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Portuguese mainland road network safety performance indicator☆

Sandra Viera Gomes[a,*], João Lourenço Cardoso[a], Carlos Lima Azevedo[b]

[a] National Laboratory of Civil Engineering, Transportation Department, Av. Brasil, 101, 1700-066, Lisbon, Portugal
[b] Massachusetts Institute of Technology, 77 Massachusetts Ave, 02139, Cambrdige, Massacusetts, United States

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ABSTRACT

Stepping away from traditional crash-based road safety measurements, several safety performance indicators (SPI) have been proposed in the past few years. SPI can incorporate quantitative and qualitative information on specific aspects that are known to have influence in the safety levels and, not only measure the influence of various safety interventions but also enable comparisons between different road systems. This paper presents the results of the application of a road network SPI to the entire Portuguese road network. This SPI aims at evaluating at the network level, if the connections between urban centres within a region are made by the adequate type of roads regarding generic safety criteria. To this end, the connections to be assessed were classified into pre-defined theoretical safety classes, based on the population of the connected urban centres. Then, the observed safety class of these connections was assessed according to the characteristics of their cross-section and associated road environment of the existing connection between the two urban centres. If the observed class is ensured by a road of higher or equal class than the pre-defined theoretical level in all its extension, the link is considered to be of the appropriate class. For each connection, the results of its evaluation are expressed as a binary value: 0 when the class is not appropriate; and 1 when it is appropriate. The evaluation results are weighted by the road length and aggregated by connection class and throughout the whole road network. The results show a satisfactory network configuration with an SPI of 94% connections with class equal to or higher than the adequate for the type of connection between urban centres they established. The above insights can help in the identification of potential operational inconsistencies that may require safety-related interventions and used for international benchmarks against existing SPI evaluations.

1. Introduction

Road users, vehicles and infrastructure are key elements of the road transport system and their characteristics are important determinants in the overall road safety level of a region. Besides, the interactions between these elements greatly enhances the complexity of the whole phenomenon (Hermans et al., 2008) and to a large extent explain the wide spatial and temporal variations in crash frequency, risk and severity. This complexity explains the diversity of indicators that have been developed for monitoring, evaluating, and comparing the status and progress of road safety (Chen et al., 2016). The existence of several stages in road transport systems' development cycles (e.g., concept, planning, design, construction, operation and maintenance) further contribute to the variety of available indicators, some of them designed precisely for a specific stage.

A safety performance indicator (SPI) is defined as any variable which can be used to measure changes in the conditions of road traffic safety (Auerbach-Hafen et al., 2006a, 2006b). The SPI can incorporate quantitative and qualitative information on aspects that are known to have some influence in the safety levels and to measure the influence of various safety interventions and to enable comparisons between different road traffic systems (e.g. countries, regions, etc.). Small variations in such aspects can be identified, allowing to detect problems at an early stage, before accident's occurrence.

The development of a road network safety performance indicator was foreseen in scope of the National Road Safety Strategy defined by the National Road Safety Authority (ANSR 2009, 2014). The proposed road network safety performance indicator is based on the methodology proposed by the consortium of the SafetyNet project, co-financed by the European Union under the 6th Framework Programme for Research and Development (Auerbach-Hafen et al., 2007). This indicator was based on the Sustainable Safety approach (Koornstra et al., 1992; Weijermars and Wegman, 2011) and the indicator proposed by Dijkstra (2003).

The SafetyNet project aimed to provide a platform of knowledge at European level in the field of road accidents, including the creation of an observatory with relevant information to support the development of

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* Corresponding author.
E-mail address: sandravieira@lnec.pt (S. Viera Gomes).

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road safety policies. Under this project, several activities were carried out:

1. Congregation, under a common and independent structure, of existing data on road accidents and their consequences, to support the definition of plans and strategies for road safety.
2. Development of a common methodology for calculating performance indicators for road safety, suitable for use by each Member State;
3. Collection of relevant data to the use of safety performance indicators consistent with the proposal for a harmonized methodology.
4. Development of new tools for the collection and analysis of data related to road accidents.

Within the activity dedicated to Safety Performance Indicators, methodologies were proposed in order to obtain harmonized indicators regarding seven relevant aspects: alcohol and drugs; speeds; protective systems; daytime running lights; vehicle crashworthiness and passive safety; road infrastructure; and trauma management (Auerbach-Hafen et al., 2005, 2006a, 2006b, 2007; Riguelle et al., 2006; Gitelman, et al., 2014).

Two types of safety performance indicators were proposed for road infrastructure: one focusing on network characteristics (Road Network SPI) and the other resulting from a combination of infrastructure characteristics which are known to influence the frequency and severity of accidents (Road Design SPI). The former is intended for application at the planning level; the latter is mainly useful at the design and operation levels.

The Road Network SPI helps to assess whether the existing road category linking two urban centres is adequate. At the aggregate level, this SPI is defined as the percentage of the total road network length with an adequate category. In this sense, “adequate category” means that the analysed road presents the minimum requirements to ensure an acceptable level of safety, based on the current road function and traffic volume. The sizes of the urban centres that are connected by a road are assumed to determine its function and the amount of traffic volume.

The applicability of this Road Network SPI was tested successfully through a pilot study in Portugal (Arsenio et al., 2008; Yannis et al., 2013), which only covered the national continental territory South of the Tagus River. Also, in that study spatial and demographic territorial data (e.g. geometry, population and number of houses) were collected at the parish administrative level, since no lower disaggregation was available. This paper presents the results of applying the methodology developed in the SafetyNet project to the entire Portuguese road network, thus considering all Portuguese mainland urban areas. A description of the method and the characteristics of the information used in the calculations are presented in Section 2. Section 3 presents the findings of the study and discusses relevant issues for improvement of the procedure.

2. Methodology and results

The road network SPI allows to assess whether the road connection between two urban centres is appropriate from the road safety point of view. The initial concept was defined in German guidelines for road categories (FGSV, 1988). Dijkstra (2003) made an adaptation of this concept, with an application to the European context. The idea behind this concept is based on the definition of the minimum requirements that a road must comply with, based on its function and traffic volume, to ensure an acceptable level of safety. It was considered that the function and the traffic volume depend on the size of the urban centres that are connected by this road. It was assumed that higher traffic volumes are associated with more demanding geometric design requirements and that traffic volumes are higher when larger urban centres are linked. The minimum requirements that must be met by a road are related to the prevention of different types of conflicts. The aggregated road network SPI is defined as the percentage of roads with an adequate category.

The spatial data used to calculate the SPI was provided by Infoportugal S.A., which is a technology company specialized in Geographic Information Systems and Tourism (http://infoportugal.pt/). It includes the following descriptors:

- Limits of urban settlements;
- Administrative limits (parishes, municipalities, districts);
- Centroids of urban settlements;
- Land use;
- Road network.

The methodology used in the definition of the SPI applied to the Portuguese road network comprises seven steps, as presented in the following paragraphs.

2.1 STEP 1 – Calculation of the population for each urban area

The first step for the SPI definition concerns the calculation of the population in each urban area. Population data is available in the National Statistical Institute at various disaggregation levels: at the lower administrative boundary (parishes), for 2011 and at the municipality level, for 2012.

Thus, for 2012 the population by parish was estimated, based on the development of the population in the relevant municipality between 2011 and 2012, according to Eq. (1).

$$\mathrm{Pop}_{2012}^{\mathrm{Parish}} = \mathrm{Pop}_{2011}^{\mathrm{Parish}} \times \left(1 + \frac{\mathrm{Pop}_{2012}^{\mathrm{Mun}} - \mathrm{Pop}_{2011}^{\mathrm{Mun}}}{\mathrm{Pop}_{2011}^{\mathrm{Mun}}}\right) \quad (1)$$

The distribution of this population in each urban settlement was performed according to Eq. (2).

$$\mathrm{Pop}_{\text{urban settlement}} = \frac{\text{Urban settement area} \times \mathrm{Pop}_{\mathrm{Parish}}}{\text{Parish urban area}} \quad (2)$$

2.2 STEP 2 – Urban settlements definition

Many urban areas, although physically separated, present a rather

Fig. 1. Example of a proximity case in the urban settlements and its aggregation.