Analysis of Regional Road Safety Evaluation Model in the Czech Republic

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Abstract: Road safety is a topic that especially in advanced countries receiving a lot of attention for a long time. The aim of the paper is comparison of the road safety performance between regions in Czech Republic in 2007-2009. The road safety level in a country is influenced by many various factors. A wider set of road safety related indicators divided into two groups is formulated in this paper and real data are collected from various available sources. On the basis of selected indicators is calculated road safety rate for each region. Finally, the regions are compared with each other.

Key-Words: Model evaluation, road safety, indicators, regional comparison, road safety rate, Czech Republic

1 Introduction
Safety in the traffic is long-lastingly considered as a very important and if it is adequate, it means that the society is developed well. As a result of the accidents is a high social cost. Decreasing the number of accidents has become the objective of all developed countries since the 70s of the last century.

The Czech Republic (CR) belonged to the most progressive countries till the half of the 80s in this field. Since then there have been several changes during the following years and the CR has become the worst from the European countries, in the studied indicators of the accidents frequency. The attempt about leaving this position is clearly declared also by the CR government. In the National Road Safety Strategy (NRSS) 2004-2010 [1], which was accepted by the government in April 2004, CR claimed to meet this objective with other European countries, declared primarily in the White Paper about the transport policy of EU [2], i.e. decreasing the number of dead people in the traffic by the year 2010 to the half of the statistics of the year 2002. An important part of this strategy is to use a system approach and its continuous application to achieve the objectives. The system approach is applied mainly to solve complex problems that cut across the various areas of human knowledge and cognition [3,4,5,6]. According to the statistics, it is now known, that this objective has not been met at last. New appeals were accepted by the government in published NRSS 2011-2020 [7].

To increase the level of safety of the traffic, it is important to study different factors influencing the safety itself. As the safety of the traffic presents the complex multidimensional problem, the very good knowledge of this field is needed for its complex understanding. For the analysis and evaluation of the traffic risks, it will not be rational to take into consideration only several selected simple indicators. On the other hand the long experience proves that 10 to 15 indicators can be evaluated lucidly. With the higher number of the indicators it is less tabular, less understandable in needed context and the explanatory power of the analysis. Similarly as in other fields, the attempts to make and use composite indicators are becoming to be used in the last decade, mainly in comparing the road safety among the selected countries [8,9,10].

The aim of the paper is comparison of the road safety performance between regions in Czech Republic in 2007-2009 based on calculation of road safety rate (RSR).

2 Problem Formulation
Since 1950, the approach to the traffic safety has come through four main phases of development (focused on driver → system intervention → institutional management → shared responsibility), which tried or are trying to increase the traffic safety by many different ways. Gradually there is a change from the problematic of decreasing the number of accidents to the prevention of the injuries and partly also to change in responsibility from the user to the
system petitioner. Now there is a more common opinion, that the responsibility of the road safety is shared and more sectored. From the required results point of view the policy of the road safety is more and more ambitious, which reflects in accepting the international strategies and their implementation to the national strategies.

Because of the complex multidimensional problem of the road safety, there was a hierarchy structure for objectives setting in the field of the road safety developed in the form of pyramid. This pyramid concept was developed in New Zealand and originally had four layers [11]. The model was widely adopted in several European projects. The pyramid is still being developed, widened and adapted [10,12,13]. Within the SUNflower project [12] the pyramid was widened by another lower level. This pyramid is therefore formed by the following levels (mentioned in the order from the top to bottom):

- Social cost
- Number of killed an injured
- Safety performance indicators (SPIs)
- Measures and programs
- Structure and culture

Shown concept is broadly accepted and used by many experts in the field of road safety. Comparing the targeted objectives can be done in three dimensions: vertical one for each levels of the pyramid, horizontal one for each territorial unit and also in time, for recording the trends [10].

Because the model in the form of the pyramid cannot always clearly define the effects and relationships between each element, we can also represent it in the form of series (Fig. 1), where each element is firmly bonded with the others and its performance is significantly influenced by the previous element, the same way as the element itself influences the following one.

Before the enlargement of the pyramid by adding the bottom layer (structure and culture), there was put legislation in this series into the beginning and then the measures of the road safety representing the general operating conditions for the road safety (e.g. speed limit in the towns and villages, point system start). Successfulness of the programs in place and measures can be evaluated via indirect indicators of the road safety. This safety performance indicators taking into account those operating conditions (intermediate outputs) which have the influence to the final performance influencing the whole system (final outputs). These indicators are the important source of information reflecting the effectiveness and assets of those precautions of the road safety which are embedded in legislation and whose application is checked e.g. via Police work. The basic feature of these indicators is their ability to measure dangerous operating conditions of the traffic system and their independence on the specific safety intervention. The other groups of indicators are the final outputs expressed by mainly numbers of killed and injured road users. These outputs should not be analysed separately without deeper understanding of which elements of the system prepared conditions for their occurrence. The series is closed with overall social cost, which are the costs imposed to the society, road users, providers of the emergency services etc. as a result of accidents.

![Fig. 1 Model of the road safety system (road safety pyramid in the form of series)](image-url)

In CR the Transport Research Centre has already proposed and used the tool [14] for this purpose. The basis of the comparison was the data about numbers of accidents with personal results, which relates to relativized indicators, i.e. number of inhabitants, region area, length of the roads, the amount of registered cars. In every indicator there is learnt an average value for CR, which every regions’ values relate to. For the overall comparison of every region signifies that the more the value
differs from the republic’s average, the more positive or negative signs the regions get. In the overall comparison the number of negative signs is deducted from the number of positive signs.

Our aim is to propose the evaluation tool, based on the wider spectre of the indicators. For the evaluation of the regional road safety in CR it is necessary to form a tool with sufficient explanatory power for interregional comparison, easy to be counted and for the receivers of information also understandable enough. The objective of the comparison of the road safety in the regions of CR is to form the space for demonstrating the situation in this field including the regional differences and specifications. This comparison can be a tool for increasing the road safety especially via targeting the safety campaigns and police supervision, investment into suitable precautions etc. Setting the form of the mentioned tools can result of the analysis of the road safety in the regions and their development in time.

For reaching our objective the following steps were realized:
1. Defining the theoretical framework
2. Proposal of the wide set of indicators
3. Data collection
4. Data analysis
5. Selection of the best commonly accessible indicators
6. Weighing and aggregation of the indicators
7. Calculation of the road safety rate of every region
8. Results analyse

The scheme of proposed road safety evaluation model is shown in Fig. 2.

Before the calculation of RSR in the CR regions were firstly defined groups of indicators that creates the main structure of the conceptual framework and also have a significant role for the analysing the results. For our purpose there were preferably proposed 4 groups of indicators that come out of the pyramid concept of the road safety [12]:

- Group A - Number of killed and injured (final outputs).
- Group B - Safety performance indicators (intermediate outputs).
- Group C - Measures and programs (political outputs).
- Group D - Structure and culture (political inputs).

Then the wide file of 50 possible indicators was defined, which were put to each of the above mentioned groups. Safety performance indicators were then divided to seven related risk areas [15]: alcohol and drugs, speed, protective systems, vehicle, infrastructure and trauma management. The shorter selection of the indicators representing every levels of the pyramid ran on the basis of 8 criteria evaluation: relevance, measurability, easy understanding, data accessibility, reliability, comparability, certainty and sensibility [16].

The design of wide set of indicators:

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1. DEFINING THE THEORETICAL FRAMEWORK
2. PROPOSAL OF THE WIDE SET OF INDICATORS
3. DATA COLLECTION
   Real data sets: Annual Reports of Regions; Health
   Yearbooks; AIA, PCR, RSO and RMD statistics
4. DATA ANALYSIS
5. SELECTION OF THE BEST COMMONLY ACCESSIBLE INDICATORS
6. WEIGHTING AND AGGREGATION OF THE INDICATORS
7. CALCULATION OF THE ROAD SAFETY RATE OF EVERY REGION
8. RESULTS ANALYSIS
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The output of the model is the road safety rate in CR regions.
indicators during the evaluation of every country among each other and evaluating smaller territorial units within one country especially in their comparability.

Because of the complete absence of the needed data or their incompleteness, this group of indicators was useless for meeting our objectives. On the basis of this finding, we didn't use also structural and cultural indicators. The accessible information for forming the safety performance indicators for the risk area, relating to alcohol and drugs (road users under its impact) were not also found. This did not prevent to use of other indicators of second group.

We have utilized direct (group A) and indirect (group B) indicators for the comparison of road safety levels in the individual regions. Of course it is suitable to use objective indicators for such comparison. The comparison of regions on the basis of the absolute number of killed, slightly and severely injured and on the number of road accidents is not suitable for these purposes. Individual regions differ by the number of inhabitants, their area, population density, length of roads, by the numbers of registered cars and other indicators. When using these variables we can obtain relative indicators that take into account the individual differences between the regions and thus can be after that considered to be objective indicators. Using the comparison of the individual characteristics allows us to compare the levels of road safety in each region. When monitoring these individual characteristics in time sequence we can follow the trends in road safety in each region and in the CR at the same time. The most suitable direct indicators seem to be the number of victims with impact on their life or health within 30 days for the road accident. These data have been relativized to the number of inhabitants in each territory unit (personal safety) and to the number of vehicles registered in the territory unit (traffic safety). From among the indirect indicators it is useful to take into account those that have any relation to the already mentioned seven road safety risks areas.

The shorter set of the selected indicators was tested by the statistical analysis. Increased attention has been given from the very beginning to the region Prague, the capital city. The basic descriptive statistics confirmed the already expected specific features of this region; those features are in the majority cases very different from other regions. First, it was revealed outliers in the data that were already used for the derivation of the indicators (e.g. number of inhabitants, region area, number of registered vehicles) and in connection with that also the resulting indicators (population density, highway density, personal safety). Therefore this region has not been taken into account for and in the overall comparison. Then selected indicators were tested by the statistical analysis. In Table 1 is shown final set of 11 indicators divided into two groups. The last column contains the expected target values of indicators (more information below).

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Indicator description</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>A₁</td>
<td>Personal safety</td>
<td>10</td>
</tr>
<tr>
<td>A₂</td>
<td>Traffic safety</td>
<td>20</td>
</tr>
<tr>
<td>B₁</td>
<td>Exceeding of speed limit in extra-region (%)</td>
<td>0.5</td>
</tr>
<tr>
<td>B₂</td>
<td>Exceeding of speed limit in intra-region (%)</td>
<td>0.5</td>
</tr>
<tr>
<td>B₃</td>
<td>Using of seat belts by adults on front seat in extra-region (%)</td>
<td>99.5</td>
</tr>
<tr>
<td>B₄</td>
<td>Using of seat belts by adults on front seat in intra-region (%)</td>
<td>99.5</td>
</tr>
<tr>
<td>B₅</td>
<td>Daytime running lights in extra-region (in %)</td>
<td>100</td>
</tr>
<tr>
<td>B₆</td>
<td>Daytime running lights in intra-region (in %)</td>
<td>100</td>
</tr>
<tr>
<td>B₇</td>
<td>Average age of cars (years)</td>
<td>6</td>
</tr>
<tr>
<td>B₈</td>
<td>Highway density (km per 100 km²)</td>
<td>4</td>
</tr>
<tr>
<td>B₉</td>
<td>Number of beds of intensive care per 10,000 inhabitants</td>
<td>2</td>
</tr>
</tbody>
</table>

3 Problem Solution

Since the individual indicators have various scales and units it was necessary to normalize these values. We have used the approach based on the method “Distance to a target” [8], that takes into account also the development of indicators in time and is related to the defined target indicators values.

For the definition of the individual indictors’ weight we have used the Saaty’s matrix [23]. By means of this method various weights are assigned to the selected indicators in relation to their impact on the road safety. The result is the following vector of the individual indicators weights:

\[ \mathbf{w} = [0.259, 0.259, 0.115, 0.067, 0.115, 0.067, 0.035, 0.023, 0.023, 0.016, 0.023], \]

where maximal eigenvalue \( \lambda_{\text{max}} \) is 11.714, consistency index \( CI \) is 0.071 and consistency ratio \( CR \) is 0.047 if \( RI \) is 1.51.

Further, based on a simple formula the calculation of RSR has been done for the individual regions:
where \( n \) is number of indicators, \( I_i \) are normalised indicators, \( w_i \) are the weights for \( I_i \).

The results may range from 0 to 100. The higher values mean the higher road safety in the given region. And vice versa, lower values indicate lower road safety in the region. The target value of the RSR is 100 and it shows how close or how far the region is from the defined road safety targets. In theory the result may be higher than 100 if the road safety is on an even higher level that the defined and expected level. The RSR results should motivate and influence regions to improve their activities in the road safety area and help to define the performance gap between their actual results and the pre-defined targets. The concrete results are shown in Table 2. In Fig. 3 we can see road safety evolution between years 2007 and 2009.

### Table 2 Road safety rates of regions in 2007-2009

<table>
<thead>
<tr>
<th>Region</th>
<th>Year</th>
<th>2007 RSR</th>
<th>Rank</th>
<th>2008 RSR</th>
<th>Rank</th>
<th>2009 RSR</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMV</td>
<td>2007</td>
<td>52.77</td>
<td>1</td>
<td>54.93</td>
<td>1</td>
<td>56.80</td>
<td>1</td>
</tr>
<tr>
<td>ZLN</td>
<td>2007</td>
<td>50.33</td>
<td>3</td>
<td>52.02</td>
<td>3</td>
<td>56.28</td>
<td>2</td>
</tr>
<tr>
<td>VYS</td>
<td>2007</td>
<td>46.86</td>
<td>8</td>
<td>48.65</td>
<td>8</td>
<td>52.41</td>
<td>3</td>
</tr>
<tr>
<td>MSL</td>
<td>2007</td>
<td>49.65</td>
<td>5</td>
<td>50.41</td>
<td>6</td>
<td>51.85</td>
<td>4</td>
</tr>
<tr>
<td>OLM</td>
<td>2007</td>
<td>47.19</td>
<td>7</td>
<td>49.29</td>
<td>7</td>
<td>51.58</td>
<td>5</td>
</tr>
<tr>
<td>KVA</td>
<td>2007</td>
<td>48.71</td>
<td>6</td>
<td>51.48</td>
<td>4</td>
<td>51.36</td>
<td>6</td>
</tr>
<tr>
<td>HRK</td>
<td>2007</td>
<td>49.70</td>
<td>4</td>
<td>50.99</td>
<td>5</td>
<td>50.45</td>
<td>7</td>
</tr>
<tr>
<td>UST</td>
<td>2007</td>
<td>51.14</td>
<td>2</td>
<td>54.01</td>
<td>2</td>
<td>49.91</td>
<td>8</td>
</tr>
<tr>
<td>CBM</td>
<td>2007</td>
<td>45.21</td>
<td>13</td>
<td>47.11</td>
<td>10</td>
<td>48.55</td>
<td>9</td>
</tr>
<tr>
<td>PLZ</td>
<td>2007</td>
<td>45.97</td>
<td>10</td>
<td>47.69</td>
<td>9</td>
<td>47.82</td>
<td>10</td>
</tr>
<tr>
<td>PAR</td>
<td>2007</td>
<td>45.86</td>
<td>11</td>
<td>46.18</td>
<td>13</td>
<td>47.19</td>
<td>11</td>
</tr>
<tr>
<td>SMB</td>
<td>2007</td>
<td>45.72</td>
<td>12</td>
<td>46.70</td>
<td>12</td>
<td>46.96</td>
<td>12</td>
</tr>
<tr>
<td>LIB</td>
<td>2007</td>
<td>46.77</td>
<td>9</td>
<td>47.02</td>
<td>11</td>
<td>46.93</td>
<td>13</td>
</tr>
</tbody>
</table>

From the stated results it is obvious that the best results are achieved by the bordering regions in the south end of Moravia (SMV and ZLN). On the contrary the worst results have the northwest bohemian regions (LIB and PAR) and also the SBM region. Two significant changes in ranking of road safety occurred in 2009. VYS region had significantly mended his ways, while the UST region greatly fallen down. VYS region upward shift was due to more significant improvements in several areas studied in comparison with other regions (a significant improvement of indicator \( B_1 \), then also visible improvements of indicators \( A_2 \), \( B_3 \) and \( B_4 \)). The cause of the fall of the UST region from the second position in 2007-2008 to the eighth was a very significant deterioration of the value of a single indicator (\( B_1 \)) in 2009 compared to previous years. The trend in road safety is, with some exceptions, that it is moderately increasing.

### 4 Conclusion

The objective of our work was to develop a complex tool for the evaluation of road safety based on generally accessible data. From the beginning we have worked with four groups of indicators however during the process we have decided to concentrate on two groups of indicators due to the lack of accessibility of suitable data. Herein above we have demonstrated only one from possible methods. When using other indicators and other methods the results would be probably different. It is our intention to continue in this research in the future in the same way since the findings show that there is still a lot of challenges in front of us in the area of road safety evaluations.

The objectives of our future work in the field of evaluation of the road safety in the Czech regions are mainly:

- Create the file of best available and the best needed indicators for setting the objectives and evaluation the road safety in CR at the regional level.
- Create the aggregate index on the basis of the best accessible indicators for the evaluation of the road safety in the regions, due to which can be then compared the state and the development of the safety in the regions of CR.
- Propose the methodology procedure of the aggregate index construction for evaluating the road safety at the level of smaller territorial units with aimed at the specifications and differences in comparison with other known procedures at the level of countries.
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