PERFORMANCE ANALYSIS OF ROAD SAFETY FIVE-PILLARS POLICIES AT NATIONS' AND BRAZILIAN CITIES' LEVEL

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ABSTRACT
The road traffic deaths phenomenon suggests the development of studies that consider the complex causal relationship between the factors that influence the road safety policies. For supporting effective policies and strategies on road safety, a thorough investigation of road traffic fatalities provides useful information to decision makers. The aim of the study is to propose a benchmarking method for the analysis of public road safety policies using the structural equation modelling and factor scores index approach. The main hypothesis of the present study is that there is information in the collected data set which can be used to define latent variables that have a causal relationship with road traffic deaths. The preliminary results indicated that policies aimed at encouraging users' safe behavior were the ones that had the greatest influence in reducing road deaths followed by policies in safer vehicles, road safety management, safer roads and mobility, and post-crash response.

1. INTRODUCTION

The Commission for Global Road Safety issued a call for a Decade of Action for Road Safety 2011-2020 (DARS) providing a timeframe for actions to encourage political and resource commitments for promote road safety. These actions suggest the adoption of a systemic and comprehensive approach to halve traffic deaths by 2020. This approach is based in a concept from Vision Zero Program (Tingvall, 1998; Wegman *et al*, 2008) known as Safe Systems.

However, the most recent indicators showed that little progress has been made. Globally, in 2010, The World Health Organization (2018) reported number of road traffic deaths around 1.24 million compared to 1.36 million in 2016. Between 2013 and 2016, the number of deaths increased in 104 of 175 countries monitored. In this context, the Stockholm Declaration on Road Safety (2020) has postponed the DARS target to 2030.

These results highlight the need to expand road safety policies and investments based on evidence-based evidence. The Safe Systems suggests a multidisciplinary approach improving road safety based on five key pillars. These pillars intend to guide policies and activities to: build road safety management capacity; improve the safety of road infrastructure and broader road networks; further developing the vehicles safety; improve the behavior of road users; and the post-crash care (ITF, 2016).

The road safety policies multidisciplinary evaluate requires the development of studies that allow a better understanding of the various multisectoral factors, considering the complex causal relationship embedded in the road traffic deaths and injuries (Torres *et al, 2020)*. The vast majority of Road Safety Performance (RSP) studies involving statistical modeling are focused on a more disaggregate level, in which specific aspects of the road, vehicle or users (Barbosa *et al.*, 2014). Within this approach, the predictive models still predominate.

In several occasions, the modeling results are poorly informative about the causal relationship between contributing factors and road safety (Holló, 2010; Hauer, 2015). Furthermore, when it comes to road safety policies assessment this predictive modeling paradigm seems to be inadequate to provide objective causal inferences between the key road safety components,

such as, road users behavior, road safety management, vehicles, post-crash response, road infrastructure and built environment (Nikolaou *et al*, 2019).

Multivariate Statistical Analysis (MSA) technique have been used successfully in the social sciences, economics and road safety studies (Al-Mahameed *et al.*, 2019; Chen and Chen, 2011). The approach provides a more adequate framework allowing cause-effect inferences between the variables involved, enabling the incorporation of variables more compatible with the public policies analysis performance (Schumacker and Lomax, 2004). In addition, it allows the simulation of intra and interrelationships, contributing to a broader understanding of the phenomenon of road traffic deaths and injuries. Among the MSA advantages are the possibility of incorporation of latent variables and the definition of complex relationships between independent and response variables through structural equation modeling (SEM).

The main goal of this research is to propose a benchmarking method for the analysis of public road safety policies using the SEM and factor scores index approach. The main hypothesis of the present study is that there is information in the collected data set which can be used to define latent variables and that such constructs have a causal relationship with road traffic deaths (Nikolaou *et al*, 2019). The WHO Member States and the most populous Brazilian cities will be used as a case study.

2. METHODOLOGY

The methodological proposal used in this research to achieve the objectives was carried out based on the following sequential steps: i) Calibration of a SEM model using road safety indicators (SPI) from WHO Members States; ii) Application of the proposed structural model using SPI from Brazilian cities; iii) Index definition based on factor scores approach; v) Road safety policies benchmarking of Brazilian cities.

2.1 SEM WHO Members States calibration

The estimation of the model parameters was obtained from the optimization of a function that relates the S-matrix (observed variance-covariance) with $\Sigma(\theta)$ (variance-covariance matrix of the model), constructed from the assumptions regarding the observed variable distributions and the proposed structure for the measurement models. All models were estimated using the lavaan library of the R software statistical application through the maximum likelihood (ML) method. The routine also allowed the use of Lagrange multiplier tests (modindices() function) which allow changes in structure to improve model fit.

2.2 SEM Brazilian cities application

In an effort to look for indicators similar to those reported by WHO, a vast search was carried out in national, state and municipal databases and a designed questionnaire will be applied in municipal transit agencies. The indicators were adapted to the Brazilian reality in order to represent, in the best possible way, each of the five pillars approach. The idea is applying the proposed SEM developed in the previous step in level of Brazilian cities with more than 100 thousand inhabitants. The estimation of the model parameters and the model fit criteria will follow the same method performed in the calibration step.

2.3 RSP policies index compositing

The construction of an index is a mathematical aggregation of a set of individual indicators that measure multi-dimensional concepts but usually have no common units of measurement.

One approach to combining variable is to calculate a index via an optimally weighted linear combination of the factor loadings (a SEM output), called the Factor Scores. So, each weight will be derived from its factor loading. The core idea of this technique is that cities road safety police performance will be measure by the five road safety indicator dimensions.

2.4 Brazilian cities benchmarking

This step consists of comparing the Brazilian cities analyzed using the composite indicator developed in the previous step. This effort will allow the development of hypotheses about policies to promote traffic safety in Brazil. Spatial analysis tools will be applied to define the cluster that will allow a better diagnosis of the potential of policies in different regions (i. e. Cluster Analysis and Local Indicators of Spatial Association). Benchmarking is a powerful lever to encouraging policy makers to follow best practices and encourage consideration of policies employed by the best-performing cities.

3. PRELIMINARY RESULTS

The main products produced so far were the definition of the SEM model structure for the WHO Member States and the design questionnaire for municipal transit agencies. After some exploratory SEM structure and the analysis of Lagrange modification indices, the proposed SEM for Nations level model was defined as shown in Figure 1. This model presented a better fit than the others and converged with 96 interactions.

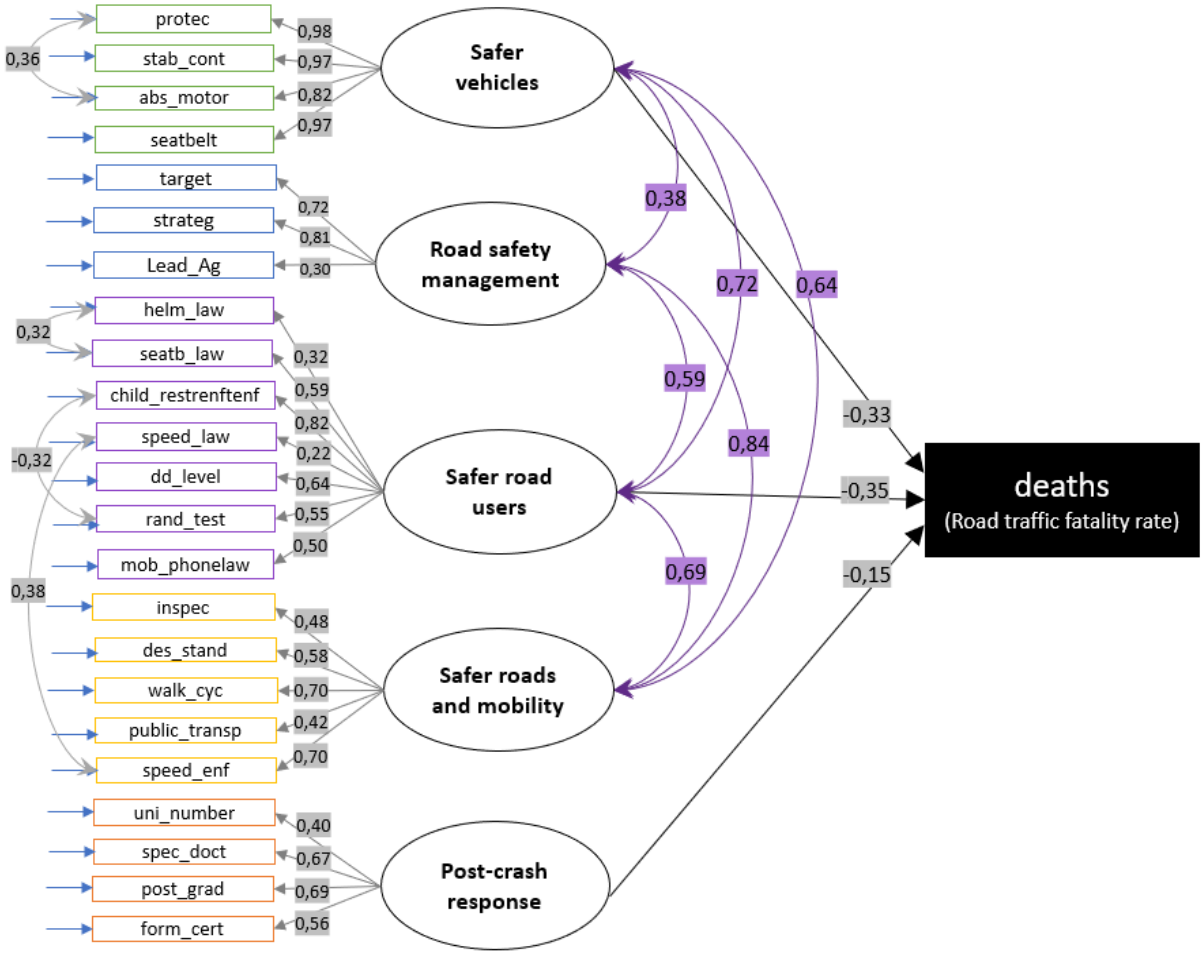

Figure 01: Structural equation model proposed structure

The proposed SEM structure indicated that management, as expected, has a strategic role in public policies, having an indirect influence on reducing the mortality rate through *safe vehicles*, *safe users*, and *safe roads and mobility*. The existence of targets, strategies and leading agency were the most important factors for road safety management policies.

A stricter legislation promoting safe user behavior was the pillar of action with the greatest direct impact on reducing the mortality rate. Among the variables tested, those that influenced incisively were seatbelt use enforcement level, existence of laws for speed limit, allowed alcohol limits, randomization of breath tests and seatbelt, helmet and cellphone use.

Policies that promote safe roads and mobility indirectly influence the reduction of mortality through *safe users*, *road safety management*, and *safe vehicles*. Policies aimed at improving the quality of accident response also directly influence the reduction of mortality rates in the countries analyzed.

Comparatively, the results indicated that the promotion of safe vehicles and safe users have a greater impact in reducing mortality when compared with post-crash response. Thus, we highlight that, despite the importance of post-crash care, prevention initiatives can be even more effective in reducing global mortality.

These preliminary results were recently published at Transportation Research Record (Torres *et al*, 2020) and were awarded for best paper in the urban and road traffic category at the 33rd Associação Nacional de Pesquisa e Ensino em Transportes (ANPET) Conference.

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