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SAFESIDE: A computer-aided procedure for integrating benefits and costs in roadside safety intervention decision making

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ABSTRACT

Collisions with dangerous roadside obstacles and rollovers are responsible for many injuries and deaths in highways worldwide. International crash data indicate that roadside characteristics contribute to more than half of all run-off-road injury crashes (RORIC) involving serious injury or death. Furthermore, roadside geometric characteristics are believed to be the leading cause of rollover in single-vehicle RORIC. Differences in each country's road network features, car vehicle stock, driving behavior, characteristics of roadside obstacles and economical aspects justify the need for evaluating the merit of specific approaches to roadside safety issues. Results from recent studies carried out at the Laboratório Nacional de Engenharia Civil – LNEC have shown that important differences exist between RORIC in Portuguese roads, when they are compared with RORIC in roads from other countries. A framework was developed for assisting in cost-effective decisions as regards roadside safety interventions, which is based on results from the analysis of registered data and the observation of inservice performance of installed equipments on Portuguese roads. A brief description is provided of cost–benefit analysis software tools for safety evaluation and simulation of roadside scenarios, which were developed at LNEC under a dedicated research project – SAFESIDE-roadside safety. The software contains a list of roadside safety measures (including the present value of their implementation costs and their safety effects) and an accident categorization (based on predictive models for crash frequencies and crash costs). The software is being disseminated by road authorities and relevant technical stakeholders, within the current revision of Portuguese road design standards.

1. Introduction

Collisions with roadside obstacles are responsible for many injuries and deaths in highways worldwide. Each year, more than 700 persons die and about 45,000 are injured in Portugal, as a result of road crashes. The latest monetary estimates for road crash losses in Portugal date back to 1995, when they amounted to over 3100 million euros (about 3% of the country's GDP). Portuguese crash data indicate that roadside characteristics, such as dangerous obstacles and slope geometry are involved in more than half of all run-off-the-road injury crashes (RORIC) resulting in serious injury or death (Roque and Cardoso, 2012a). Furthermore, roadside characteristics are the leading cause of rollover in single-vehicle RORIC.

In highly motorized countries the widespread integration of the concepts of self-explaining and forgiving roads in road design standards reflects the importance of roadside characteristics for a safe road environment. However, in some countries these issues have not been dealt satisfactorily yet, the practice being to use the same criteria exactly as developed and applied elsewhere. Differences in each country's road network features, car vehicle stock, driving behavior, characteristics of obstacles hit and economical aspects justify the need for evaluating the merit of distinctive approaches to roadside safety issues. Results from recent studies carried out at the *Laboratório Nacional de Engenharia Civil* – LNEC (National Laboratory for Civil Engineering) have shown that important differences exist between RORIC in some high speed Portuguese main roads, when compared with RORIC in roads from other countries. Indeed, a higher percentage of collisions with obstacles in the inside of horizontal curves (49%) were registered in Portuguese trunk roads (Cardoso and Azevedo, 2006), than in worldwide published studies of safety in road curves.

According to ERSO (2012), the most significant reduction in single vehicle fatalities in the European Union during the period 2001–2010 occurred in Spain (58%) and Austria (54%). In 2010, the number of these fatalities decreased significantly in Hungary (41%), Finland (26%) and United Kingdom (25%). In contrast, Portugal is the only country with an increase in 2010 (59%).

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In fact, Portugal has a paradoxical development in this matter (see Fig. 1). In the last 15 years the number of RORIC has consistently increased (almost 40%), although the total number of crashes (including RORIC) has been continuously declining (20%, in total).

In road safety, as in other fields, cost–benefit analysis (CBA) is used to support decisions regarding the investment of public money and setting up project priorities. The principle behind CBA is that public funds should only be invested in projects where the expected benefits exceed the expected direct costs of the project. CBA compares a safety treatment with the existing (baseline) condition and alternative safety treatments. CBA procedures can be used to study individual sites or to develop general guidelines.

The objective of this paper is to document the framework for cost-effective decisions, using CBA and statistical methods, as regards roadside safety benefits developed to support recommendations about efficient roadside safety measures for Portuguese roads. The framework is applied through a computer-aided procedure. The prototype software for safety evaluation and simulation of roadside scenarios presented in this paper is intended to support decisions concerning both roadside design and the installation and selection of road restraint systems complying with the European Committee for Standardization standards (CEN-EN 1317).

2. Background

The forgiving roadside concept provides errant vehicles with a traversable recovery area free of fixed objects.

In the U.S., clear zones were created since the early 1970s to increase the likelihood that a roadway departure results in a safe recovery rather than a crash, and mitigate the severity of crashes that do occur (Donnell and Mason, 2006). Under this philosophy, roadside hazards within the clear zone are either eliminated or moved. When hazards cannot be removed or relocated, a determination needs to be made if a safety device (e.g., guardrail or crash cushion) is warranted to protect occupants from the roadside obstacle. This principle has guided the development of design policies to the present day, such as the fourth edition of American Association of State Highway and Transportation Officials' (AASHTO) Roadside Design Guide (RDG) (2011).

In Portugal, knowledge concerning run-off-the-road crashes recently increased as a result of a roadside safety research project (called SAFESIDE) and new methods for roadside design and maintenance of interurban roads were introduced. Furthermore, the project contributed to the adoption and application of the "forgiving roadside" and "clear zone" concepts as well the relevant European technical standards, namely EN 1317 and EN 12767, which are currently not yet used in Portugal. For this purpose two design guideline manuals were developed at LNEC at the request of the Portuguese road administration (Roque and Cardoso, 2010, 2011).

With the first edition of the AASHTO RDG (1998) a benefit/cost analysis program called ROADSIDE was presented to be used in site-specific decision-making processes (Mak et al., 1998). In fact, when determining locations and roadside safety measures to be used, a highway engineer needs to weigh the risk of death or injury to road users against the cost of installing and maintaining roadside safety improvements.

After the publication of the 2002 AASHTO RDG, under National Cooperative Highway Research Program (NCHRP) Projects 22-9 and 22-9(2) an improved cost effectiveness analysis procedure for assessing roadside safety improvements was developed. The result of these research efforts was the first version of Roadside Safety Analysis Program (RSAP). RSAP is based on the encroachment probability approach and incorporates two integrated programs: the Main Analysis Program, which contains the cost-effectiveness procedure and algorithms; and the User Interface Program, which provides a user-friendly environment for data input and review of program results. The cost-effectiveness procedure incorporated into RSAP is based on the concept of incremental benefit/cost analysis. The encroachment model uses roadway and traffic information to estimate the expected encroachment frequency along a highway segment (Mak and Sicking, 2003). Compared to ROADSIDE, RSAP has presented significant improvement in how encroachments and eventual crashes were assigned by adopting a stochastic solution method instead of a deterministic approach (Albuquerque et al., 2011).

The encroachment-based method used in ROADSIDE and RSAP is one of the two approaches that have been followed in parallel in recent years to model the relationship between roadway and roadside features and RORIC risk (Pardillo-Mayora et al., 2010). This approach uses a series of conditional probabilities of the sequence of events that lead to a run-off-the-road crash following the encroachment of an errant vehicle on the roadside.

Encroachment-based methods have a major obstacle to their development: the lack of encroachment frequency data. Recently, under NCHRP Project 22-27, an updated version of RSAP was developed and encroachment frequency data collected in the 70s in North America (Cooper, 1980) was re-analyzed to

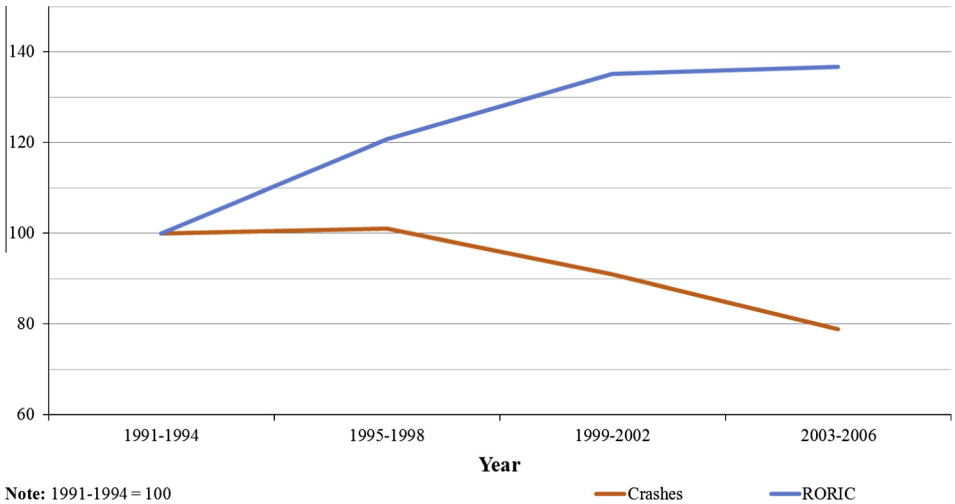

Fig. 1. Development in the numbers of accidents and RORIC in Portugal (1991–2006).