DOI: 10.7251/JTTTP1901026T
UDC: 656.08:352.07(4-672EU)

PRELIMINARY COMMUNICATIONS

Identifying the Most Significant Indicators of the Total Road Safety Performance Index- Case Study: European Union

Milan Tešić
Pan- European University Apeiron, The College of Traffic Engineering, Banja Luka, Bosna and Herzegovina, milan.z.tesic@apeiron-edu.eu
Elke Hermans
Transportation Research Insitute (IMOB), Hasselt University, Diepenbeek, Belgium, elke.hermans@uhasselt.be
Krsto Lipovac
The Faculty of Transport and Traffic Engineering, Belgrade, Serbia, k.lipovac@sf.bg.ac.rs
Dalibor Pešić
The Faculty of Transport and Traffic Engineering, Belgrade, Serbia, d.pesic@sf.bg.ac.rs

Received: March 4, 2019
Accepted: April 14, 2019

Abstract: The review of the national and international literature dealing with the assessment of the road safety level has shown great efforts of the authors who aimed to define the methodology for calculating the composite road safety index on a territory (region, state, etc.). The procedure for obtaining a road safety composite index of an area has been largely harmonized. The question that has not been fully resolved yet concerns the selection of indicators. There is a wide range of road safety indicators used to show the road safety situation in a territory. The road safety performance index (RSPI) obtained on the basis of a larger number of safety performance indicators (SPIs) enables decision makers to more precisely define earlier goal- oriented actions. Recording a broader comprehensive set of SPIs helps identify the strengths and weaknesses of an area's road safety system. Therefore, there is a need for calculating a road safety performance index with a limited number of indicators ($RSPI_{In}^{n}$) which will provide a comparison of sufficient quality, of as many countries as possible. The application of the Data Envelopment Analysis (DEA) method and correlation analysis has helped to check if the $RSPI_{In}^{n}$ is likely to be of sufficient quality. A strong correlation between the $RSPI_{In}^{n}$ and the RSPI based on all indicators has been identified using the proposed methodology. This will help achieve the standardization of indicators including data collection procedures and selection of the key list of indicators that need to be monitored.

Keywords: road safety level, road safety performance index, most significant indicators.

INTRODUCTION

Due to the multidisciplinary nature of road safety, policy makers must consider numerous contributory factors when making decisions affecting road safety. A wide range of such contributory factors can be combined by applying the composite index approach which has been used increasingly in international cross-country comparisons. No final methodology for road safety composite index design has yet been adopted globally. The accuracy of a composite index does not depend only on selected indicators, weight allocation and data aggregation methods, but also on the strength of correlation between indicators and road crashes and their consequences (Hermans et al., 2009b).

This paper deals with the comparison of countries at the international level. It contains information on the territories (countries) that have been subject to research, the period to which available data on safety performance indicators belong and the software used for the optimization method of selecting safety performance indicators (**Section 2**). The international cross- country comparison of territories takes into account 21 European countries. In order to compare the results, data for the international comparison have been taken over from Hermans, 2009a and represent the snapshot in terms of six chosen safety performance indicators belonging to the period from 2002 to 2008. This manuscript also offers greater details on all seven steps of the methodology for the calculation of the road safety performance index (**Section 3**), with focus on the fourth step concerning the "allocation of weights" and the fifth step that is dealing with the "aggregation method", as the most contributing steps in the process of calculating a road safety performance index. **Section 4** shows the results of the methodology applied for the selected countries. The results thereof have been analyzed from the following two aspects (**Section 5**): 1) correlation analysis of the value of a road safety performance index with a limited number of indicators and the road safety performance index obtained on the basis of all indicators concerned and 2) comparison of countries' ranks on the basis of values of a road safety performance index with a limited number of indicators and the road safety performance index obtained on the basis of all indicators concerned.

STUDY DESIGN

Study objectives

The main objective of this paper is to develop a scientifically sound and appropriate methodology for the creation of a road safety performance index with a limited number of indicators ($RSPI_{ln}^{n}$) that can be used for the monitoring and comparison of road safety performance among countries. This methodology should offer relevant, reliable, and comparable values of the $RSPI_{ln}^{n}$ having the strongest correlation with the RSPI obtained on the basis of the six selected SPIs. Depending of the $RSPI_{ln}^{n}$ a comparable analysis of countries' rankings has been made, highlighting the strength of the correlation with the mortality rate and the human development index, two important indexes which have been linked to the RSPI before (Al- Haji, 2007; Hermans 2009a; Chen et al., 2016). The application of the above methodology will help identify the most significant indicators in the total road safety performance index, on the basis of data measured as a snapshot in time. Also, it allows for a comparison of the largest number of countries possible and provides an adequate, simple and efficient way of road safety monitoring, which, on the other hand, generates actions for the development of a sustainable system for periodical measuring of indicators in low-ranked territories. From a practical point of view, we aim to make credible comparisons of countries in conditions when the availability of data concerning the values of same indicators for a larger number of countries, in a defined time period, is rather limited.

The subject of this study is the continuation of the research conducted so far, by taking into account practical issues of scarce data. The methodology for calculating a road safety performance index with a limited number of indicators used in this paper is of universal and open nature, and is able to allow extension of data to be analyzed in three directions: 1) spatial: it is able to include a larger number of countries, regions, etc. (territories) by adding appropriate data; 2) temporal: it is possible to span more years (time series), and 3) quantitative: involvement of a larger number of indicators or different indicators. Having this in mind, this concept is valuable for the development of a road safety performance index. This reinforces the credibility, acceptability and future development of the road safety performance index with a limited number of indicators for this set of European countries.

Collection and selection of indicators

Attention should be paid to the collection of reliable data because the validity, interpretability and explanatory power of the constructed index depends on data quality and their completeness. The focus of this study is put on European countries with the aim of evaluating the road safety performance of countries with a comparable level of mobility development (i.e. countries characterized by a similar transport system and motorization rate). Nonetheless, a broader analysis on a worldwide scale may be interesting but availability of data concerning the values of the same indicators for a larger number of countries, in a defined time period, constitutes a significant limitation. In addition to data availability, comparability of available data from the point of view of definitions and the manner of measuring them in the field is also disputable. In the present study, data collection starts from the seven risk domains considered in the SafetyNet project (Vis, 2005) as it is a key source with respect to the following road safety performance indicators: alcohol and drugs, speed, protective systems, daytime running lights, vehicle, roads and trauma management. Each indicator used for the calculation of a road safety performance index represents one risk domain. The performance of countries with respect to daytime running lights is not captured by this indicator, as the nature of this indicator distinguishes only three possible values (countries with the mandatory use of DRL on all roads during the entire year; countries with the mandatory use of DRL on some roads and/or during some periods of the year; and countries enacting no DRL law) and the classification is characterized by some level of uncertainty. Therefore, it is decided not to incorporate the indicator for the daytime running lights domain in the index construction process.

The subject of analysis includes the following 6 road safety performance indicators that have been collected on the basis of a selection process: (SPI_1) % of surveyed car drivers < BAC (Blood Alcohol Concentration limit); (SPI_2) % of surveyed car drivers < speed limit in urban areas; (SPI_3) seat belt wearing rate at front seats of cars and vans; (SPI_4) % of cars < 6 years; (SPI_5) density of motorways and (SPI_6) total health expenditure as a % of GDP. The available data relating to the SPIs were collected and compiled from some international databases and several publications. Data collected for each indicator belong to the period [2002; 2008]. The data set of the core set of basic road safety performance indicators (SPIs) was available for only 21 European countries (20 EU Member States plus Switzerland). Data unavailability is a common limitation for all studies dealing with country comparisons from the road safety point of view. This limitation is particularly highlighted in case of data on the road safety performance index. The fact is that "safety performance indicators" were introduced for the first time only in 2001 (European Transport Safety Council, 2001).

From a theoretical point of view, a larger number of indicators provides a road safety performance index of higher quality by means of which decision makers are able to more precisely define the earlier goal- oriented actions. Or, it is possible to more precisely identify the strengths and weaknesses of a country's road safety system by recording a broader comprehensive set of SPIs. However, from the point of view of practical use, a road safety performance index with a limited number of indicators is valuable to calculate.

METHODOLOGY

The calculation in this paper has been made using the methodology for developing a composite road safety performance index for cross-country comparisons, developed by Hermans, 2009a. This methodology consists of several steps: 1) Selecting the appropriate indicators to combine in an index; 2) Collecting the data on indicators; 3) Making data analyses/ normalization of data; 4) Assigning weights to each indicator; 5) Aggregating the weighted values of indicators; 6) Testing the robustness of the index and 7) Computing, evaluating and visualizing the scores of the final index. This methodology has been applied to create a composite road safety performance index relating to the intermediate outcome layer. The text below presents two important steps for the calculation of a composite index with a limited number of indicators: the weighting method and the aggregating of indicators.

One of the most significant steps in the process of composite index calculation is "**Assigning the weights to each indicator**". The Data Envelopment Analysis (DEA), originally developed by Charnes, Cooper and Rhodes (1978), is a non- parametric mathematical optimization technique used to assess the relative efficiency of a homogeneous set of decision- making units (DMUs), on the basis of multiple inputs and multiple outputs. The degree of other DMUs' inefficiency can be measured on the basis of their distance from the frontier. For each country, there can be obtained a composite index score between zero and one, with higher values indicating a better relative performance.

Step 5 of the methodology deals with the "**Selection of a data aggregation method"** according to recommendations of Hermans 2009a.

General Concepts of Ordered Weighted Averaging (OWA)

The Ordered Weighted Averaging (OWA) operators are used as an expert method for data aggregation. OWA functions are the second type of common averaging aggregation functions. They have been introduced by Yager (1988). As far as this method is concerned, it is important to mention that weights differ in the case of the "weight allocation method" and the case of the "OWA function". In case of OWA, a weight is no longer associated with the meaning of a particular criterion (or indicator)– such as the alcohol weight– but with its magnitude. Very common aggregation operators include maximum, minimum and arithmetic mean. The weighting vector $\vec{w}$ of these operators is given as: 1) max: $\vec{w} = (1,0,..,0)$, considering only the best performance; 2) min: $\vec{w} = (0,..,0,1)$, considering only the worst performance, and 3) arithmetic mean: $\vec{w} = (1/n, 1/n..,1/n)$, considering each performance equally. One of the methods for obtaining relevant OWA weights is the "orness" concept. The degree of orness corresponds to the degree of optimism of a decision maker (Yager, 1997). For an OWA weighting vector, the degree of orness is defined as shown in Eq. 4.1.

$$orness\ (\vec{w}) = \frac{1}{l-1}\sum_{i=1}^{l}(l-i)\vec{w_i} = \frac{1}{l-1}\sum_{i=1}^{l-1}(l/i)^{\alpha} \quad (4.1)$$

$$\vec{w_i} = Q\left(\frac{i}{l}\right) - Q\left(\frac{i-1}{l}\right) \text{ for } i = 1, \dots, l$$

$$Q(r) = r^{\alpha} \text{ with } \alpha \geq 0$$

In case of six indicators, the above formulas result in:

$$\vec{w_1} = [\tfrac{1}{6}]^{\alpha}; \vec{w_2} = [\tfrac{2}{6}]^{\alpha} - [\tfrac{1}{6}]^{\alpha}; \vec{w_3} = [\tfrac{3}{6}]^{\alpha} - [\tfrac{2}{6}]^{\alpha};$$

$$\vec{w_4} = [\tfrac{4}{6}]^{\alpha} - [\tfrac{3}{6}]^{\alpha}; \vec{w_5} = [\tfrac{5}{6}]^{\alpha} - [\tfrac{4}{6}]^{\alpha}; \vec{w_6} = [\tfrac{6}{6}]^{\alpha} - [\tfrac{5}{6}]^{\alpha} \quad (4.2)$$

In terms of road safety, α represents the degree to which the occurrence of road fatalities depends on the magnitude of the six performances. For α equal to one, the number of road fatalities per million inhabitants is considered to result equally from good and bad performances. The value of α that is higher (lower) than one implies that the worst (best) performances affect the number of road fatalities more and therefore low (high) indicator values are emphasized in that case.

Linguistic formulations of Ordered Weighted Averaging (OWA)

In order to incorporate the aggregation idea that is deduced by means of linguistic formulations, i.e. in order to punish bad performances, by a panel discussion, the following principles regarding the aggregation were put together:

- In case a country scores badly on more than a few indicators, its final road safety index score should be small.
- In case a country scores badly on a few indicators, its final road safety index score should be between small and average.

The first step in transforming the guidelines into restrictions for α is to give a specific meaning to the concepts 'badly' (with respect to indicator performance), 'a few' (with respect to the number of indicators), 'small' and 'average' (with respect to the index score). As for the performance, it will be classified as 'good', 'average' or 'bad', depending on specific indicators. Here, score 1 is assigned to good; score 0.5 to average and score 0 to bad performances. On a total of six indicators, 'a few' corresponds to two; 'most' to four and 'almost all' to five. A 'small' index score is 0.25 at the most, an 'average' index score corresponds to 0.5 whereas a 'large' index score is at least 0.75. By using the (Eq. 4.2.), restrictions for α can be deduced.

$f_\alpha(1,1,1,0,0,0) \le 0.25$ (Small index score) (4.3)

$\Leftrightarrow \overrightarrow{w_1} + \overrightarrow{w_2} + \overrightarrow{w_3} \le 0.25$ (More than two indicators are bad = three indicators are good)

$$\Leftrightarrow \left[\frac{1}{6}\right]^\alpha + \left[\frac{2}{6}\right]^\alpha - \left[\frac{1}{6}\right]^\alpha + \left[\frac{3}{6}\right]^\alpha - \left[\frac{2}{6}\right]^\alpha < 0.25$$

$$\Leftrightarrow \left[\frac{1}{2}\right]^\alpha \le 0.25$$

$$\Leftrightarrow \alpha \ge 2$$

$0.25 < f_\alpha(1,1,1,0.5,0,0) < 0.5$ (Index score lying between small (0.25) and average (0.5)) (4.4)

$\Leftrightarrow 0.25 < \overrightarrow{w_1} + \overrightarrow{w_2} + \overrightarrow{w_3} + 0.5 \times \overrightarrow{w_4} < 0.5$ (Two indicators are bad = three indicators are good and one indicator has an average score)

$$\Leftrightarrow 0.25 < \left[\frac{1}{6}\right]^\alpha + \left[\frac{2}{6}\right]^\alpha - \left[\frac{1}{6}\right]^\alpha + \left[\frac{3}{6}\right]^\alpha - \left[\frac{2}{6}\right]^\alpha$$

$$+ 0.5 \times [\left(\frac{4}{6}\right)^\alpha - \left(\frac{3}{6}\right)^\alpha] < 0.5$$

$$\Leftrightarrow 0.25 < 0.5 \times \left(\frac{3}{6}\right)^\alpha + 0.5 \times \left(\frac{4}{6}\right)^\alpha < 0.5$$

$$\Leftrightarrow 1.2946 < \alpha < 2.6526$$

Based on (Eq. 4.3.) and (Eq. 4.4.) we can conclude that α should range in the interval [2;2.65] to aggregate the six indicators in a way that is acceptable for the experts. The orness value in the interval [0.236; 0.306] is obtained by inserting the limit values of α in Eq. 4.1. The selected value of α producing the strongest relation with the ranking is based on the number of road fatalities per million inhabitants. The result is the value of α equal to 2.0 and an OWA vector of (0.03; 0.08; 0.17; 0.27; 0.42; 0.58). Reflecting on the experts and decision makers' attitudes is very useful in this respect. However, if one wants to avoid compensation between good and bad scores, this method is the most useful aggregation operator for the road safety index case because it enables the experts/ decision makers/ stakeholders at the national level to agree on the linguistic formulation for the purpose of this aggregation method. This also provides a higher degree of acceptability of the results obtained, which opens the door to the definition of earlier goal- oriented actions.

Index methodology

Obtaining the final road safety performance index scores requires making a decision that concerns indicator selection, weighting and aggregation. These steps have been dealt with in the previous sub- headings. (Eq. 4.5.) represents the algebraic model used to compute the final road safety performance index score (RSPI) for a country j (j = 1,…, n):

$$RSPI_j = \frac{max}{\overline{w_{ij}}} \sum_{i=1}^{l} \overline{r_{ij}}\,\overline{w_{ij}} \quad (4.5)$$

$$\sum^{l} \overline{w_{ij}} = 1$$

$$0.236 \le \frac{1}{l-1} \sum_{i=1}^{l} (l-1)\overline{w_{ij}} \le 0.306$$

$$L_m \le \frac{r_{mj} w_{mj}}{\sum_{i=1}^{l} \overline{r_{ij}}\,\overline{w_{ij}}} \le U_m$$

$$\overline{w_{ij}} \ge 0$$

With:
l = number of indicators
¯ = ordered value; r = rescaled value; w = weight
m = {alcohol; speed; protective system; vehicle; road; trauma management}
L = lower limit; U = upper limit

As shown in (Eq. 4.5.), the road safety performance index score of a country consists of the ordered rescaled indicator values (i.e. values between zero and one, in decreasing order) and ordered weights (i.e. the first weight is corresponding to the best performance). More specifically, the share of each of the six indicators in the total index score was restricted by a lower and upper limit, using the budget allocation weights from a panel of experts.

The weights obtained by calculating the RSPI served for the calculation of $RSPI_{ln}^{3}$, $RSPI_{ln}^{4}$ and $RSPI_{ln}^{5}$ that are used in this study, since the programme could not find a feasible solution. The reason for that is the reduction in the space for searching an optimum solution based on three or four indicators. The additive aggregation method has been used in these cases, which helps obtain the value of the product of the allocated weight and the normalized value of the indicator (defined by Eq. 4.5.) without the software retrieval of the possible solution. The mentioned aggregation method has been used following the recommendations of Nardo et al., 2005 and those of Pešić, 2012, who made a test in which the linear aggregation method, based on pre- defined criteria, scored the best result.

Depending on the value of their road safety performance index, the countries have been assigned a specific level of $RSPI_{ln}^{n^*}$ in the following way: 1) High RSPI- countries with a value over 0.500; 2) Average RSPI- countries with a value from 0.307 to 0.499; and 3) Low RSPI- countries with a value under 0.306. The index score is bounded by the highest and lowest indicator's value and has been made using the ordered weighted averaging (OWA) operators.

A system of "indicator combinations" with three, four and five indicators has been designed for the calculation of the $RSPI_{ln}^{n}$. The formula (Eq. 4.6.) has served to determine the total number of indicator combinations for the calculation of values of a road safety performance index, i.e. total number of combinations $\binom{6}{3}$, the value of $RSPI_{ln}^3$ is calculated for 20 combinations:

$$C_k^n = \binom{n}{k} = \frac{n!}{k!(n-k)!} = \frac{n\cdot(n-1)\cdots(n-k+1)}{k\cdot(k-1)\cdots 1}, n \geq k \geq 0, (n,k) \in N \quad (4.6)$$

RESULTS OF THE INTERNATIONAL CROSS-COUNTRY COMPARISONS

The results obtained in this study will be discussed in two parts. Based on the correlation strength between the $RSPI_{ln}^n$ and RSPI, the most significant indicators for 21 countries have been identified first. In addition, the change in the country ranking depending on the most significant three, four and five indicators based on OWA operators has been also analyzed. The values of $RSPI_{ln}^{n*}$ have been compared using the mortality rate and the human development index, as relevant references.

Correlation analysis between the $RSPI_{ln}^n$ and RSPI

The application of Spearman's correlation analysis of the results obtained by calculating the road safety performance index for various combinations of three, four and five indicators and the composite index obtained on the basis of all six indicators has helped obtain the results shown in Table 1. Column 1 contains the combination of indicators marked by SPI codes and sorted by correlation coefficient values from Column 2. Cohen, 1988 (taken over from Pallant, 2011) ranked the correlation values in the following way: 1) small correlation (r = .100 - .299); medium correlation (r = .300 - .499), and large correlation (r = .500 - 1.000).

Based on these guidelines for the correlation interpretation, it is possible to conclude that among the road safety performance index values ($RSPI_{ln}^3$), only the combination of "protective system, vehicle and trauma management" (: 3_4_6) has a medium correlation (r = .471, p= .01), while all other values of $RSPI_{ln}^3$ have a large correlation with the value of RSPI (r ≥ .50, p= .01). The most significant indicators are "speed, roads and trauma management" (: 2_5_6), giving the highest value for the correlation coefficient (r = .906, p= .01) amongst the values of composite index $RSPI_{ln}^3$ and the value of RSPI for 21 countries.

Table 1. The most significant indicators based on Spearman's rho (rank correlation coefficient) with RSPIs

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
$RSPI_{ln}^3$ (SPI code)	Rank based on r values	$RSPI_{ln}^4$ (SPI code)	Rank based on r values	$RSPI_{ln}^5$ (SPI code)	Rank based on r values
2_5_6	0.906	1_2_5_6	0.958	1_2_3_5_6	0.994
2_3_5	0.905	1_2_3_6	0.936	1_2_3_4_5	0.957
2_3_6	0.878	2_3_5_6	0.931	1_2_4_5_6	0.957
1_2_5	0.871	1_2_3_5	0.927	1_2_3_4_6	0.948
1_5_6	0.866	2_3_4_5	0.912	2_3_4_5_6	0.927
2_4_5	0.856	1_2_4_5	0.895	1_3_4_5_6	0.821
2_3_4	0.848	1_4_5_6	0.891		
1_2_3	0.842	2_4_5_6	0.866		
1_2_6	0.803	2_3_4_6	0.852		
1_4_5	0.801	1_2_4_6	0.848		
2_4_6	0.792	1_2_3_4	0.829		
1_3_6	0.751	1_3_5_6	0.825		
1_3_5	0.726	1_3_4_5	0.777		
4_5_6	0.710	1_3_4_6	0.749		
1_4_6	0.694	3_4_5_6	0.669		
1_2_4	0.681				
3_5_6	0.666				
3_4_5	0.626				
1_3_4	0.536				
3_4_6	0.471				

SPI codes:	1	Alcohol: % of surveyed car drivers < BAC limit
	2	Speed: % of surveyed car drivers < speed limit in urban areas
	3	Protective system: seat belt wearing rate at front seats of cars and vans
	4	Vehicle: % of cars <6 years
	5	Roads: density of motorways
	6	Trauma management: total health expenditure as GDP%

When looking at Columns 3 and 4 in Table 1. it can be noticed that all the combinations of indicators of $RSPI_{ln}^4$ offer a large correlation (r ≥ .500, p= .01 for all combinations) with the RSPI. The most significant four indicators are "alcohol, speed, roads and trauma management" (1_2_5_6), having a correlation coefficient of r = .958. Finally, Columns 5 and 6 show the ranking of values for $RSPI_{ln}^5$ with the RSPI. The correlation coefficient of the combination containing five indicators is extremely large (r > .900). The most significant five indicator combination is the one with "alcohol, speed, protective system, roads and trauma management" where r =.994 (almost complete congruence of values of the composite index $RSPI_{ln}^5$ with the RSPI). Regardless of which indicator combination is in question, the strength of the correlation with the RSPI is extremely large, with the exception of the combination 3_4_6 which is ranked as a medium correlation.

Rank variations depending on $RSPI_{ln}^{n*}$ based on OWA operators and correlation analysis with final outcomes

The value of a road safety performance index has been calculated for the most significant three, four and five indicators, on the basis of which the countries have been ranked. The countries are grouped within obtained classes (three colours) and the standard deviation of country rankings on the basis of different $RSPI_{ln}^{n*}$ has been also calculated. The analysis of changes in country ranking in relation to the final ranking of the countries based on the value of RSPI leads to the following results given in Figure 1.. The similarity in country ranking on the basis of values of $RSPI_{ln}^{n*}$ and the ranking on the basis of RSPI values is considerable. The matching rate of these values is higher if the calculation of a road safety performance index is made on the basis of a larger number of indicators.

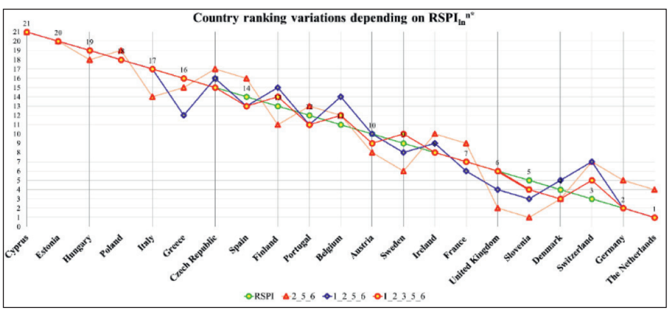

Figure 1. Final country ranking variations depending on $RSPI_{ln}^{n*}$

Two countries whose ranking is consistent across different combinations have been singled out. They are: Estonia and Cyprus, while some countries sustained changes in their positions, for one place only (Poland and Hungary), by adding certain indicators into the calculation. The remaining countries largely deviate in ranks, having therefore the most unstable standing (change in two or more positions), for example Slovenia (5 positions), Switzerland (4 positions), Belgium (4 positions), etc. The most essential differences amongst the rankings are observed for Finland (between 11th and 15th place), Sweden (between 6th and 10th place) and Slovenia (between 1st and 5th place). The text below shows the mapping of the analyzed countries per value of the RSPI obtained on the basis of various combinations of indicators (three, four, five) that are having the highest correlation with the RSPI obtained on the basis of all six indicators concerned (Figure 2., 3. and 4.). Figure 5. shows the map

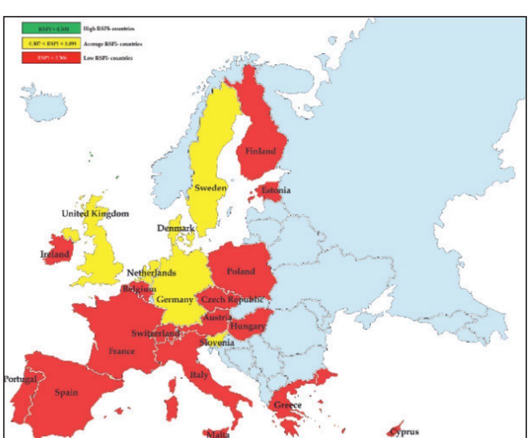

Figure 2. Coloured map on road safety performance index based on RSPIln3*: 2_5_6

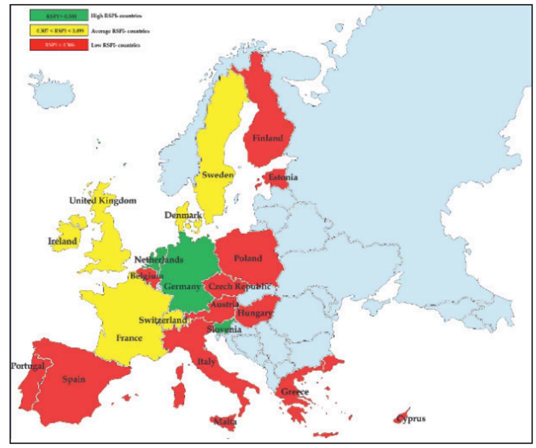

Figure 3. Coloured map on road safety performance index based on

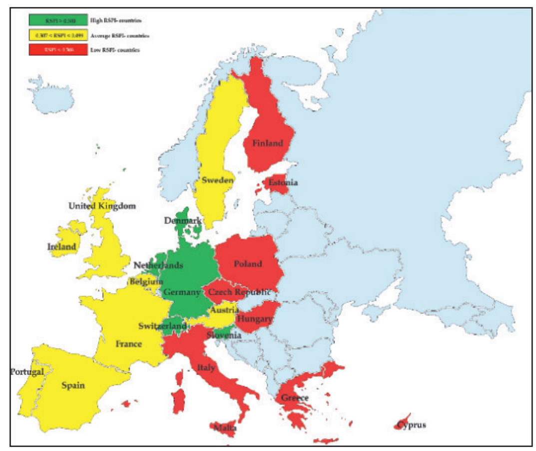

Figure 4. Coloured map on road safety performance index based on $RSPI_{ln}^{5*}$: 1_2_3_5_6 $RSPI_{ln}^{4*}$: 1_2_5_6

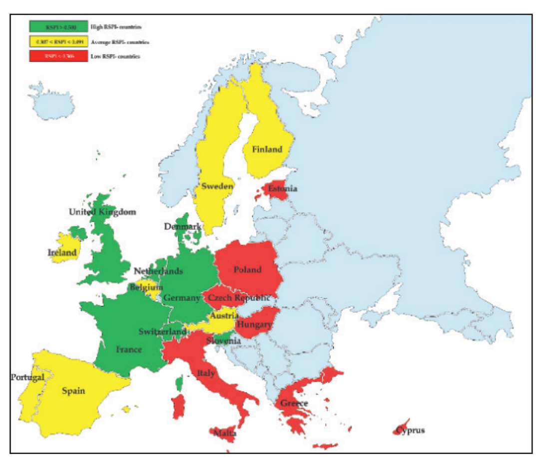

Figure 5. Coloured map on road safety performance index based on RSPI (all six indicators)

of countries ranked on the basis of values of a RSPI obtained using all the indicators involved.

Matching of country rankings on the basis of RSPI values and values of $RSPI_{ln}^{3*}$, $RSPI_{ln}^{4*}$ and $RSPI_{ln}^{5*}$ is expressed in the correlation coefficient value (Table 2.). The strength of correlation among country rankings depending on the indicator combination is extremely large and ranges from r= .926 to r= .992. The value of a road safety performance index with a limited number of indicators is reliable for cross- country comparisons and for defining earlier goal- oriented actions.

Table 2. Spearman's correlations of the rankings

			Ranking $RSPI_{ln}^{3*}$: 2_5_6	Ranking $RSPI_{ln}^{4*}$: 1_2_5_6	Ranking $RSPI_{ln}^{5*}$: 1_2_3_5_6
Spearman's rho	**RSPI Ranking**	Corr. Coefficient	.926**	.961**	.992**
		Sig. (1-tailed)	.000	.000	.000
		N	21	21	21

** Correlation is significant at the 0.01 level (1-tailed).

As the country ranking matching rate is very high, regardless of the selected combination of most significant indicators, the correlation strength has been calculated between the mortality rate and the Human Development Index (HDI), and the road safety performance indicators (RSPI) and $RSPI_{ln}^{3*}$, $RSPI_{ln}^{4*}$ and $RSPI_{ln}^{5*}$. A high value of correlation coefficient is shown in Table 3. Looking at the values of correlation coefficients among certain factors, it can be noticed that $RSPI_{ln}^{3*}$: 2_5_6 correlates more strongly with the mortality rate when compared to the RSPI. The remaining values of the composite index $RSPI_{ln}^{4*}$: 1_2_5_6 and $RSPI_{ln}^{5*}$: 1_2_3_5_6 have a somewhat lower correlation rate.

Table 3. Spearman's correlation of a road safety performance index with a limited number of indicators with the mortality rate and the Human Development Index

			RSPI	$RSPI_{ln}^{3*}$: 2_5_6	$RSPI_{ln}^{4*}$: 1_2_5_6	$RSPI_{ln}^{5*}$: 1_2_3_5_6
Spearman's rho	**Mortality rate**	Correlation Coefficient	-.685**	-.727**	-.615**	-.643**
	HDI		.714**	.633**	.651**	.689**
		Sig. (1-tailed)	.000	.000	.000	.000
		N	21	21	21	21

Regardless of the selected combination for the calculation of the composite index, the strength of the correlation with the final outcomes (in this case: mortality rate) and the RSPI is significant. Spearman's correlation coefficient is used to evaluate the degree of consistency between the RSPI and $RSPI_{ln}^{n*}$ ranking with the HDI ranking. The results show that a road safety performance index and a road safety performance index with a limited number of indicators, irrespective of indicator combination (the number of indicators (3, 4 or 5), have a very strong positive correlation with the HDI (RSPI, r= .714, p<.01; $RSPI_{ln}^{3*}$, r= .633, p<.01; $RSPI_{ln}^{4*}$, r= .651, p<.01, $RSPI_{ln}^{5*}$, r= .689, p<001).

DISCUSSION AND CONCLUSIONS

As shown in Table 1., the correlation analysis has revealed that all the combinations have a large correlation (Spearman's coefficient rho is over .536) with the RSPI, with the exception of the indicator's combination of "protective system, vehicle and trauma management" that has medium correlation strength. Overall, there exists a high degree of matching (congruence) of indicator's combinations (three, four or five). Based on this, the most significant indicators having the largest correlation with the RSPI values have been identified. To further capture the graphical insight into the specific relationship between the rankings, the comparison of country rankings, based on the $RSPI_{ln}^{n*}$, is illustrated in Figure 1., where the basic ranking is built on the basis of the RSPI. It can be seen that:

- Overall, the four rankings (RSPI, $RSPI_{ln}^{3*}$, $RSPI_{ln}^{4*}$and $RSPI_{ln}^{5*}$) are relatively consistent, with slight deviations across the different combinations of indicators. The ranks of Estonia and Cyprus are consistent across different combinations. At the same time, the rankings of Finland, Sweden and Slovenia are associated with relatively large deviations. Countries whose rankings fluctuate by at least one to mostly three positions, depending on indicator combination, are ranked in-between.
- The rankings derived from different combinations of indicators are almost identical to the RSPI rankings. The matching is strongest with the values of $RSPI_{ln}^{5*}$, and weakest with the values of $RSPI_{ln}^{3*}$ which is expected as the value of a road safety performance index is more accurate when a larger number of indicators is involved in the calculation. However, the value of a road safety performance index with a limited number of indicators is reliable and robust enough for international cross- country comparisons as it provides an adequate, simple and efficient way of road safety monitoring, which, on the other hand, generates actions for the development of a sustainable system of periodical measuring of indicators in (low- ranked) territories.

Validity of a road safety performance index with a limited number of indicators can be compared to the country ranking which is made according to the values of the mortality rate and the Human Development Index (HDI). In general, it can be concluded that the developed road safety performance index and road safety performance index with a limited number of indicators are linked with the mortality rate and the human development index. A strong correlation between the $RSPI_{ln}^{3*}$ and the mortality rate (r = - .727, p = .01), confirms the significance of indicators (2_5_6) in cases of scarce or missing data. These three indicators allow for comparisons of a larger number of countries and are sufficient for defining the earlier goal- oriented actions in those three risk domains that will serve for road safety improvement. This reinforces the credibility, acceptability and future development of the road safety performance index with a limited number of indicators for this set of European countries. Previous results have been confirmed by the strength of correlation among the rankings of a road safety performance index and road safety performance index with a limited number of indicators. The correlation strength in this case is extremely high and the value of the correlation coefficient is above r > .926, (Table 2.), regardless of which indicator combination is considered. However, the following are the most significant indicators for the 21 countries set (Table 1.):

- Three most significant indicators are "speed, roads and trauma management" (abbr.: 2_5_6), (r = .906, p= .01);
- Four most significant indicators are "alcohol, speed, roads and trauma management" (abbr.: 1_2_5_6), (r= .958, p=.01), and
- Five most significant indicators are "alcohol, speed, protective system, roads and trauma management" (abbr.: 1_2_3_5_6), (r = .994, p= .01).

Therefore, the most significant indicators ensure the optimum selection of indicators and reliable comparison of the safety performance indicators of countries in conditions of unavailable and scarce indicator data. Since there is a strong correlation between the RSPI and $RSPI_{ln}^{n}$, it will be possible to identify a common list of indicators for all analyzed countries on the basis of the most contributing indicators per country. This ensures a simpler monitoring of indicators, simple understanding of road safety situation as well as the international comparisons and benchmarking process. Also, the most significant indicators provide the selection of right actions for the improvement of weak points within the road safety system, whose accuracy is increasing with the number of indicators included in an analysis. A road safety performance index is a quality tool for country comparisons, identification of successful practices and definition of timely measures for improving the road safety situation. Also, the RSPI serves decision makers to recognize and understand road safety issues. Selection of indicators is the most demanding part of the RSPI calculation methodology, having the strongest impact on its value. Also, the proposed methodology for the calculation of the road safety performance index with a limited number of safety performance indicators offers the possibility of monitoring and comparing territories (both at international and national level), on the basis of several combinations of the most significant safety performance indicators and indicator standardization.

REFERENCES

[1] Al- Haji, G. (2007). Road Safety Development Index (RSDI): Theory, Philosophy and Practice. Department of Science and Technology. Linköping University, http://ir.nmu.org.ua/bitstream/handle/123456789/126470/0bb47fc915be24e29d6a9f7912a5abe3.pdf?sequence=1

[2] Charnes, A., Cooper, W., Rhodes, E., 1978. Measuring the efficiency of decision making units. European Journal of Operational Research, 2, 429–444. http://www.utdallas.edu/~ryoung/phdseminar/CCR1978.pdf

[3] Chen, F., Wu, J., Chen, X., Wang, J., and Wang, D. (2016). Benchmarking road safety performance: Identifying a meaningful reference (best-in-class). Accident Analysis and Prevention, 86, 76-89, doi: doi:10.1016/j.aap.2015.10.018

[4] Cohen, J. (1988) Statistical Power Analysis for the Behavioral Sciences, 2nd ed. Hillsdale, NJ: Erlbaum.

[5] European Transport Safety Council. (2001). Transport Safety Performance Indicators. Brussels, http://etsc.eu/wp-content/uploads/Transport-safety-performance-indicators.pdf .

[6] Hermans, E. (2009a). A methodology for developing a composite road safety performance index for cross- country comparasion. PhD Thesis. University of Hasselt, http://trid.trb.org/view.aspx?id=1152165

[7] Hermans, E., Van den Bossche, F., and Wets, G. (2009b). Uncertainty assessment of the road safety index. Reliability Engineering and System Safety, 94, 1220-1228, doi:10.1016/j.ress.2008.09.004.

[8] Nardo, M., Saisana, M., Saltelli, A., and Tarantola, S. (2005a). Handbook on Constructing Composite Indicators: Methodology and user guide. Retrieved November 20, 2014, from OECD Statistics Working Papers 2005/03; OECD Publishing: http://dx.doi.org/10.1787/533411815016

[9] Pallant, J. (2011). SPSS survival manual. McGraw-Hill Education (UK). http://eunacal.org/metodakerkimi/wp-content/uploads/spss/SPSS_Survival_Manual_4th_Edition.pdf

[10] Pešić, D. R. (2012). Developing and improving the method for measuring the level of traffic safety at the territory. PhD Thesis. Faculty of Transport and Traffic Engineering. Belgrade: Faculty of Transport and Traffic Engineering.

[11] Tešić, M. (2018). Road safety assessment based on a road safety performance index. PhD Thesis. Faculty of Transport and Traffic Engineering. Belgrade: Faculty of Transport and Traffic Engineering.

[12] Tešić, M., Hermans, E., Lipovac, K., and Pešić, D. (2018). Identifying the most significant indicators of the total road safety performance index. Accident analysis and prevention, 113, 263-278, https://doi.org/10.1016/j.aap.2018.02.003

[13] Vis, M. A. (2005). Deliverable D3.1: State of the art Report on Road Safety Performance Indicators. Loughborough University. SWOV, http://erso.swov.nl/safetynet/fixed/WP3/Deliverable%20wp%203.1%20state%20of%20the%20art.pdf

[14] Yager, R.R. (1997). On the inclusion of importances in OWA aggregations. In the ordered weighted averaging operators. Dordrecht: Kluwer Academic Publishers.

[15] Yager, R.R. (1988). On ordered weighted averaging aggregation operators in multi-criteria decision making. IEEE Transactions on Systems, Man and Cybernetics, 18 pp. 183-190.