Sigma J Eng & Nat Sci 38 (2), 2020, 769-784

Sigma Journal of Engineering and Natural Sciences
Sigma Mühendislik ve Fen Bilimleri Dergisi

Research Article

DEVELOPMENT OF A COMPOSITE ROAD TRAFFIC SAFETY PERFORMANCE INDEX: A BASIS FOR COMPARING TURKISH METROPOLITAN CITIES

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Received: 15.01.2020 Revised: 06.04.2020 Accepted: 31.05.2020

ABSTRACT

In this study, we aimed to measure and compare the road traffic safety performance of the current thirty metropolitan cities in Turkey by applying principal components analysis (PCA) with the data from 2016. A total of ten road traffic safety performance indicators from different fields were selected to present the current road traffic safety situation in these cities. The structural and cultural characteristics of the cities were also considered by applying Ward's cluster analysis. Four indicators were used in the cluster analysis, then the cities were ranked according to their road traffic safety performance. The cities with the highest and lowest road traffic safety score were Erzurum and Muğla, respectively. The cities were divided into four classes according to the cluster analysis. The first group includes only İstanbul. The other three groups include seven, ten and twelve cities, respectively.
Keywords: Road safety, traffic safety, principal components analysis, indexes, comparison.

1. INTRODUCTION

Traffic accidents cause more than 1.2 million traffic fatalities in the world every year. Therefore, they have a significant impact on health and the economy. Traffic accidents are the primary reason for traffic fatalities among young people aged 15-29. The economic loss to countries is approximately 3% of their gross national product [1].

Traffic accidents mostly occur in countries with low and moderate incomes. In these countries, traffic accidents are becoming unavoidable when the rapid increase in vehicle ownership is combined with unsafe roads and poor traffic management systems. Compared to high-income countries, two times more traffic accidents occur in countries with low and moderate incomes. In addition, 90% of the fatalities due to traffic accidents in the world occur in countries with low and medium incomes [1].

The total number of accidents that occurred in Turkey in 2016 is 1,182,491 according to TurkStat (Turkish Statistical Institute). 997,363 of these are accidents involving material loss only and the other 185,128 of these are accidents involving fatalities and injuries. The number of those

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who died in traffic accidents was 7300 while the number of those who were injured in traffic accidents was 303,812 [2].

If Turkey is compared with Germany, vehicle ownership in Germany is almost 3 times that in Turkey but the number of traffic fatalities per 1 million people in Turkey is 2.5 times that in Germany. If vehicle ownership was at the same level, it is really thought-provoking to consider how many accidents per person there would be [3; 4; 5].

2. LITERATURE REVIEW

Studies on the development of a composite road traffic safety performance index gained speed after the 2000s. In 2002, the transport and road safety departments of Sweden, the UK, and the Netherlands came together to make a comparison of road safety development in their countries. In this project, which they named SUNflower, they adapted the target hierarchy for road traffic safety from the report on the Road Safety Strategy 2010 of New Zealand published in 2000. This target hierarchy can be seen in Figure 1. In the first SUNflower study in 2002, three countries with the best road safety records in the world were examined. The study aimed to identify the key factors underlying the policies and programs that made these countries effective in traffic safety, and thus to identify the most appropriate policies and programs that can help reduce traffic casualties, especially in European countries. Therefore, past, present and planned national strategies; four case studies (drinking and driving, seat belts, local infrastructure improvements, and level of safety on inter-urban road networks); and traffic risks in the last 20 years were examined. It was stated that all fields could not be examined in detail, so the study could not provide a comprehensive explanation. According to evaluation of the available data, it was found that the three countries showed a similar level of road safety performance [6; 7].

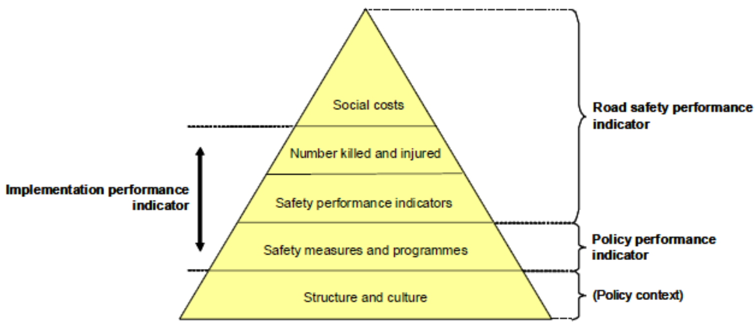

Figure 1. A target hierarchy for road safety [6; 7]

In the second SUNflower study in 2005, nine countries (three of them were countries investigated in the first SUNflower study) were studied using a similar method. Topics not covered in the previous study such as speed management, traffic risk in different modes of transportation, pedestrians and cyclists, motorized two-wheeled vehicles, young drivers and low-cost improvement implementations were examined. Besides road safety performance indicators, another level of the target hierarchy was examined in terms of transportation modes, user behaviors, road characteristics, and trauma management. An approach aiming to define a "footprint" was developed for each country as a result of the evaluations. The deviation of each country against a reference safety level was analyzed in detail and summarized according to the footprint approach [8].

The third SUNflower study in 2008 covered twenty-seven European countries. In addition to the previous two SUNflower studies, it focused on developing a composite road safety index. The cluster analysis applied in the p revious SUNflower study was also applied in this study. The social costs of traffic accidents were considered for the first time in a SUNflower study. Principal components analysis and factor analysis methods were used for comparison of the countries. In the end, it was decided that the study would need to be carried out again more comprehensively in the future since all the existing data was not always made available. It was also emphasized that the study should be applied regionally and intercity [9].

Another project carried out across Europe is the SafetyNet project. The aim of the project carried out between 2004 and 2008, was to build a European Road Safety Observatory (ERSO) framework, which would be the main focus for road safety data and knowledge. ERSO takes into account three different areas: macroscopic data, in-depth-data and knowledge on road safety topics. This can be seen in Figure 2. In the study, the risk exposure data and road safety performance indicators were especially emphasized. The traffic risk indicators in the study are population, road network, vehicle fleet, driver population, vehicle-kilometer, passenger-kilometer, number of trips, time in traffic and fuel consumption. Seven safety areas were identified as road safety performance indicators: alcohol and drugs, speed, protective systems, daytime running lights, vehicles (passive safety), roads and trauma management [10].

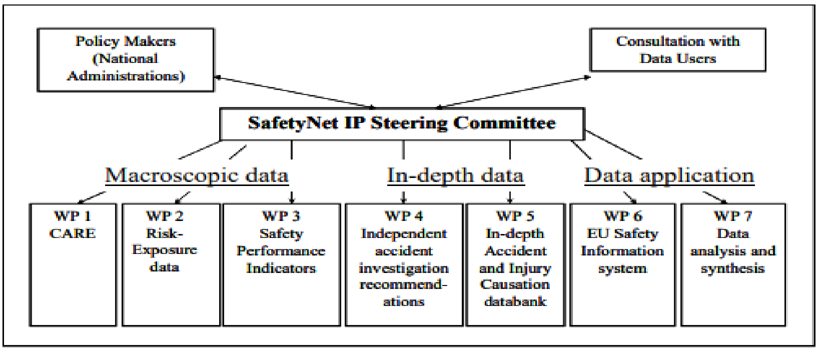

Figure 2. SafetyNet management and technical structure [10]

Another project based on the road safety target hierarchy is the DaCoTa project carried out in 2012. The project aimed to provide a method to facilitate comparison of road safety performance between countries. The study compared 27 European countries according to their road safety performance. Data envelopment analysis was applied to compare the countries and factor analysis was applied to classify them. In the study, indicators related to traffic casualties were used as final outcomes; road user behavior and vehicle-related indicators were used as intermediate outcomes; and indicators such as population, GDP and vehicle ownership were used as structural and cultural indicators. It was stated that data envelopment analysis is an effective method of creating indexes and it was emphasized that the indicators can be improved. It was also stated that the indicators can be developed for more effective policy performance [11].

In the study conducted by Khaled Abbas in 2004, a hierarchy pyramid approach was developed. It can be seen in Figure 3. The factors affecting road safety were represented through 14 aspects. These are political, institutional, safety lobbying, safety research, engineering, accident management systems, evaluation, behavior, legislation, enforcement and standards, emergency, education, mass media, and coordination and cooperation. 40 criteria have been developed for these aspects [12].

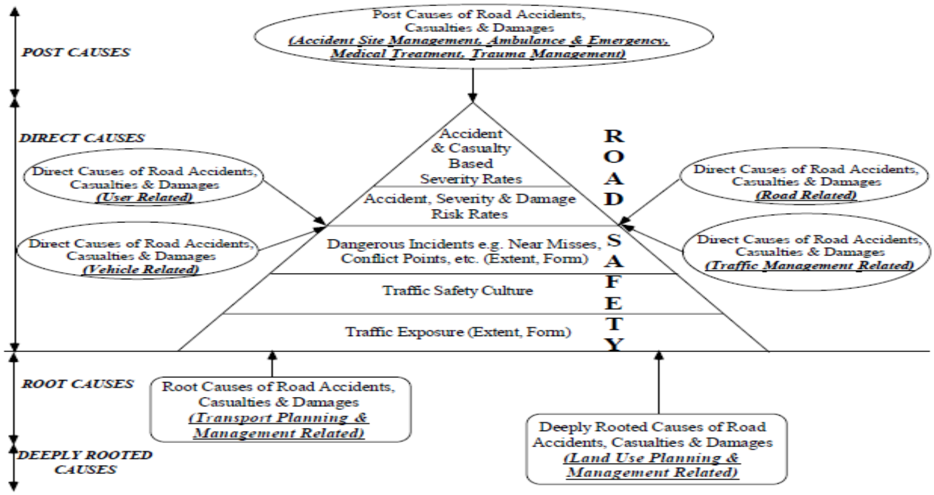

Figure 3. Conceptualisation of road safety pyramid: components and affecting factors [12]

An approach for children's road safety was developed by Khaled Abbas in 2017. This approach includes four different hierarchical pyramid structures. The first pyramid represents road safety components for children at different time intervals (pre-accident, during an accident, and post-accident). It also reveals factors related to traffic accidents. The second pyramid contains three basic elements required in the road safety diagnosis method for children. These key elements are the children's road safety culture, indicators, and data analysis. The third pyramid explains the indicators and the level at which they can be used to observe changes over time. The fourth and last pyramid includes the road safety approach for children. This study is very important in terms of developing and enriching the classical approach of the "3 E's of road safety": evaluation, education and enforcement. In the study, which is handled very comprehensively, road safety is expressed with 14 E's. It has critical importance regarding the multidimensionality of the subject [13].

Figure 4. Integrated road safety strategy comprising 14 'E' cornerstones [14]

An approach that can be used all over the world was developed in the study published by Khaled Abbas in 2017, which includes road safety assessments in the Middle East and West Asian countries. It was stated that there are three main factors required to represent detailed methodological road safety diagnostics. The first is the introduction of a road safety culture through a set of criteria. The second factor is the detailed calculation of the main road safety indicators. The third and last factor is to analyze traffic accidents and to identify the underlying causes of traffic accidents. The study provides a comprehensive road map for road safety. This road map with eighteen action plans can be seen in Figure 4 [14].

There are several statistical methods used for road safety performance measurement. In the literature, principal components analysis (PCA) and data envelopment analysis (DEA) are the two most used methods. Please see the references [9; 10; 11; 15; 16; 17; 18; 19; 20].

3. ROAD TRAFFIC SAFETY PERFORMANCE INDICATORS AND INDEXES

An indicator is usually a qualitative or quantitative measure that obtains an index of observed facts and is capable of revealing the relative states of a particular region. When evaluated at regular intervals, an indicator can show the direction of change between different units and different times [21; 22].

The choice of each indicator is very important depending on the type of data collected in terms of answering questions such as what the indicators are to be used for, their purpose, and what we want to measure. There is no definite number of indicators for what we want to achieve. Selected indicators should be as few as possible. It is possible to find many indicators associated with a single point, thus requiring a clear answer, in particular, as to which one was chosen and why. Therefore, we must first focus on more comprehensive and effective indicators. The data for the collection process should be available and accessible from year to year so that they can be used whenever needed. Data and indicators should be updated frequently [23].

In order to compare the safety achievements of countries, there is a need to reduce the size of the problem and to work with a composite indicator that can identify all the appropriate components in a comprehensive and concise way. The composite indicators will allow countries/regions/provinces to be ranked according to their performance or at least to identify various groups of countries/regions/provinces at different levels of safety performance [24]. However, the position of a country may be greatly influenced by the methodological choices in the composite indicator process [25].

The index can be defined as an indicator of the proportional change in the dimension of time or space, in the numerical data of a particular event or the change occurring over time in a field. The index consists of numbers and/or percentages as a result of a series of transactions using averages and proportions.

Multidimensional indexes have been developed internationally and have been used to measure progress in different aspects of life and success across countries. The indexes have been developed for environmental issues, sustainable development, globalization issues, agriculture, economy, information technology and more [26].

Issues to be considered when calculating the index are:

- Data should be comparable and accessible,
- Selection of variables to be used in comparisons is important,
- The selection of weights used in the index is important, and
- The calculation method should be effective for the result [27].

Indexes that capture the many dimensions of risk information and present the whole road traffic safety picture offer many advantages in terms of communication, benchmarking and reviewing of road traffic safety movements [28].

Table 1. The positive and negative aspects of the indexes [21]

Positive Aspects	Negative Aspects
Summarize complex, multi-dimensional facts to support decision-makers.	If they are improperly formed or misinterpreted, they may send misleading policy messages.
Evaluate the progress of countries over time.	Can invite oversimplified policy outcomes.
Reduce the visible size of a set of indicators without dropping the essential knowledge base.	Can be misused, for example, to support the desired policy: if the construction process is not transparent and/or does not have sound statistical or conceptual principles.
Easier to interpret than many separate indicators.	The choice of indicators and weights can be the subject of political conflict.
Possible to include more information within the current boundaries.	Can conceal serious failures of some size and increase the difficulty of identifying appropriate corrective action if the construction process is not transparent.
Put country performance and progress issues at the center of the policy arena.	Can ignore performance dimensions that are difficult to measure which may lead to inappropriate policies.
Facilitate communication with the general public (citizens, the media, etc.) and increase accountability.	
Help create and support narratives for both unskilled and educated audiences.	
Allow users to compare complex dimensions effectively.	

4. METHODOLOGY

In this section, the data set used in the road traffic safety performance index analysis is presented. The method used to create the index from the indicators obtained from this data set is explained. Whether the data in the analysis is consistent, sufficient and reliable is measured. The analysis is performed using the IBM SPSS statistics 23 program and its results are presented. Finally, a cluster analysis is applied to classify the cities, and the results are shared.
The contributions of the study to the literature are as follows:

- It is an original case.
- It compiles information about the region.
- It is the latest study on the road traffic safety index covering the metropolitan cities of Turkey.
- The data set used is specific to this study. In this respect, it is expected that it will constitute a reference point for future research and it offers a comparative opportunity for researchers from all over the world.
- This study differs from similar studies in terms of showing just how much road traffic safety can be explained when the data is not of the desired quality and adequacy. From this aspect, it is expected to be a reference for the literature. The most comprehensive and reliable indicators can be found in the SUNflower, SafetyNet, DaCoTa studies and the studies carried out by Khaled Abbas [7; 8; 9; 10; 11; 12; 13; 14].

4.1. Data Set

Data are the main need when an index is created. It is especially important to have high-quality data to create a healthy index. The availability of high-quality data will also influence the choice of indicators. However, on a practical level, it is difficult to find reliable and comparable data, so data considered to be optimal are used. Data sources have an impact on data collection and selection of indicators. Data sets should be of the same quality for all cities, to be compared.

In this study, data were collected from the Turkish Statistical Institute, the General Directorate of Highways, the Turkish National Police, the Ministry of Health and the Ministry of Development (now Presidency of Strategy and Budget) which were considered to be of equal quality for the cities to be compared.

4.2. Selected Indıcators

The first step when creating an index is to select indicators. This step is mainly theory-oriented. Potential indicators can be listed and evaluated according to a number of selection criteria.

As part of the study, various data showing road traffic safety performance were requested from the relevant institutions. However, some of these data were stated to be unavailable and some of them were not shared. Therefore, the data used in the study were obtained from the data published online and from some ministry reports.

Selected indicators are given below:

- Traffic fatalities per 100,000 people [2],
- Traffic injuries per 100,000 people [2],
- Fatal or injurious traffic accidents per 100,000 people [2],
- Number of vehicles per 1000 people [29],
- The ratio of fatal or injurious traffic accidents to all traffic accidents (accident severity level) [2],
- Percentage of the population with at least an associate's degree [30] ,
- Number of hospital beds per 100,000 people [31],
- Number of ambulances per 100,000 people [31],
- Population density [32], and
- Traffic fines per traffic control [33].

4.3. Method

The principal components analysis (PCA) was used in this study. PCA is a size reduction tool that converts a large set of variables into a small set of variables that still contains the information in it [34]. The PCA targets to reduce data, make estimations, convert the data set into a format that some methods can analyze, calculate principal component scores of units from related variable sets, and sort the units according to these scores. [35]. It is common to use PCA to create an index. However, this method expresses the relationship between indicators rather than assigning a weight to them. This method is a valuable tool for analyzing many selected indicators when measuring various risk areas [15]. If the indicators are selected appropriately, PCA may give the best results. PCA is a successful method to create a road traffic safety index. It seems to be a convenient method to simplify the data and find the weight for the road traffic safety performance index [23; 21; 36].

PCA may not be suitable for all data sets. The suitability of the data for PCA can be examined by the Kaiser-Dieter-Olkin (KMO) coefficient and Bartlett sphericity test. The KMO coefficient gives information about whether the data matrix is suitable for PCA and whether the data structure is suitable for factorization. The KMO coefficient is expected to be greater than 0.60 for factorization. If this coefficient is less than 0.60, this interpretation may not be realistic. The Bartlett test examines whether there is a relationship between variables based on partial correlations [37].

Cronbach's alpha coefficient is a measure of internal consistency, indicating how closely related a set of elements is to the group. The scale is considered to be a measure of reliability. A "high" value for alpha does not mean that the scale is one-dimensional. Technically, Cronbach's alpha coefficient is not a statistical test, it is a reliability or consistency coefficient [34]. Some authors state that the limit of 0.60 is acceptable, but may vary by field of study [21].

If there are very high correlations between the variables in the data set, if the measurement units of the original values are very different (kg, cm, lt, etc.), or if the variables vary enough to affect the ranges of variations, it is appropriate to normalize the data before analysis [35]. Normalization is planned to be between 0 and 1. However, in the road traffic safety index study conducted among European countries, a country with a score of 0 in the index was avoided by using a value of 0.1 [11]. Normalization was made between 0.1 and 1 by considering this situation. With the following Formula 1, normalization can be made in the desired range [a, b].

$$X' = (B - A)\frac{X - X_{min}}{X_{max} - X_{min}} + A \quad (1)$$

X′ = Normalized value
B = Desired upper limit (in this study, b = 1)
A = Desired lower limit (in this study, a = 0.1)
X = Indicator value
Xmin = minimum value
Xmax = maximum value

4.4. Analysis Results

In this section, the PCA results are given.

Table 2. KMO (Kaiser-Meyer-Olkin) and Bartlett's test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.627
Bartlett's Test of Sphericity	Approx. Chi-Square	279.161
	df	45
	Sig.	0.000

Table 3. Communalities

Indicators	Initial	Extraction
Traffic fatalities per 100,000 people	1.000	0.875
Traffic injuries per 100,000 people	1.000	0.943
Fatal or injurious traffic accidents per 100,000 people	1.000	0.969
Number of vehicles per 1,000 people	1.000	0.934
The ratio of fatal or injurious traffic accidents to all traffic accidents	1.000	0.888
Percentage of the population with at least an associate's degree	1.000	0.867
Number of hospital beds per 100,000 people	1.000	0.910
Number of ambulances per 100,000 people	1.000	0.839
Population density	1.000	0.648
Traffic fines per traffic control	1.000	0.972

The KMO test result was 0.627. Thus, it can be said that our data set is sufficient to perform the analysis. The Bartlett test result was smaller than 0.05. From this it can be said that the data set is compatible with the analysis.

The values in the 'Extraction' column show the ratio of each variable's variance that can be explained by the principal components. Variables with high values are well represented in the common factor space, whereas variables with low values are not well represented [38].

Table 4. Total variance explained

Component	**Initial Eigenvalues**			**Extraction sums of squared loadings**			**Rotation sums of squared loadings***
	Total	% Variance	% Cumulative	Total	% Variance	% Cumulative	Total
1	4.08	40.76	40.76	4.08	40.76	40.76	3.91
2	2.52	25.23	65.99	2.52	25.23	65.99	2.38
3	1.61	16.14	82.12	1.61	16.14	82.12	1.85
4	0.63	6.32	88.45	0.63	6.32	88.45	2.09
5	0.51	5.07	93.52				
6	0.28	2.79	96.30				
7	0.20	2.00	98.30				
8	0.10	0.99	99.30				
9	0.06	0.63	99.93				
10	0.01	0.07	100.00				

* When components are correlated, sums of squared loadings cannot be added to obtain a total variance.

Eigenvalues are the variance of the principal components. The variables were standardized since the principal components analysis was performed on the correlation matrix. This means that the variance of each variable is 1 and the total variance is equal to the number of variables used in the analysis, in which case the total variance is 10 since there are 10 variables.

In Table 4, the 'extraction sums of squared loadings' section reproduces the values in the 'initial eigenvalues' section. The principal components with eigenvalues greater than 1 are determined in the 'extraction sums of squared loadings' section. This indicates the number of principal components.

The 'rotation sums of squared loadings' section of Table 4 represents the distribution of variance after direct oblimin rotation. The direct oblimin rotation attempts to achieve a simpler and more meaningful factor solution compared to the unrotated solution. As explained under Table 4, when components are correlated, sums of squared loadings cannot be added to obtain a total variance. Therefore, the variance accounted for by each rotated factor is calculated by dividing the loadings into the number of components. According to calculations, the total variance of the four principal components is 88.45%. The contribution of the first component to the variance is 40.76%. The contribution of the second component to the variance is 25.23%. The contribution of the third component to the variance is 16.14%. The contribution of the fourth component to the variance is 6.32%.

Table 5. Rotated component matrix

Indicators	Component			
	1	2	3	4
Traffic fatalities per 100,000 people	**0.865**	-0.053	-0.126	-0.107
Traffic injuries per 100,000 people	**0.917**	-0.072	-0.121	-0.076
Fatal or injurious traffic accidents per 100,000 people	**0.972**	-0.028	0.014	-0.035
Number of vehicles per 1000 people	**0.940**	0.247	0.179	0.075
The ratio of fatal or injurious traffic accidents to all traffic accidents	0.086	**-0.891**	-0.024	-0.130
Percentage of the population with at least an associate's degree	-0.308	**-0.863**	-0.032	-0.043
Number of hospital beds per 100,000 people	0.116	-0.595	**0.785**	0.140
Number of ambulances per 100,000 people	-0.078	0.196	**0.902**	-0.125
Population density	-0.191	0.441	**0.455**	0.212
Traffic fines per traffic control	-0.049	0.027	-0.112	**0.980**

Table 5 shows the weights of the indicators under two factors. The correlation between indicators and factors can be seen in the same table. If an indicator has a high value within the absolute value, this means its relationship with that factor is high. In general, values above 0.50 are considered appropriate. Only one indicator is slightly below the desired level.

The 10 indicators used in the study were divided into 4 factor groups. The first-factor group is the group that has the highest impact on road traffic safety performance scores with 46%. The impacts of the second, third and fourth-factor groups are 29%, 18%, and 7%, respectively. Factors and indicator groups are as follows:

Table 6. Factors and indicator groups

1st Factor	• Traffic fatalities per 100,000 people, • Traffic injuries per 100,000 people, • Fatal or injurious traffic accidents per 100,000 people, • Number of vehicles per 1000 people.
2nd Factor	• The ratio of fatal or injurious traffic accidents to all traffic accidents, • Percentage of the population with at least an associate's degree.
3rd Factor	• Number of hospital beds per 100,000 people, • Number of ambulances per 100,000 people. • Population density.
4th Factor	• Traffic fines per traffic control

Cronbach's alpha coefficient values are shown in Table 7. The Cronbach's Alpha Coefficient values were higher than the threshold limit for our four factor groups.

Table 7. Cronbach's alpha (1st, 2nd, 3rd and 4th factors)

Groups	Cronbach Alfa	Number of Items
1st Factor	0.950	4
2nd Factor	0.842	2
3rd Factor	0.624	3
4th Factor	Not tested since there is no second indicator.	1

The general factor score (GFS) is calculated according to the Formula 2:

$$GFS = \frac{0.408\times FACTOR1+0.252\times FACTOR2+0.161\times FACTOR3+0.063\times FACTOR4}{0.884} \quad (1)$$

The ranking showing the road traffic safety performance of the cities is shown in Table 8. The table also shows the principal component scores and general factor scores. In Figure 5, the road traffic safety index and the normalized rates of traffic accidents, fatalities and injuries in cities can be seen. The road traffic safety scores of the cities are also shown in Figure 6 as a bar graph. Erzurum came first on the road traffic safety index with a score of 100 according to the results of the analyses. Of the three cities with the largest population in Turkey, İstanbul ranked fourth with a score of 94.590, Ankara ranked fifth with a score of 90.893 and İzmir ranked twelfth with a score of 82.535. There are only 3 cities that take positive contributions from all factor groups. These cities are Erzurum (first place), Trabzon (third place) and Malatya (sixth place). There is no city that takes negative contributions from all factor groups.

Table 8. Road traffic safety index

Place	City	Score of 1st Factor	Score of 2nd Factor	Score of 3rd Factor	Score of 4th Factor	General Factor Score	Road Traffic Safety Index
1	**Erzurum**	0.650	0.438	2.692	0.937	0.982	100.000
2	**Diyarbakır**	1.552	0.594	0.280	-0.356	0.910	98.361
3	**Trabzon**	0.375	0.809	1.651	0.821	0.764	95.037
4	**İstanbul**	1.463	2.496	-2.499	-2.606	0.744	94.590
5	**Ankara**	0.021	2.211	0.047	-0.952	0.581	90.893
6	**Malatya**	0.369	0.122	1.657	0.447	0.539	89.948
7	**Eskişehir**	-0.173	1.201	1.361	-0.410	0.482	88.654
8	**Kahramanmaraş**	0.231	1.006	-0.001	0.855	0.455	88.029
9	**Gaziantep**	0.855	0.154	-0.316	-0.183	0.367	86.043
10	**Van**	1.479	-1.469	0.602	-0.205	0.358	85.830
11	**Kocaeli**	0.385	0.711	-0.993	0.264	0.218	82.663
12	**İzmir**	0.068	1.206	-0.798	-0.248	0.212	82.535
13	**Adana**	0.173	0.409	-0.519	0.641	0.148	81.066
14	**Mardin**	1.597	-1.589	-1.063	0.391	0.117	80.369
15	**Samsun**	-0.194	0.301	0.291	0.712	0.100	79.995
16	**Kayseri**	-0.152	0.399	0.034	0.668	0.098	79.936
17	**Ordu**	0.739	-0.696	0.803	-3.424	0.044	78.710
18	**Şanlıurfa**	1.280	-1.880	-0.677	-0.292	-0.091	75.658
19	**Tekirdağ**	-0.019	-0.133	0.130	-1.521	-0.132	74.731
20	**Bursa**	0.332	-0.672	-1.045	-0.186	-0.243	72.217
21	**Denizli**	-1.101	0.105	0.527	0.348	-0.356	69.638
22	**Hatay**	-0.127	-0.947	-0.424	0.601	-0.363	69.482
23	**Konya**	-1.005	-0.093	0.298	0.600	-0.392	68.822
24	**Sakarya**	-0.449	-0.508	-0.780	0.069	-0.489	66.624
25	**Antalya**	-1.063	0.442	-0.813	0.073	-0.507	66.224
26	**Aydın**	-1.071	-0.268	-0.213	0.676	-0.561	65.007
27	**Manisa**	-1.230	-0.564	0.127	0.560	-0.665	62.643
28	**Mersin**	-1.043	-0.521	-0.565	0.662	-0.685	62.188
29	**Balıkesir**	-1.435	-0.549	-0.130	0.637	-0.796	59.672
30	**Muğla**	-2.507	-0.554	0.335	0.422	-1.222	50.000

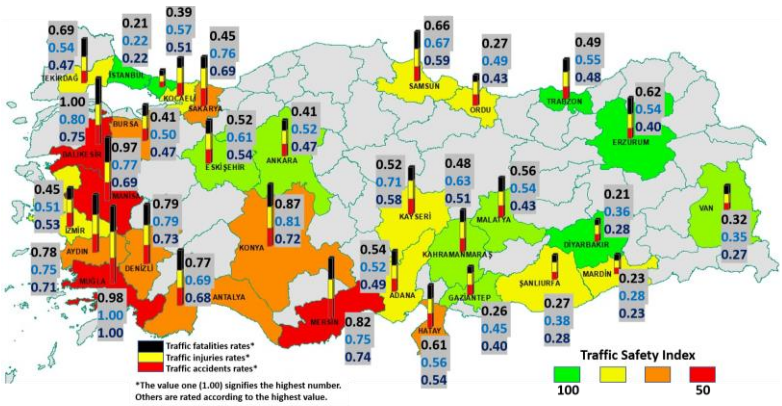

Figure 5. Road traffic safety scores of cities and the rates of traffic fatalities, injuries, and accidents per capita (prepared in ArcGIS)

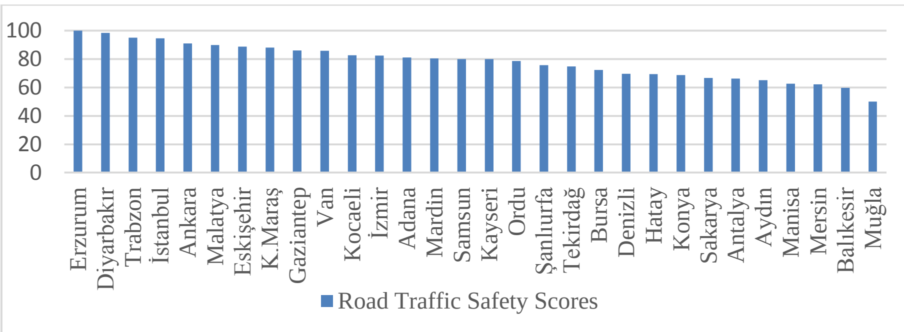

Figure 6. Road traffic safety scores of cities

Population density, vehicle ownership, road length per km2 and GDP per capita were used as indicators. Analysis results can be seen in Table 9. 30 metropolitan cities were divided into 4 clusters according to the results of the analysis. The first cluster included only İstanbul. The second cluster included cities with high population density. Cities with vehicle ownership ratios close to the average are also in this cluster. The third cluster included cities with low income per capita. The fourth cluster included cities with a high vehicle ownership ratio.

Table 9. City clusters

1st Cluster	• İstanbul
2nd Cluster	• Ankara, Bursa, Gaziantep, Hatay, İzmir, Kocaeli, Sakarya
3rd Cluster	• Diyarbakır, Erzurum, Kahramanmaraş, Kayseri, Malatya, Mardin, Ordu, Şanlıurfa, Trabzon, Van
4th Cluster	• Adana, Antalya, Aydın, Balıkesir, Denizli, Eskişehir, Konya, Manisa, Mersin, Muğla, Samsun, Tekirdağ

The road traffic safety scores and the traffic fatalities per 100,000 people can be seen together in Figure 7. Road traffic safety scores increase as traffic fatalities per person decrease according to the results of the analysis. The colors represent the cluster to which the cities belong: green (first cluster), yellow (second cluster), blue (third cluster) and pink (fourth cluster).

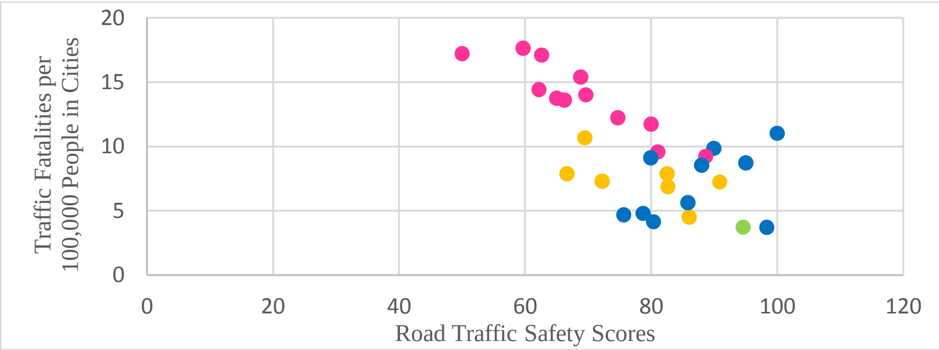

Figure 7. Relation between the traffic fatalities and road traffic safety scores (green-first cluster, yellow-second cluster, blue-third cluster and pink-fourth cluster).

The clusters of the cities are visualized with the map prepared in ArcGIS and the road traffic safety scores of the cities are also recorded on the map which can be seen in Figure 8. The average of the road traffic safety scores of the second, third and fourth clusters is 78.637, 87.188, and 69.053, respectively. If İstanbul is excluded, the cluster with the highest average road traffic safety score is the third cluster. According to cluster analysis, the common point of the third cluster cities is their low income per capita.

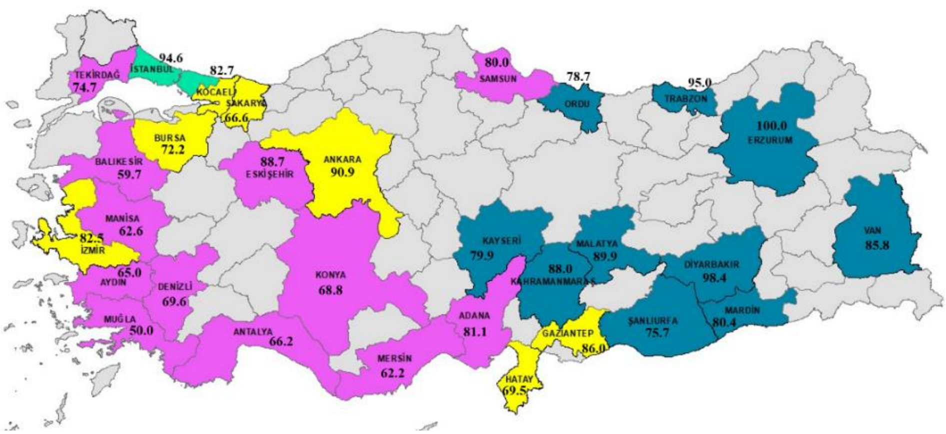

Figure 8. Clusters and road traffic safety scores of the cities

5. CONCLUSIONS AND RECOMMENDATIONS

In this study, the road traffic safety performance of the metropolitan cities in Turkey was measured by applying principal components analysis. In the study, a total of 10 indicators were selected regarding traffic casualties (traffic accidents, fatalities and injuries), educational level, trauma management, enforcement, demography and characteristics of the cities. Then, Ward's cluster analysis was applied to classify the cities. The indicators used in the cluster analysis included population density, vehicle ownership, road length per km^2 and GDP per capita. The conclusions and suggestions of the study are presented as follows:

Conclusions:

- This is the latest study on the road traffic safety index covering the metropolitan cities of Turkey.
- This study differs from similar studies in terms of showing just how much road traffic safety can be explained when the data are not of the desired quality and adequacy.
- Cities with higher traffic density are mostly at the top places in the index. Perhaps one reason for this is that traffic speeds are lower in these cities. This is because in the case of a traffic accident, lower traffic speeds will often lead to accidents with only material damage.
- Cities that are frequently visited by tourists, especially in summer, are mostly on the lower places in the index. It is observed that these cities have a vehicle ownership ratio above the national average. However, it should be investigated whether the residents of the city or the tourists are the reason for this high ratio. In addition, accident severity levels in these cities are mostly higher than in other cities.
- Unfortunately, the indicators used in the study are not at the desired level. In addition, these indicators do not seem sufficient considering current approaches to road traffic safety. For example, it would be more realistic to use traffic accident-fatality-injury indicators per vehicle-kilometer or passenger-kilometer instead of per population. Another example is the two indicators used in the analysis to represent trauma management. To represent it properly, an indicator such as the reaction time during an emergency should be used instead. The number of recommendations related to this situation should be increased. However, the indicators used in the study were chosen to cover the field as much as possible, considering current approaches.
- According to the cluster analysis, it is seen that one of the clusters includes only İstanbul. In Turkey, there is no city similar to İstanbul with its unique structural characteristics. This classification will provide a fairer comparison of road traffic safety performance of cities. It will also be more appropriate to make an evaluation considering the cluster analysis for other cities.
- There are limitations in this study due to the quality and availability of data: it seems that the desired data for some indicators are not measured citywide and, also, that the data that are produced are not always publicly shared.
- Attention is drawn to the lack of an interdisciplinary institute in the field of road traffic safety in Turkey.

Recommendations:

- A successful and comprehensive data analysis is essential to produce appropriate solutions in the prevention of traffic accidents that cause a loss corresponding to approximately 3% of the GDP of countries [1]. Keeping these analyses up-to-date is important for making the right decisions, evaluating the impact of the measures taken, and monitoring the situation constantly.
- One of the aims of this study is to show what cities can learn from each other and thus provide ideas for decision-makers and practitioners. From this perspective, the importance of cluster analysis becomes more apparent. Cluster analysis can also be repeated and improved with more and higher quality data.
- Although there is a unit working on road traffic safety within the organizational structure of the Turkish National Police (TNP) and General Directorate of Highways (GDH), there is no unit consisting of various disciplines working on this. GDH can only conduct an inspection on the road network which is under its responsibility. There is need for an institution that will take responsibility across the country in this field to increase cooperation and facilitate communication. The National Road and Transport Research Institute in Sweden (VTI), the Transport Research Laboratory in the UK (TRL) and the Institute for Road Safety Research in the Netherlands (SWOV) can be taken as models for a similar institution to be established in Turkey.

- It is very important to produce quality data and share it publicly for this and similar studies to be more meaningful and contribute more to the literature.
- The study should be updated when the desired data are provided. Thus, this and any updated study can be compared and examined to show how adequate, or not, the existing data are.
- Different analysis methods should also be evaluated in future studies on the road traffic safety index. In this way, the advantages and disadvantages of different methods can be seen clearly.

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