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An approach to accidents modeling based on compounds road environments

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ABSTRACT

The most common approach to study the influence of certain road features on accidents has been the consideration of uniform road segments characterized by a unique feature. However, when an accident is related to the road infrastructure, its cause is usually not a single characteristic but rather a complex combination of several characteristics. The main objective of this paper is to describe a methodology developed in order to consider the road as a complete environment by using compound road environments, overcoming the limitations inherented in considering only uniform road segments. The methodology consists of: dividing a sample of roads into segments; grouping them into quite homogeneous road environments using cluster analysis; and identifying the influence of skid resistance and texture depth on road accidents in each environment by using generalized linear models. The application of this methodology is demonstrated for eight roads. Based on real data from accidents and road characteristics, three compound road environments were established where the pavement surface properties significantly influence the occurrence of accidents. Results have showed clearly that road environments where braking maneuvers are more common or those with small radii of curvature and high speeds require higher skid resistance and texture depth as an important contribution to the accident prevention.

1. Introduction

Numerical modeling is a common tool for estimating the frequency of road accidents. Various models have been intensively tested and validated (Abdel-Aty and Radwan, 2000; Caliendo et al., 2007; Cardoso, 1996; Maher and Summersgill, 1996; Mountain et al., 1996; Persaud and Dzbik, 1993; Wang et al., 2006). The adjustment of the models is based on historical accident data and on the characteristics of experimental sections selected from the road network. These models are useful for estimating the expected number of accidents based on variables related to traffic, road geometry and road environment.

The occurrence of accidents is a typical case that cannot be modeled as continuous data using a normal regression. Generalized linear models (*GLM*), first presented in 1972 by Nelder and Wedderburn and later developed by MacCullagh and Nelder (1983), are considered the most suitable models for determining relationships between accidents and characteristics of traffic and road geometry (Cardoso, 1996; Greibe, 2003; Lebaye, 1997; Maher and Summersgill, 1996; Wood, 2002).

Modeling of accidents is often based on uniform road sections, but this is an important constraint. In fact, a study focused on a single characteristic of a road segment (circular or straight alignments, width of lanes, shoulders properties) is very limiting because it does not consider the influence of other possible variables of the road environment (Cardoso, 1996). The most appropriate technique is to consider compound road environments characterized by similar properties. In order to obtain these types of road environments, cluster analysis can be a useful statistical tool. This technique is suitable for classifying and recognizing objects and grouping them according to similar characteristics. Cluster analysis has the advantage of grouping the objects without having to set criteria for inclusion in a given group beforehand.

The most important surface properties related to pavement adherence are skid resistance and texture depth. In fact, many countries have guidelines to ensure safe levels of these properties on their roads (Highways Agency, 2004; Transit NZ, 2002), supported by research carried out on the relationship between adherence and accident risk. With respect to the influence of road infrastructure on accidents modeling, different research studies have been conducted in order to evaluate the influence of skid resistance and texture depth on accident risk (Carney and Styles, 2005; Ferrandez, 1993; Gothié, 2000; Rizemberg et al., 1976; Roe et al., 1991; Yerpez and Ferrandez, 1986). In general, the results clearly confirm that traffic safety depends on these surface pavement properties. For example, an increase in the accident rate is normally

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observed when the pavement surface shows low skid resistance values. However, the tendencies observed are strongly dependent on the road environment. This means that the relationships vary from one case study to another, and it is not possible to establish a fully defined relationship (Patte, 2005). Taking this into account, levels of adherence in quality control should not be always the same. Different categories of roads belonging to different regions will obviously have different surface properties. The relative importance of the surface pavement characteristics of road sections with different traffic volumes, road geometry and weather conditions must therefore be assessed.

In the specific case of the influence of skid resistance on accident risk, the biggest challenge is to achieve the best relationship with other road characteristics, such as traffic flow and geometrical design. Accident risk tends to be higher when braking forces and/or lateral forces are unusually high: as in the case of collisions at intersections and accidents on curves (Ferrandez, 1993). Some researchers have proposed linear functions between skid resistance and the risk of accident (Murad, 2006; Noyce et al., 2005), but others authors believe that non-linear functions are more suitable. Accident risk is usually expressed as occurrences per million vehicles km, where occurrences may be victims or accidents with and/or without victims. A good review of studies conducted in Europe of the influence of skid resistance on accident risk was compiled by Wallman and Astrom (2001).

The present work also addresses the importance of numerical modeling of road accidents, but in this case using a new methodology based on the concept of compound road environments. The construction of these types of road environments was based on cluster analysis, as an innovative tool for this objective. The application of this methodology has demonstrated that it is possible to achieve a more realistic approach to the multiple facets of road infrastructure that could affect the occurrence of accidents. Skid resistance and texture depth were also identified as the most important surface pavement characteristics in accident risk analysis and modeling of road accidents was based on *GLM*.

2. Methodology

The methodology can be applied in three phases as it is drawn with detail in Fig. 1 (Fernandes, 2010). The phases basically consist of:

(1) Dividing a sample of roads into segments.
(2) Grouping the sample into quite homogeneous road environments using cluster analysis, taking into consideration characteristics like traffic, road geometry and weather conditions.
(3) Modeling road accidents in order to identify the influence of a specific feature of the infrastructure in each environment by using *GLM*.

It is in the Phase 1 that the sample of roads is chosen for the study. This selection should be done randomly or using a non-random sampling method, depending on the data availability. This phase has a particular importance because the sample selected must be representative of the roads from the larger road network being studied. In fact, to avoid a biased sample, different types of roads should be chosen to ensure a varied distribution throughout the road network and to include accidents of different origins. During this phase, a good characterization of road segments is desirable. Information about traffic, the presence of intersections, urban characteristics, road geometry, and weather and pavement conditions should be also collected.

The Phase 2 involves the definition of road environments. To separate sample into different road environments with distinct traffic characteristics, road geometry and weather and pavement conditions, a cluster analysis must be performed by using the most appropriate criteria.

The modeling of the expected number of road accidents, performed in the Phase 3, consists of using *GLM* in order to assess the influence of the specific road feature on accidents. In each case, the selected variable should be the most representative of the feature

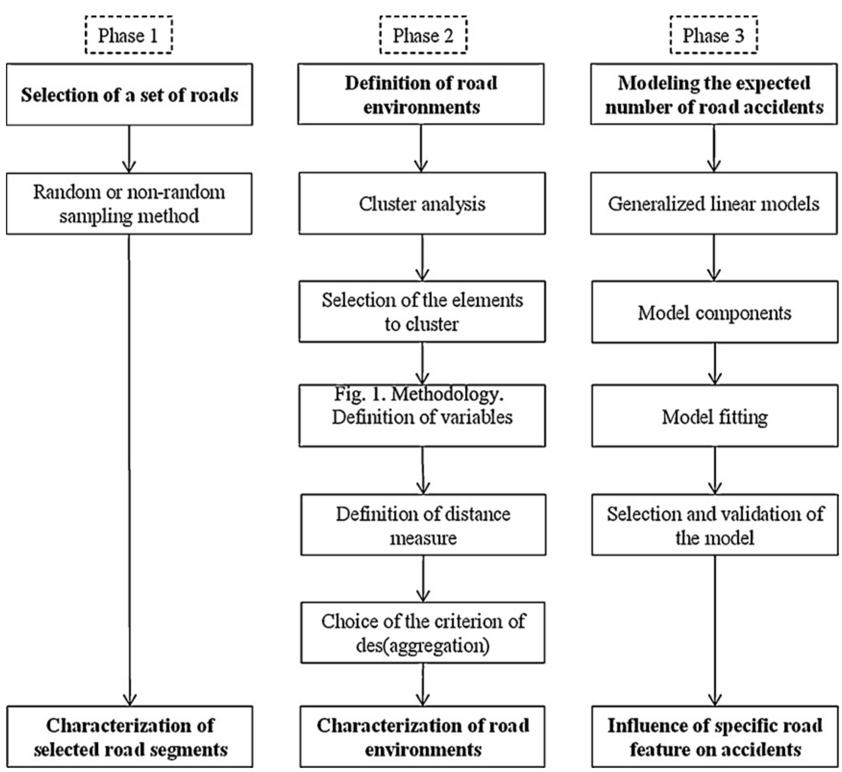

Fig. 1. Methodology.