09)
21	PT	0
22	RO	10
23	SI	3
24	SK	4
25	FI	BE (0,05) BG (0,08) LV(0,14) SI (0,14)
26	SE	LV(0,19) RO(0,01) SK (0,10)
27	UK	RO (0,12)
28	TR	0

Table 13. Weights of inefficient countries based on VRS analysis results compared to efficient countries and the number of efficient countries' being references

	DMU	Number for efficient countries to be references (dark) Name and weight of reference country for inefficient countries (light)
1	BE	2
2	BG	0
3	CZ	LV(0,41) RO(0,16) SK(0,43)
4	DK	LV (0,53) SK (0,47)
5	DE	LV (0,78) RO (0,22)
6	EE	2
7	IE	BE (0,02) MT (0,28) SK (0,70)
8	EL	LV (0,23) RO (0,11) SK (0,65) TR(0,01)
9	ES	LV (0,36) RO (0,36) SK (0,28)
10	FR	LV (0,57) RO (0,31) SK (0,12)
11	IT	LV (0,67) RO (0,33)
12	CY	0
13	LV	11
14	LT	0
15	LU	0
16	HU	0
17	MT	1
18	NL	0
19	AT	EE (0,40) LV (0,60) SK (0,00)
20	PL	LV (0,53) RO (0,06) SK (0,30) TR (0,10)
21	PT	1
22	RO	9
23	SI	0
24	SK	10
25	FI	BE (0,12) EE (0,83) PT (0,04) SK(0,01)
26	SE	LV (0,65) RO (0,03) SK (0,32)
27	UK	LV (0,47) RO (0,53)
28	TR	2

Table 12 and Table 13 also illustrate the times efficient countries became references for inefficient ones (shaded in grey). For example, based on CRS analysis results (for Model 3), Turkey could not become a reference for other countries although it was efficient (Table 12). According to VRS analysis results, on the other hand, Turkey became a reference as an efficient country for Poland and Greece (Table 13).

3.4. GENERAL EVALUATION OF DATA ENVELOPMENT ANALYSIS RESULTS

Through three different input-oriented models (Model 1-3) and two different DEA models (CRS and VRS), it was concluded that Turkey is more efficient than EU countries in terms of converting its road transportation indicators into useful outputs (Table 14). Turkey had an efficiency score of 100% in all the three models we worked on. Along with Turkey, Romania and Slovenia are other efficient countries. That is, their road transportation indicators caused less number of accidents, less number of casualties and less number of accidents with casualties within residential areas. In addition, they managed to keep the share of transportation within GNP in its maximum with respect to main indicators; which suggests that they utilized traffic indicators efficiently.

Table 14. General evaluation

	MODEL 1		MODEL 2		MODEL 3	
DMU	CRS	VRS	CRS	VRS	CRS	VRS
BE	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%
BG	82,66%	100,00%	100,00%	100,00%	100,00%	100,00%
CZ	87,43%	92,00%	84,41%	92,82%	50,28%	76,53%
DK	23,83%	91,69%	46,12%	92,19%	44,98%	91,69%
DE	100,00%	100,00%	100,00%	100,00%	15,85%	69,86%
EE	46,19%	100,00%	57,02%	100,00%	100,00%	100,00%
IE	54,36%	88,94%	43,29%	86,55%	50,72%	86,55%
EL	54,38%	68,91%	85,53%	86,37%	57,05%	67,37%
ES	77,37%	85,14%	95,08%	96,23%	19,68%	62,40%
FR	66,32%	83,70%	100,00%	100,00%	21,64%	65,25%
IT	100,00%	100,00%	100,00%	100,00%	21,22%	55,46%
CY	54,60%	93,92%	47,15%	93,90%	100,00%	100,00%
LV	100,00%	100,00%	77,58%	100,00%	100,00%	100,00%
LT	63,07%	100,00%	100,00%	100,00%	87,36%	100,00%
LU	29,43%	100,00%	47,65%	100,00%	100,00%	100,00%
HU	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%
MT	73,37%	100,00%	100,00%	100,00%	100,00%	100,00%
NL	100,00%	100,00%	100,00%	100,00%	40,23%	100,00%
AT	100,00%	100,00%	100,00%	100,00%	52,96%	77,52%
PL	100,00%	100,00%	100,00%	100,00%	62,47%	75,18%
PT	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%
RO	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%
SI	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%
SK	59,77%	100,00%	75,75%	100,00%	100,00%	100,00%
FI	39,00%	80,06%	38,67%	80,60%	35,27%	80,06%
SE	49,43%	82,22%	54,83%	83,87%	23,41%	78,54%
UK	100,00%	100,00%	100,00%	100,00%	9,39%	62,56%
TR	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%

4. CONCLUSIONS

Attaining a high level of performance is a key factor of success for every organization. To this end; it is today an important managerial instrument to define the criteria necessary for development, improve the existing performance and understand why some units in the organization are operating inefficiently. In the study, using Data Envelopment Analysis that is a technique for measuring efficiency and total factor productivity, performance was demonstrated subjectively.

The accession period to the EU, which has a significant place especially in the recent years in Turkey's social and economic development, has accelerated harmonization efforts. "Transportation" is among the chapters opened as part of this process of harmonization and works are ongoing under this chapter. This study will contribute to the adaptation of road transportation indicators into the EU criteria. DEA is employed in order to determine the performance of many enterprises and to define the policies to be employed to improve this performance. In this study, it was aimed to determine the performances of road transportation indicators comparatively in terms of their positive and negative consequences, and thus Turkey's position among EU countries was determined. It is aimed, through the subjective results obtained, to provide information about the limitations of main indicators that will maximize the performance of transportation indicators and about the strategies and targets to be followed.

For countries' efficiencies, three different models were developed. Therefore, main road transportation elements such as countries' numbers of accidents, numbers of deaths and injuries caused by accidents on roads, and numbers of these incidents in residential areas were analyzed subjectively.

The input-oriented model investigates to what extent the inputs belonging to the DMU whose efficiency is explored can be reduced in order to measure a certain level of output. Therefore, through four different input-oriented models employed in this study, it was investigated how much the inputs (main road traffic indicators) should be reduced by keeping output levels (e.g. number of accidents) constant. Also, countries that were found to be efficient were ranked among themselves. For this ranking, the concept of scale-efficiency was employed.

Outcomes of this study will provide those who work on and make policies about this issue with information regarding Turkey’s current situation in comparison to EU member countries in concrete (quantitative) values. In addition, it was concluded in this study that the intense utilization of road transportation in Turkey does not create a disadvantage vis-a-vis other countries. When the road transportation data, which is an important component of the chapter of transportation for Turkey, are compared with EU countries with respect to multiple parameters; it is observed that Turkey’s young and high population, existing road transportation infrastructure and main road indicators such as road-km and passenger-km are balanced. This analysis produced important data for developing road transportation policies in Turkey’s accession period to the EU. Useful conclusions were drawn for the use of policy-makers within the field of transportation in Turkey.

REFERENCES

1. Ministry of Transportation, “Transportation Strategy Report”,ITÜ, Ministry of Transportation, Ankara, 23-30 (2004).
2. Çubuk, K. and Cansız, Ö.F.“Energy Status between Transportation Systems in Turkey”, Energy Efficiency Conference, Ministry of Energy and Natural Resources, Ankara, 47-49 (2005)
3. J.A Beasley, Data Envelopment Analysis, http://mscmga.ms.ic.ac.uk/jep/jep.html (03.04.2004)
4. Aydoğdu, A., (2006), “Transportation and energy policies that Turkey should develop in order to reduce the number of traffic accidents in the EU accession period”, Master’s Thesis, GaziUniversity, Institute of Science
5. Bedrettin, M., (2004) “Traffic Law and Fundamental Traffic Knowledge”, General Directorate of Security
6. “EU transport in figures”, Statistical Pocket Book 2011, European Commission
7. Chen, Y., Liang, L., Yang, F., Zhu, J., “Evaluation Of Information Technology Investment: A Data Envelopment Analysis Approach”, Computers& Operations Research, 33 :1368–1379 (2006).
8. uggiero, J., “Measurement Error, Education Production And Data Envelopment Analysis”, Economics of Education Review, 42:653-662 (2005) .