Safety Science 79 (2015) 39–54

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/ssci

Road safety risk evaluation by means of improved entropy *TOPSIS–RSR*

Faan Chen [a,b,*], Jianjun Wang [b], Yajuan Deng [b]

[a] The Key Laboratory of Road and Traffic Engineering of the Ministry of Education, Tongji University, Shanghai 201804, China
[b] Institute for Transportation Engineering Research, School of Highway, Chang'an University, Xi'an 710064, China

ARTICLE INFO

Article history:
Received 5 September 2013
Received in revised form 18 January 2015
Accepted 13 May 2015
Available online 1 June 2015

Keywords:
Road safety
Composite index
Performance evaluation
Sub-national comparison
Decision support system

ABSTRACT

Currently, comparisons of road safety performance at a national or sub-national level are worthy of being conducted; both in order to better understand one's own situation in regards to road safety risk, and to find a meaningful reference (best-in-class) to learn lessons in terms of action program formulation. In this respect, the composite road safety performance index, which condenses the vast amount of road safety information in a comprehensive manner to produce a broad picture of road safety, is rapidly developing and becoming increasingly popular. Mainly due to the unsatisfactory explanation of more detailed aspects of crash causation and injury prevention when considering isolated indicators such as fatality rate. To this end, a means to measure the multi-dimensional concept of road safety in a scientific and systematic manner is urgently required; specifically a performance measuring technique that can combine the multilayer safety performance indicators (SPIs) into an overall index. In this study the improved entropy TOPSIS–RSR methodology is structured to conduct the road safety risk evaluation process from an overall perspective, based on a composite Road Safety Risk Index (RSRI). Using the results of clustering analysis as a relevant reference, a given set of provinces are grouped into several specific classes based on the RSRI score for case study. The contrasts in results prove to verify the robustness of the proposed model. Furthermore, they indicate the feasibility of applying this model as a valuable tool for road safety policymakers to decision-making activities and performance evaluation that contains multi-alternative and multi-criteria.

1. Introduction

Road traffic injuries have been recognized as one of the most significant public health issues facing humanity today. Without new or improved developments, it is predicted to rise to become the fifth leading cause of death by 2030, as the use of motor vehicles is continuously increasing globally (World Health Organization, 2013, 2006, 2004; Organization for Economic Co-Operation & Development, 2002). Worldwide the total number of road traffic deaths remains unacceptably high at 1.2 million per year, with an additional 20 to 50 million people suffering non-fatal injuries. In most regions of the world this epidemic of road traffic injuries is still increasing (World Health Organization, 2013). Over 90% of the world's fatalities on the roads occur in low-income and middle-income countries (developing or transitional countries). These countries have only 48% of the world's registered vehicles, with approximately half of all fatalities in Asia and Pacific (World Health Organization, 2013; Jacobs et al., 2000). Projections indicate that these figures will increase by about 65% over the next 20 years unless there is a significant increase in commitment to create new, or improve current, prevention techniques (World Health Organization, 2004). In China, there were nearly 190,756 traffic accidents in 2012. Resulting in an estimated 57,277 people are killed, and as many as 210,554 are injured (Annual Statistical Report of Road Traffic Accidents P.R. China, 2012). The financial cost of these accidents alone was in excess of 1100 million U.S. dollars. Approximately 157 people die every day in vehicle accidents – one death every 10 min (Annual Statistical Report of Road Traffic Accidents P.R. China, 2012). The sharp increase in accidents resulted in economic costs in excess of 10 billion U.S. dollars over the past years (China Statistical Yearbook, 2012). With such a high number of casualties, resultant suffering and socio-economic costs, effective and efficient countermeasures are urgently required.

Under the severe circumstances, an increasing number of countries have realized the present crisis of road safety and have taken a series of countermeasures to improve the current road safety situation. Over the past three years, a large number of road safety

* Corresponding author at: Room A520, Tongda Pavilion, Tongji University, 4800 Cao'an Road, Shanghai, China. Tel.: +86 21 6598 9270.
E-mail address: allenchenfun@gmail.com (F. Chen).

http://dx.doi.org/10.1016/j.ssci.2015.05.006
0925-7535/

strategies and programmes have been launched and put into effect in China (National Plan of Action for Road Traffic Safety P.R. China, 2011; The Twelfth Five-year Plan for Road Traffic Safety P.R. China, 2011). In Shanghai, road safety targets for the short term, near term and long term, have been set; whilst plans of action and policy for road traffic safety in the short term have already been implemented (White Paper on Transport Development in Shanghai, 2013). Several other provinces and cities, including Beijing, Xinjiang, Guangzhou and Nanjing, also have implemented similar plans.

However, the effect of countermeasures varies from province to province, depending on its policies and its conditions of socio-economic development. Learning from each other and then applying this knowledge into practice is an indispensable part of gaining maximum improvement in road safety; in doing so, comparisons can be a starting point to it (Wegman et al., 2008). In China, it's essentially that province policy-makers compare their own road safety achievements with other better-performing provinces or countries. It is not enough for policy-makers to focus their attentions solely at a provincial level. As currently in many inwardly looking provinces this problem is being underestimated and neglected, especially in backward provinces where the issue is more challenging. Consequently, it is important for a province to understand its relative road safety situation, then compare it with other provinces, and one step further, learn from those better-performing provinces; with respect to road safety policy making, countermeasures, programmes development, and target setting for accident prevention and casualty reduction.

Currently, the road safety performance is mostly measured by means of traditional approach, only using fatality rate (fatalities per head of population, vehicles, etc.) (Wegman et al., 2008; Al Haji, 2005). Due to the lack of details, such as crash causation and injury prevention, provided by the traditional approach, there is a growing interest globally in the development of a composite road safety performance index, specifically designed to capture an enriched picture of road safety over the last decade (e.g. Bax et al., 2012; Wegman et al., 2008; Al Haji, 2005; ETSC, 2001).

In general, road safety can be represented by a series of safety performance indicators (SPIs). Provinces could be compared on each indicator individually from different perspectives. However, road safety, which involves a high number of accident factors and indicators of human, vehicles, roads, environment, and management, is of high complexity, time-dependence and uncertainty (Wang and Chen, 2012a,b; Al Haji, 2005; Haddon, 1980). These factors and indicators are not fully independent of each other, showing a coupling relationship and close connection (Wang and Chen, 2012a,b). Comparing each indicator individually doesn't account for the aggregation of indicators. This may then lead to partial even incorrect results, as they describe road risk from different points of view. In other words, provinces may have different evaluation results using different exposure information, as there exist differences between the region concerning traffic systems, population, education, economy, etc. This is unfavorable for policy-makers in assessing their own relative road safety performance and drawing up targeted programmes.

Consequently, it is attractive, desirable and necessary to create an overall road safety performance index. One which presents the overall perspective on a province's road safety by capturing a multitude of risk information in one index score, instead of considering isolated indicators such as accident rate, and offers advantages in terms of communication (Wegman et al., 2008), benchmarking (Wegman and Oppe, 2010; Hermans et al., 2009), and decision making (Bao et al., 2012). In this respect, we introduce a hierarchical structure of Road Safety Risk Index (RSRI) for road safety performance evaluation. This structure is based on a wide literature review which involves seven main dimensions (Human factors, Vehicle factors, Road factors, Environment factors, Management factors, Personal risk, and Traffic risk).

The combination of road safety performance indicators into an index consisting of various steps is a methodologically intensive process. It includes assigning weights of road safety performance indicators and aggregating road safety performance indicators (Hermans, 2009). In this respect, new methods are worthwhile exploring and testing for the road safety case, as there is a potential for innovation in the methodological process. In this study, a new methodology, the improved entropy TOPSIS–RSR, seamlessly integrates three isolated models in a systematic way, which can be treated as a natural extension of the three basic models and considered as a unique methodology of measuring the road safety achievements. TOPSIS (Hwang and Yoon, 1981), which is Technique for Order Preference by Similarity to an Ideal Solution and one of the well-known classical multi-criteria decision-making (MCDM) methods, is investigated. The entropy method (Shannon and Weaver, 1947) is nested to obtain result weights that will be used as the input weights of TOPSIS. The RSR method (Tian, 1993) is integrated to group provinces with inherent similarity in their practices. In application, the proposed model is used to assess the road safety performance for a set of provinces. The results are then compared with the ones derived from clustering analysis as a relevant point of reference.

The remainder of this paper is structured as follows. Initially, we review the literature in Section 2. In Section 3, we introduce a hierarchical structure of composite Road Safety Risk Index (RSRI) and collect data used in this study. In Section 4, we present the improved entropy TOPSIS–RSR methodology for road safety risk evaluation, which seamlessly integrates three isolated models, namely entropy method, classical TOPSIS and RSR method. Section 5 presents the application of the methodology for road safety risk evaluation and provides computational results. Subsequently, the corresponding results are discussed in Section 6. Finally, the paper ends with concluding remarks and further research in Section 7.

2. Literature review

2.1. Road safety performance indicators (SPIs)

Road safety is a complex system, integrating all possible main valuable parameters of human-vehicle–road-environment-manage ment, and road traffic accidents can be caused by one, or a combination of the five main dimensions (Wang and Chen, 2012a,b; Haddon, 1980). These five dimensions are not fully independent of each other, and each dimension is influenced by many factors and indicators (Wang and Chen, 2012a,b; Al Haji, 2005; Rumar, 1999).

Selecting a set of SPIs, which should serve as supportive tools of benchmarking for policymakers (Wegman et al., 2008), is a complex issue. The choice of each indicator is crucial and mainly depends on the type, availability, and quality of data being collected (Papadimitriou et al., 2013). Moreover, the selected indicators should be capable of integration in a composite index, which can combine all the relevant parameters in a concise and comprehensive way (Wegman et al., 2008). Furthermore, the composite index should be engineered to be as well-balanced as possible (Al Haji, 2005).

Over the last decade, more and more indicators are suggested to produce a composite index for use in the field of road safety (Wegman et al., 2008; Hakkert et al., 2007; Al Haji, 2005; ETSC, 2001). Wegman et al. (2008) developed an integral and comprehensive set of indicators, which worked with a composite index to condense the vast amount of information related to road safety.