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Research Paper

Composite Road Safety Performance Indicators in Developing Countries; a Result Focus Comparison Analysis

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Abstract

Among the many goals of global plans, one can refer to the development and implementation of sustainable road safety strategies and programs which can lead to an ambitious but feasible goal of reducing road fatalities by monitoring road safety performance indicators. With global goals in mind, this study attempts to provide a rational framework for comparing several mathematical models for achieving national-level road safety targets in Iran and among a number of developing countries and emerging economies. The main purpose of this paper is to develop a multi-criteria decision making model for analyzing and selecting the best composite indicator from the results of several previous studies in this field over the fifteen countries. For this purpose, the PROMETHEE method was used to analyze the robustness of the results of four methods. These four methods are simple ranking by fatality rates, Success Indicators using data envelopment analysis by a two-objective nonlinear programming model, integration of Structural Equation Modeling and Data Envelopment Analysis (SEM-DEA method), and the outranking method of ELECTRE that were used simultaneously in a study to analyze road safety performance indicators in the same 15 countries. By applying the preference function used in this study, the ELECTRE method has presented higher robust results. Interventions that should be emphasized in Iran in priority order are the development of vehicle safety, the improvement of the road safety management structure and the development of post-crash response.

Keywords: Outranking methods, Composite road safety performance indicators, Data Envelopment Analysis, Road safety pillars

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1. Introduction

Road safety is a well-known global issue. According to the World Health Organization [WHO, 2018], road crashes have been recognized as the eighth leading cause of death in the world in recent years. In 2010, the United Nations General Assembly declared 2011-2020 as a decade of action for road safety [United Nations Road Safety Collaboration, 2011]. Among the many goals of this World Initiative, one can refer to the development and implementation of sustainable road safety strategies and programs which can lead to an ambitious but feasible goal of reducing road fatalities by monitoring road safety performance indicators. With this regard, international bodies such as the World Health Organization are required to set performance targets in relation to road safety risk factors in the member states [Independent Council for Road Safety International, 2020].

In setting targets for road safety interventions in countries, especially in developing societies, policy makers have problem with setting reliable quantities which could credibly ensure needed implications in a result-focus road safety management system. Such targets are much useful in establishing national plans.

Various studies have proposed several models for analyzing road safety performance indicators and generating composite indicators using them. These models can lead to different results from countries' efficiency and rating levels. Choosing the most appropriate method for achieving robust results in this area has been a concern for decision makers. The idea to provide a method to analyze and compare different models and to achieve a model with the highest reliability has been on the agenda. In this study, four approaches that have been presented in three previous studies for 15 developing countries have been investigated simultaneously (see Figure 1).

Iran is one of the countries with the highest number of deaths and injuries due to road crashes, which is so worrying compared to other countries in the world. With global goals in mind, this study attempts to provide a rational framework for comparing several mathematical models for achieving national-level road safety targets in Iran and among a number of developing countries. This study assesses Iran among developing societies or emerging economics. This comparison provides a better and deeper understanding of the road safety status in these countries. Accordingly, the five pillars of road safety development, including road safety management, safer roads and mobility, safer vehicles, safer road users, and post-crash response were used to rank countries. In these five pillars, Road Safety Performance Indicators (RSPIs) are classified into different levels and layers as shown in Table 1.

The outranking method used in this study can best highlight the preferred method amongst a set of indicators that have been existing or developed before. The simplest indicator is the fatality rate per population which could only point out a general national status (i.e. social risk) but is disable to set targets. Thereby, the supplementary indices had been developed as composite indicators but still there is a dilemma to select the preferred method. This way, we may convince governments and ensure robustness of policies by innovating such a comparison effort on previous integrated studies using multiple ranking criteria. Simply put, we have had a story by a same narrator and for same countries which could have reached a decisive end in this paper.

Achieving an effective combination and robust values of road safety performance indicators requires comparing the results of various methods and analyzing different indicators in this area. Each index can contain some additional information about the three levels of final outcomes, intermediate outcomes, and intervention outputs, as well as a level of exposure. The purpose of the comparison is to give the rating a reliable result. Hermans et al. [2007] emphasize that a country's position can be influenced by methodological choices. As they recommend, a common process for generating a composite indicator consists of several important steps: selecting the appropriate indices, normalizing the index values, determining the weight for each index, and their aggregation method, each of which can affect the final ranking results.

In this study, 14 developing countries were considered as following to compare Iran with other similar countries and identifying the target indicators for Iran:

- Emerging economies known as BRICS member states including Brazil, Russian Federation, India, China, and South Africa;
- Developing countries whose road safety management system has already been structured on the basis of the Global Road Safety Facility guidelines [Bliss&Breen, 2013; and Bliss&Raffo, 2013] including Argentina, Malaysia, and Poland; and
- Six countries which are immediately located above Iran in terms of the Human Development Index [World Bank Group, 2015] including Mexico, Kazakhstan, Turkey, Lebanon, Oman, and Romania.

All dtailed data about the road safety condition in all 15 countries are shown in Table 2.

Multi-criteria decision-making methods have been used in different studies with different objectives to solve decision-making problems in road safety planning. We used the study by four distinct methods because the previous researches on the same countries were limited to these ones only and we wanted to reach final conclusion following the conduction of a set of distinct studies. The main purpose of this paper is to develop a multi-criteria decision making model for analyzing and selecting the best composite indicator from the results of several previous studies in this field over the fifteen countries mentioned above. The first study [Behnood, 2018] included the designation of a virtual intermediate outcome index as a measure of success for each road safety pillar in each of the 15 countries. The main purpose of this research was to find a scoring index to express the success of each pillar using the concepts of result focus management and identifying best practices in a set of developing countries, focusing on the results in Iran. The objective of the second study [Behnood et al., 2020] was to search for effective safety pillars in road safety capacity strengthening based on the experiences of the leading countries. This study tried to use the results of a structural equations model (SEM) with partial least squares approach to select an index as the representative index of each road safety pillar. Then, using the data envelopment analysis (DEA), the ratio of the fatality rate to the sum of five calculated weights for a set of developing countries was calculated. In the third study [Sarikhani et al., 2020], a multi-criteria decision-making approach called the outranking, including the ELECTRE method was used to evaluate the road safety performance. In this method, the hierarchical analysis process (AHP) was used to find the weights of the indices as input weights in the ELECTRE model.

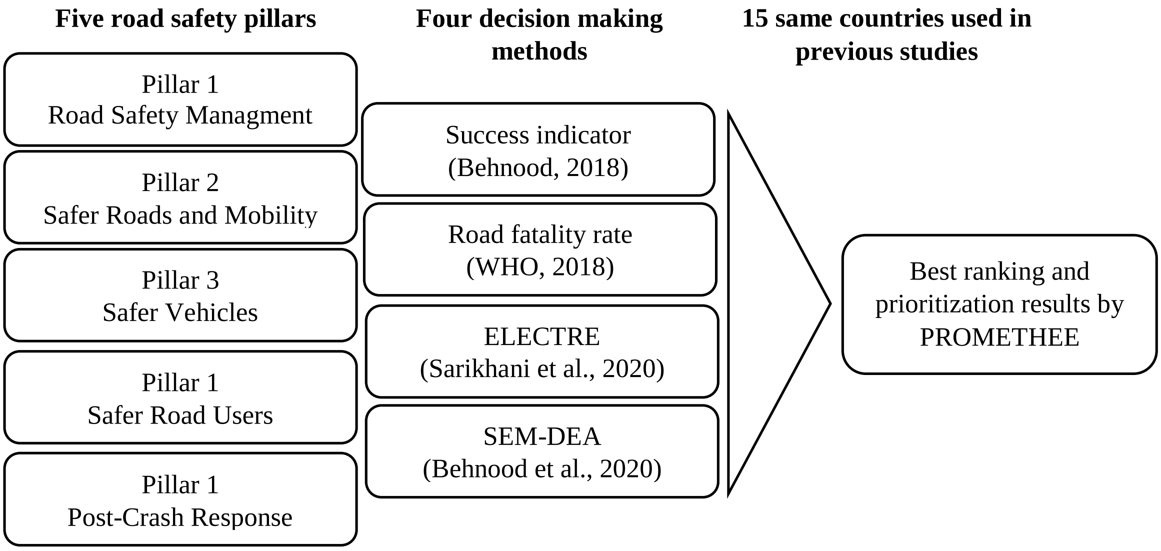

Figure 1. Components and methods in the study

Table 1. Road safety performance indicators in five road safety pillars

Road Safety Pillar		Intervention		Value
Road Safety Management	RSM	Lead agency	Lead agency	1: both case exist 0.5: one case exists 0: no case exists
			Funded Lead agency	
		Coordination		1: Exists 0: Not exists
		Legislation		
		Monitoring & Evaluation		
Safer Roads and Mobility	SRM	Formal audit		1: Exists 0.5: Subnationally exists 0: Not exists
		Regular inspection		
		Walking and cycling		
		Public transport		
		Facilities for vulnerable road users		
Safer Vehicles	SV	Seat belt	Seat belt	1: both case exist 0.5: one case exists 0: no case exists
			Seat-belt anchorages	
		Side and frontal impact	Frontal impact	
			Side impact	
		Electronic stability		1: Exists 0: Not exists
		Pedestrian protection		
		Child seats		
Safer Road Users	SRU	Speed		Efficiency score assigned by World Health Organization
		Alcohol		
		Helmet		
		Seat belt		
		Child restraint		
Post-Crash Response	PCR	Training in emergency medicine	For doctors	1: both case exist 0.5: one case exists 0: no case exists
			For nurses	
		Injury surveillance system		1: Exists 0: Not exists
		Vital registration system		

This method checks for the matching and mismatch of each pair of options and defines the relationship between the two options through graphs. The method used in this study was also applied to Iran and the fourteen developing countries with the aim of examining the road safety status in Iran in relation to the others. In addition to the above mentioned methods, the simple ranking method was also analyzed using the fatality rate (number of road deaths per 100,000 population).

In the last two decades a great deal of effort has been put into constructing composite indicators for the purpose of performance analysis. In many studies, data envelopment analysis (DEA) has been used as a suitable methodological tool [e.g. Emrouznejad & Yang, 2018; Emrouznejad & Thanassoulis, 2018; and Peykani et al., 2019]. The DEA is a non-parametric mathematical optimization method developed by Charnes et al. [1978] and extended by Banker et al. [1984]. In these two decades, the final outcomes attributable to road crashes (including injury and fatality indicators) have been analyzed as a major concern of communities in terms of undesirable output variables in the DEA method [e.g. Hermans et al., 2009; Ahmadvand et al., 2011; and Behnood et al., 2014]. Hermans et al. [2008] emphasize that the weight allocation to individual indicators is an important step in the process of constructing composite performance indicators. The DEA method is able to handle multiple inputs and outputs and helps uncover relationships that may be hidden under other methods. This method is a suitable tool for measuring performance that can be analyzed and quantified. One of the limitations of this method is the number of variables to be analyzed, the sample must be at least two times less than the number of combined input and output measurements.

Table 2. Road safety performance indicators classified by results in road safety management system

Country	Income*	Fatality/100,000 inhabitants	Road Safety Management		Safer roads and mobility					Safer vehicles					Safer road users					Post-crash care	
			lead agency	management functions	formal audit	regular inspection	walking& cycling	public transport	vulnerable road users	seat-belt	frontal and side impact	electronic stability	pedestrian protection	Child seats	speed	drink driving	helmet	seat belt	child restraint	Training in emergency medicine	injury surveillance system
Iran	M	32.1	0.5	1.0	0.0	1.0	0.5	1.0	0.5	0.0	0.0	0.0	0.0	0.0	0.7	0.8	0.5	0.7	0.0	1.0	1.0
Brazil	M	23.6	1.0	1.0	1.0	1.0	1.0	1.0	0.5	1.0	1.0	0.0	0.0	1.0	0.7	0.8	0.6	0.7	0.6	1.0	1.0
Russian Federation	H	18.9	1.0	1.0	1.0	1.0	0.5	0.5	0.5	1.0	1.0	1.0	1.0	1.0	0.8	0.6	0.6	0.7	0.6	1.0	1.0
India	M	16.6	1.0	1.0	1.0	0.0	1.0	1.0	0.5	1.0	0.0	0.0	0.0	0.0	0.3	0.4	0.4	0.4	0.0	1.0	0.0
China	M	18.8	1.0	0.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.8	0.9	0.6	0.8	0.0	0.5	1.0
South Africa	M	25.4	1.0	1.0	1.0	1.0	0.0	1.0	1.0	0.5	0.0	1.0	1.0	1.0	0.3	0.4	0.5	0.2	0.0	1.0	0.0
Argentina	M	13.6	0.5	1.0	1.0	1.0	0.5	1.0	0.5	1.0	1.0	0.0	0.0	0.0	0.7	0.6	0.6	0.6	0.0	1.0	1.0
Malaysia	M	24.0	1.0	1.0	1.0	1.0	0.5	1.0	1.0	1.0	1.0	1.0	0.0	1.0	0.6	0.5	0.5	0.4	0.0	1.0	0.0
Poland	H	10.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.5	0.8	0.9	0.7	0.8	1.0	0.0
Mexico	M	12.3	0.0	0.0	0.0	1.0	0.5	0.5	0.0	0.5	0.0	0.0	0.0	0.0	0.5	0.5	0.6	0.7	0.4	1.0	0.0
Kazakhstan	M	24.2	1.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	1.0	1.0	1.0	0.7	1.0	1.0
Turkey	M	8.9	1.0	1.0	1.0	1.0	0.5	1.0	0.0	1.0	1.0	1.0	1.0	1.0	0.4	0.3	0.3	0.2	0.3	0.5	1.0
Lebanon	M	22.6	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.2	0.3	0.0	1.0	0.0
Oman	H	25.4	1.0	1.0	1.0	1.0	0.5	1.0	0.5	0.0	0.0	0.0	0.0	0.0	0.9	0.8	1.0	0.9	0.5	1.0	1.0
Romania	M	8.7	0.5	0.7	1.0	1.0	1.0	1.0	0.5	1.0	1.0	1.0	1.0	1.0	0.5	0.8	0.9	0.7	0.7	1.0	0.0

* H= High income, M= Middle income

Analyzing data from European countries, they identified the use of DEA analysis as the best way to create composite indicators for road safety performance and efficiency analysis. Shen et al. [2011] applied 13 road safety performance indicators as input parameters (such as percentage of helmet violations by motorcyclists) and four outputs (such as number of deaths per million inhabitants) for 19 European countries as decision making units (DMUs). A multilayer DEA (MLDEA) was used to form weights at each hierarchical level. Shen et al. [2015] examined the final outcome of serious injuries in addition to the number of fatalities for a road safety measure and its impact on European countries' ranking. They showed that when countries had a severe injury index, most countries achieved a higher degree of risk, which suggests that more attention should be paid to confront the severity of injury in countries than road deaths. Artz and Huyngs [2015] compared three local area grouping methods including traditional (provincial), simple, and advanced to model road safety performance in the Netherlands. In this study, the urbanization level was identified as the most important factor in the simple method, and advanced clustering method was superior in modeling and analyzing the performance of suburban areas. Nicolaus and Dimitriou [2018)] also analyzed the performance of road safety policies at EU level over a decade (2005 to 2014) according to their socio-economic and demographic considerations. Behnood et al. [2014] developed a model to evaluate the effectiveness of annual interventions implemented in 30 provinces of Iran using an inefficiency index including the ratio of the weighted sum of road fatality risk indicators to the total weight of road safety interventions. They then proposed a fuzzy decision support system to provide a pathway for qualitative decision-making policies [Behnood et al, 2017]. Ganji and Rasafi [2019] also evaluated performance indicators of road safety in 30 provinces of the country using a DEA model and the Malmquist Productivity Index (MPI) with two frontiers. Tavakoli Kashani et al. [2019] proposed a composite safety performance index that takes performance efficiency into account using a three-dimensional approach called 'Risk-Exposure-Resources'. In addition to the risk and exposure indicators, four variables pertaining to the safety equipment and resources allocated to each spatial unit were considered in the analysis as indicators of the Resources dimension. The Risk-Exposure-Resources framework was regarded as an appropriate complementary tool for evaluating the safety performance and facilitating fair comparison among subnational regions.

Sarraf et al. (2020) compared five decision-making techniques (AHP, Fuzzy AHP, TOPSIS, Fuzzy TOPSIS and PROMETHEE) through two real-world case studies. As a result, comparative studies have not been able to adequately determine the results of Multi-Criteria Decision Making (MCDM) methods. Grdinić-Rakonjac et al. (2021) presented an innovative weighting method using gray relational analysis, which selects ten hierarchical indicators of road safety in the form of a two-layer model with three categories related to behavior, safety, and system. Pajković et al. (2021) proposed a road safety performance index based on fuzzy data using the DEA-GRA model, which provides a more reasonable and comprehensive measure of performance and can obtain the overall ranking position of municipalities. Tufail et al. (2021) developed a general road safety performance index (RSPI) using two methods (principal component analysis (PCA) and equal weight method (EW)) for developing countries based on the facilities and behavior of road users and with a selection of four main safety performance indicators (protection system, road, number of pedestrians and number of vehicles). Ayadi et al. (2021) presented a compensatory and partially compensatory approach for constructing composite indices, using fuzzy MCDM methods. Chen et al. (2022) introduced the CRITIC-ELECTRE-FCM method for multi-criteria decision making, which evaluated the road safety performance of 11 countries in Southeast Asia and the robustness of the analysis with other widely used methods. Asdamarji et al. (2022) presented a new prioritization index for prioritizing ITS projects in one of the main corridors of Iran (Tehran-Bander Imam), which was designed according to the average of solutions.

The concept of robustness of composite performance indicators is a necessity for the formation of such indicators. Kukić et al. [2013] emphasize the correlation between the observed risk and the average value of risk estimation in the relevant classification (social or traffic risks) to determine the indicator that best represents the risk. Bao et al. [2012] used Pearson correlation analysis to provide a quantitative and clear comparison of relationships, and for this purpose, considered the fatality rate as an appropriate reference point. Bastos et al. [2015] also considered the correlation between the amount of indices obtained and the two references including GDP per capita and fatality rate for model comparison. In a comprehensive study in this area, Rosić et al. [2017] used a performance indicator comprising composite indices derived from different models (DEA and TOPSIS models) to present the PROMETHEE-RS model and select the optimal method used to create the composite index.

2. Methods

The three comparative studies in this study were based on data from the Global Status Report on Road Safety 2015 [WHO, 2015]. In this research, the PROMETHEE method was used to select the optimal composite indicator. In this method, without data normalization, a preference function is used and the responses are compared against each other. The PROMETHEE method provides a simple ranking tool and can be used to compare multiple methods with multiple criteria [Brans et al., 1985; and Brans et al., 1986]. The preference function converts the difference between two options for each criterion into a priority degree between zero and one.

Given that no single fully validated measure can be applied to the analysis of road safety performance indicators, when estimating the robustness of the composite indicator, for any index that has contributed to creat it, we have to do with a wide range of different weights. In this study, *s* different indicators constituting or associated with the composite indicator is considered in *n* different ways to develop it. Each index has a weight indicating its importance (w_k; k=1,…,s) and these weights are used in the method of producing the composite indicator, depending on the nature of the model. The results for *m* decision making units (DMUs) can be generalized as shown in two Tables 3 and 4. Table 3 presents information on the values and ranks obtained by each method for generating the composite indicator in each DMU, and Table 4 presents the rank for each index included in the composite indicator for each DMU. The rank variance (V_{jk}) as well as the cluster variance (C_{jk}) for each composite indicator obtained by the method *j* and the rank obtained for the index *k* can be obtained by using the following equations:

$$V_{jk} = \frac{1}{m}\sum_{i=1}^{m}\left|r_{ij} - p_{ik}\right| \quad (1)$$

$$C_{jk} = \frac{1}{m}\sum_{i=1}^{m}\left|g_{ij} - h_{ik}\right| \quad (2)$$

The mean rank variance (V_j) as well as the mean cluster variance (C_j) for the method j are obtained from the following equations:

$$V_j = \sum_{k=1}^{5} w_k * V_{jk} \quad (3)$$

$$C_j = \sum_{k=1}^{5} w_k * C_{jk} \quad (4)$$

$$\sum_{k=1}^{5} w_k = 1 \quad (5)$$

Where $V_{jk}$is rank variance, C_{jk} is cluster variance, r_{ij}, g_{ij} are shown in table 3, p_{ij}, h_{ij} are shown in table 4, s refers to different indicators, n refers to different methods, w_k is the indicator weight, and m denotes decision making units (DMUs). V_j, C_j are shown in table 5.

The mean rank variance and mean correlation coefficient are the weighted average of these criteria and the relationship is defined as the sum of these weights for normalization equals one. Using this weighted average, the model assumes the previously assigned and selected weights for each indicator. The reason for considering the weight is that the robustness of the composite index in relation to each constituent index should be evaluated with respect to its importance. In other words, the index that is less important during the process of composite indicator creation will have lower values of the mean rank variance, mean cluster variance, and correlation coefficient. Because of the negative Pearson correlation coefficient, its absolute value is used in the analysis. Pearson correlation coefficient between the values obtained from the method j and the values of the index k is calculated using the following equation:

$$P_{jk} = \frac{\sum_{i=1}^{m}(x_{ij} - \overline{x_j})(y_{ij} - \overline{x_j})}{\sqrt{\sum_{i=1}^{m}(x_{ij} - \overline{x_j})^2}\sqrt{\sum_{i=1}^{m}(y_{ij} - \overline{x_j})^2}} \quad (6)$$

Where $x_{ij}, \overline{x_j}$ are shown in table 3 and $y_{ij}, \overline{y_j}$ are shown in table 4.

The mean correlation coefficient for method j is the mean of correlation for a particular method and between the indicators and can be obtained using the following equation:

$$P_j = \sum_{k=1}^{5} w_k * |P_{jk}| \quad (7)$$

The multi-criteria decision-making problem in this study consists of n different methods for generating a composite road safety performance indicator which are ranked based on three criteria: average correlation, mean rank variance and mean cluster variance using PROMETHEE method. To simplify the whole model, the following preference functions are used:

- For mean rank variance:

$$F_1(M_i, M_k) = \begin{cases} 0, & d \geq 0 \\ 1, & d < 0 \end{cases} \quad (8)$$

Where: $d = V_j - V_k \quad , for\ i,k = 1, \dots\dots, n$

- For mean cluster variance:

$$F_2(M_i, M_k) = \begin{cases} 0, & d \geq 0 \\ 1, & d < 0 \end{cases} \quad (9)$$

Where: $d = C_j - C_k \quad , for\ i,k = 1, \dots\dots, n$

- For mean correlation:

$$F_3(M_i, M_k) = \begin{cases} 0, & d \leq 0 \\ 1, & d > 0 \end{cases} \quad (10)$$

Where: $d = P_j - P_k \quad , for\ i,k = 1, \dots\dots, n$

Table 3. Pattern of composite indicators and respondents' ratings for each DMU and each method

DMU	Method 1			Method k			Method n		
	Value	Rank	Group	Value	Rank	Group	Value	Rank	Group
1	x_{11}	r_{11}	g_{11}	x_{1j}	r_{1j}	g_{1j}	x_{1n}	r_{1n}	g_{1n}
2	x_{21}	r_{21}	g_{21}	x_{2j}	r_{2j}	g_{2j}	x_{2n}	r_{2n}	g_{2n}
i	x_{i1}	r_{i1}	g_{i1}	x_{ij}	r_{ij}	g_{ij}	x_{in}	r_{in}	g_{in}
m	x_{m1}	r_{m1}	g_{m1}	x_{mj}	r_{mj}	g_{mj}	x_{mn}	r_{mn}	g_{mn}
Mean	$\overline{x_1}$	-	-	$\overline{x_j}$	-	-	$\overline{x_n}$	-	-

Table 4. Pattern of relevant indicators and respondents' ratings for each DMU

DMU	Indicator 1			Indicator k			Indicator s		
	Value	Rank	Group	Value	Rank	Group	Value	Rank	Group
1	y_{11}	p_{11}	h_{11}	y_{1j}	p_{1j}	h_{1j}	y_{1n}	p_{1n}	h_{1n}
2	y_{21}	p_{21}	h_{21}	y_{2j}	p_{2j}	h_{2j}	y_{2n}	p_{2n}	h_{2n}

DMU	Indicator 1			Indicator k			Indicator s		
	Value	Rank	Group	Value	Rank	Group	Value	Rank	Group
i	y_{i1}	p_{i1}	h_{i1}	y_{ij}	p_{ij}	h_{ij}	y_{in}	p_{in}	h_{in}
m	y_{m1}	p_{m1}	h_{m1}	y_{mj}	p_{mj}	h_{mj}	y_{mn}	p_{mn}	h_{mn}
Mean	$\overline{y_1}$	-	-	$\overline{y_k}$	-	-	$\overline{y_s}$	-	-
Weights	w_1			w_k			w_s		

Table 5. Prioritization pattern used in PROMETHEE

	Average Rank Variance	Average Cluster Variance	Average Correlation
Method 1 (M1)	V_1	C_1	P_1
Method j (Mj)	V_j	C_j	P_j
Method n (Mn)	V_n	C_n	P_n

Two values (zero or one) can be assigned to the preference function, where one means the preference of the M_i method over the M_k method. Preference functions are defined such that the larger the correlation coefficient and the lower the variance of rank and cluster, the better the conditions. These differences are calculated for each pair of options and for all three criteria. The global preference index for each pair of options is calculated using all criteria simultaneously as follows:

$$\pi(A_i, A_k) = \sum_{r=1}^{3} w_r * F_r(A_i, A_k), \quad i = 1, \dots, n, \quad k = 1, \dots, n \qquad (11)$$

$$\sum_{r=1}^{3} w_r = 1 \qquad (12)$$

Based on these equations, each criterion can be assigned a weight whose sum is equal to one. Calculating the positive (output) and negative (input) rating flows for each option can be conducted using the following equations:

$$\phi^+(A_i) = \frac{1}{n-1} \sum_{x \varepsilon A} \pi(A_i, x) \qquad (13)$$

$$\phi^-(A_i) = \frac{1}{n-1} \sum_{x \varepsilon A} \pi(x, A_i) \qquad (14)$$

The positive flow (output) indicates how much an option like *i* is preferred to other options. The higher this value, the better the option. While the negative (input) flow indicates how much other options are preferred to option *i* hence the lower this value, the better the option. Finally, the net preference flow can be calculated as follows:

$$\phi(M_i) = \phi^+ - \phi^- \qquad (15)$$

The greater the net flow, the better the option. That is, the largest net preference flow indicates that one method is preferred to the others. In the meantime, some methods may be indifferent.

3. Results

In order to implement the PROMETHEE method in this study, four different methods have been used to creat the composite indicator as described in the introduction. The composite indicator considered here includes five road safety pillars including road safety management, safer roads and mobility, safer vehicles, safer road users, and post-crash response. Decision-making units also include 15 developing countries or emerging economics. The robustness analysis of the composite indicator is performed based on the three criteria of mean correlation, mean rank variance and mean cluster variance using PROMETHEE method and a preference function. For this purpose, weights were first obtained by experts' opinion using the Analytical Hierarchy Process (AHP). The weights of the five road safety pillars were obtained based on the AHP method, with the road safety management pillar being the most important and the post-crash response pillar being the least important.

The results of the criteria and methods analysis are shown in two Tables 6 and 7. In these two tables, the efficiency data obtained from the four methods examined for each country are listed and countries are ranked based on these values and indicators for the five road safety pillars. These values and rankings are then entered into the PROMETHEE analysis and calculated using the net flow preference function of each. Table 8 shows the ranking of the four methods according to the three criteria. The results of the ranking analysis are summarized as follows:

- According to the combined analysis of the composite indicators, Poland, Turkey and Romania had an inefficiency equal to one, which means the best situation while Iran was the worst.
- According to the ELECTRE method, Russia was the best-performing and Mexico was the worst-performing DMUs.
- Based on the combination of the two methods of Structural Equation Modeling and Data Envelopment Analysis (SEM-DEA), Poland, Turkey and Romania have an inefficiency equal to one, i.e., the best situation and Iran has the worst situation.
- In the method that the success index is obtained from the Data Envelopment Analysis with the two-objective function and the nonlinear programming model and the success index itself is entered as an unknown variable, the countries of Poland, Turkey and Romania have an inefficiency equal to one which means the best situation and Iran has had the worst situation.
- According to the simple fatality rate method, Romania and Iran had the best and worst situations respectively.
- The situation in Iran in four methods has been in poor condition. Iran was ranked 15th in SEM-DEA, success index and simple fatality rate methods and 13th in ELECTRE method.
- Poland has had one of the best situations of the four methods. It ranks first in Success Index and SEM-DEA methods, second in ELECTRE and third in fatality rate methods.
- The poor performance of Iran is due to its low score on safer vehicles (12th rank) and road safety management (10th rank), while its best performance has been in the field of post-crash response.

Table 6. Ratings obtained for the four analyzed methods

	Method 1			Method 2			Method 3			Method 4		
	Success Indicator			Fatality Rate			ELECTRE Method			SEM-DEA Method		
	Value	Rank	Group	Value	Rank	Group	Value	Rank	Group	Value	Rank	Group
Iran	2.539	15	5	32.1	15	5	-9	13	5	3.12	15	5
Brazil	1.341	7	2	23.6	10	4	7	3	1	2.27	11	3
Russian Federation	1.261	6	1	18.9	8	3	13	1	1	1.83	8	2
India	1.39	8	2	16.6	6	2	-2.5	10	3	1.61	6	2
China	1.404	9	2	18.8	7	3	-1	9	3	1.83	7	2
South Africa	1.932	12	4	25.4	13	4	3.5	7	2	2.44	14	4
Argentina	1.069	4	1	13.6	5	2	-5.5	11	4	1.32	5	1
Malaysia	1.579	10	2	24.0	11	4	5	6	2	2.33	13	4
Poland	1	1	1	10.3	3	1	10	2	1	1	1	1
Mexico	1.234	5	1	12.3	4	1	-13	15	5	1.19	4	1
Kazakhstan	1.629	11	3	24.2	12	4	5	5	1	2.03	9	3
Turkey	1	2	1	8.9	2	1	6	4	1	1	2	1
Lebanon	1.985	13	4	22.6	9	3	-12	14	5	2.19	10	3
Oman	2.358	14	5	25.4	14	4	1	8	3	2.29	12	4
Romania	1	3	1	8.7	1	1	-7.5	12	4	1	3	1

	Method 1 Success Indicator			Method 2 Fatality Rate			Method 3 ELECTRE Method			Method 4 SEM-DEA Method		
	Value	Rank	Group	Value	Rank	Group	Value	Rank	Group	Value	Rank	Group
Mean	1.515			19.027			0.000			1.83		

Also, the results of the ranking of the four methods using PROMETHEE analysis show that the ELECTRE method was the most appropriate method for ranking countries based on the composite indicator. Obviously, each method provides a different set of results for determining the composite indicator. The data used for the inputs in the presented models were completely independent. However, although these differences are observable, the results are usually better to be combined, and even complex data sets can be considered to create the final composite indicator.

4. Discussion

By comparing the methods studied in this study for Iran and 14 developing countries and emerging economies, the ELECTRE method was identified as the most realistic method. It was also found that ranking countries using the methods studied did not have a significant relationship with their simple ranking based on the fatality rate. These results somehow illustrate the facts detailed in previous studies. In other words, the ranking of countries differs according to the weighting method and the position of a country can be influenced by the method chosen [Hermans et al., 2007; Shen et al., 2012; and Rosić et al., 2017] as shown in Figure 2, ratings obtained for the four analyzed methods based on the PROMETHEE criterias in Figure 3. In terms of benchmarking and target setting, the same results have been achieved for Iran, necessitating the development of measures in two pillars of safer vehicles (including new technologies for seat belts, child seats, and side and front impacts) and road safety management. Based on the results, both Turkey and Romania were identified as suitable benchmarks for regulating Iran's best practices in road safety management system.

Table 7. Ratings obtained for the five safety pillars examined

Country	Pillar 1 Road Safety Management			Pillar 2 Safer Roads and Mobility			Pillar 3 Safer Vehicles			Pillar 4 Safer Road Users			Pillar 5 Post-Crash Response		
	Value	Rank	Group	Value	Rank	Group	Value	Rank	Group	Value	Rank	Group	Value	Rank	Group
Iran	1.27	10	1	1.1	6	2	0	12	5	0.66	8	3	1.3	1	1
Brazil	1.44	1	1	1.25	4	1	0.62	7	3	0.84	5	2	1.3	2	1
Russian F.	1.44	2	1	0.9	12	3	1.05	1	1	0.81	6	2	1.3	3	1
India	1.44	3	1	0.87	13	3	0.21	10	4	0.37	12	5	1.3	4	1
China	0.89	12	2	1.41	1	1	0.42	8	3	0.76	7	3	1.3	5	1
South Africa	1.44	4	1	1.1	7	2	0.73	6	2	0.34	15	5	1.3	6	1
Argentina	1.27	11	1	1.1	8	2	0.31	9	4	0.61	10	4	1.3	7	1
Malaysia	1.44	5	1	1.26	3	1	0.84	5	1	0.49	11	5	1.3	8	1
Poland	1.44	6	1	1.41	2	1	1.05	2	1	0.91	3	2	1.3	9	1
Mexico	0	14	5	0.74	14	4	0.1	11	5	0.66	9	3	1.3	10	1
Kazakhstan	1.44	7	1	1.1	9	2	0	13	5	1.11	1	1	1.3	11	1

Country	Pillar 1 Road Safety Management			Pillar 2 Safer Roads and Mobility			Pillar 3 Safer Vehicles			Pillar 4 Safer Road Users			Pillar 5 Post-Crash Response		
	Value	Rank	Group	Value	Rank	Group	Value	Rank	Group	Value	Rank	Group	Value	Rank	Group
Turkey	1.44	8	1	0.95	11	3	1.05	3	1	0.37	13	5	0.96	14	3
Lebanon	0	15	5	0.38	15	5	0	14	5	0.37	14	5	1.3	12	1
Oman	1.44	9	1	1.1	10	2	0	15	5	1.01	2	1	1.3	13	1
Romania	0.72	13	3	1.25	5	1	1.05	4	1	0.89	4	2	0.69	15	5
Mean	1.141			1.061			0.50			0.68			1.24		
Weight	0.247			0.230			0.11			0.15			0.27		

Table 8. Ranking results of four methods using PROMETHEE analysis

Method	Mean rank variance	Rank	Mean cluster variance	Rank	Mean correlation	Rank	Φ	Rank
Success indicator	4.978	2	1.524	2	0.400	2	0.333	2
Fatality rate	5.715	4	1.918	4	0.095	4	-0.999	4
ELECTRE	2.978	1	1.126	1	0.496	1	0.999	1
SEM-DEA	5.639	3	1.715	3	0.344	3	-0.333	3

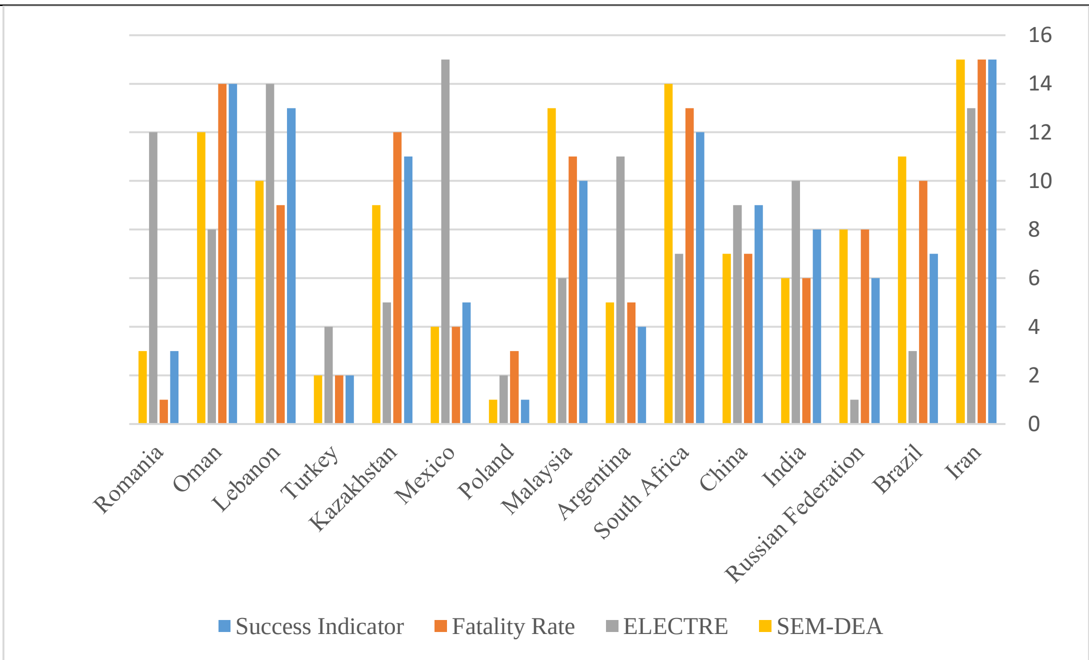

Figure 2. Ratings obtained for Countries based on the four analyzed methods

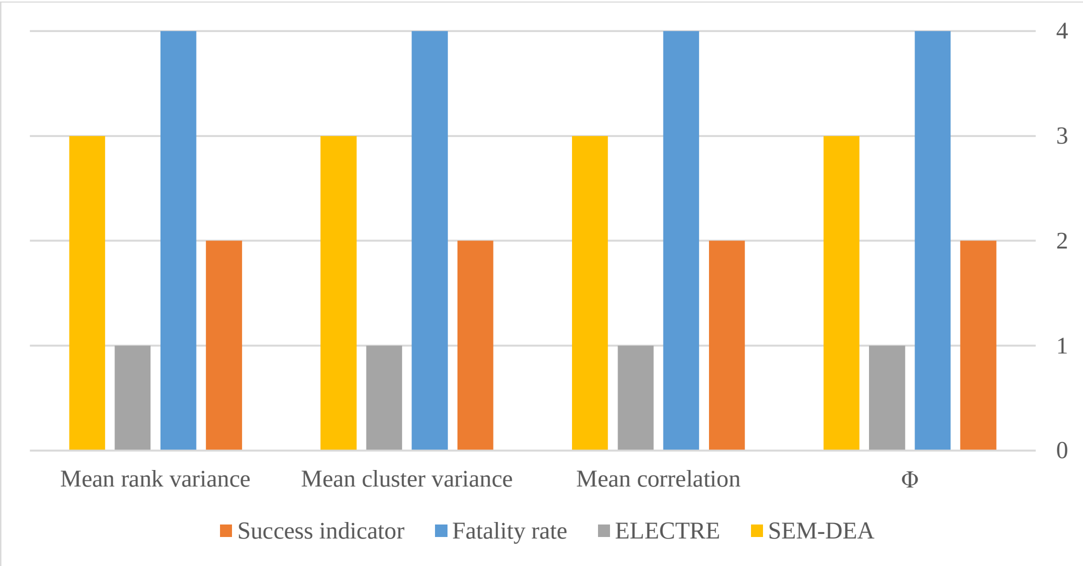

Figure 3. Ratings obtained for the four analyzed methods based on the PROMETHEE criterias

5. Conclusion

Various studies have proposed several models for analyzing road safety performance indicators and generating composite indicators using them. These models can lead to different results from countries' efficiency and rating levels. Choosing the most appropriate method for achieving robust results in this area has been a concern for decision makers. Therefore, the idea to provide a method to analyze and compare different models and to achieve a model with the highest reliability has been on the agenda. In this study, four approaches that have been presented in three previous studies for 15 developing countries have been investigated. For this purpose, the PROMETHEE method was used to analyze the robustness of the results of these four methods. These four methods are Success Indicators using data envelopment analysis by a two-objective nonlinear programming model, integration of Structural Equation Modeling and Data Envelopment Analysis (SEM-DEA method) and the outranking method of ELECTRE that were used simultaneously in a study to analyze road safety performance indicators in the same 15 countries. By applying the preference function used in this study, the ELECTRE method has presented higher robust results.

Finally, it can be concluded that Iran's success in promoting interventions in the two pillars of safer roads and safer road users were higher than other activities. Also, interventions that should be emphasized in Iran in priority order are the development of vehicle safety, the improvement of the road safety management structure and the development of post-crash response. The results show that road safety management capacities need to be doubled at the national level. In this regard, there is a low capacity to utilize and develop vehicle safety interventions that should be pursued in the upcoming years. In general, the two countries of Turkey and Romania can be considered as two suitable benchmarks in developing and implementation of national road safety programs in Iran.

6. Strengths and Limitations

The main strength of this study is that 15 countries were simultaneously compared by four different methods and derived from three independent studies over the same timeframe. On the other hand, the PROMETHEE method was used to determine the best ranking method in which three important criteria of average correlation, mean cluster variance and mean rank variance were used. This approach has been able to identify the most robust composite road safety performance indicators among a group of these indicators.

This method has clarified that ranking countries is not directly related to their road fatality rates and that these rates are not a reliable factor for comparison between countries.

This research has some limitations as well. In this study, AHP was used for weighting, but other weighting methods such as TOPSIS, Kodas, fuzzy approaches integrated in multi-criteria decision making can be applied in future researches. This study also does not take into account the socio-economic conditions in the countries and the final outcome index merely indicates the social risk of road crashes. Future studies could incorporate economic indices such as countries' GDPs or national traffic risk indices (such as fatalities per vehicle-kilometers travelled). The use of other final outcomes, such as the rate of traffic injuries was not included in this study, which can be included in future researches.

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