Accident Analysis and Prevention 60 (2013) 289–297

Contents lists available at ScienceDirect

Accident Analysis and Prevention

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

The influence of the infrastructure characteristics in urban road accidents occurrence

Sandra Vieira Gomes *

National Laboratory of Civil Engineering, Transportation Department, Portugal

ARTICLE INFO

Article history:
Received 10 October 2012
Received in revised form 26 February 2013
Accepted 28 February 2013

Keywords:
GIS
Accident prediction models
Generalized linear modelling
Road accidents
Urban intersections
Urban segments

ABSTRACT

This paper summarizes the result of a study regarding the creation of tools that can be used in intervention methods in the planning and management of urban road networks in Portugal.

The first tool relates the creation of a geocoded database of road accidents occurred in Lisbon between 2004 and 2007, which allowed the definition of digital maps, with the possibility of a wide range of consultations and crossing of information.

The second tool concerns the development of models to estimate the frequency of accidents on urban networks, according to different desegregations: road element (intersections and segments); type of accident (accidents with and without pedestrians); and inclusion of explanatory variables related to the road environment. Several methods were used to assess the goodness of fit of the developed models, allowing more robust conclusions.

This work aims to contribute to the scientific knowledge of accidents phenomenon in Portugal, with detailed and accurate information on the factors affecting its occurrence. This allows to explicitly include safety aspects in planning and road management tasks.

1. Introduction

According to official statistics, a large percentage of accidents are reported in Portuguese urban areas. For instance, from 2004 to 2010, about 70% of all injury accidents and 45% of the fatalities occurred inside urban agglomerations (ANSR, 2010). This significant problem was also identified in the city of Lisbon, which was the case study for the development of a PhD Thesis. The main purpose of the research was to develop methods for managing the safety of urban road networks, particularly those applied to Lisbon. The methods focused on the construction of a geocoded accident database and on the estimation of the expected accident frequencies that allow the identification of hazardous sites.

This paper describes the steps that were taken to build these two tools. The geocoded accident database included injury and Property Damage Only accidents (PDO) occurred in Lisbon from 2004 to 2007. A sketch was associated to each accident, allowing identifying the manoeuvres involved. In what concerns the accident predictive models (APMs), the Negative Binomial modelling framework was used. Sixteen types of models were foreseen: flow-only and models with covariates applied to accidents with pedestrians and other injury accidents occurred at intersections (three legs, four legs and roundabouts) and in segments.

The paper is organized as follows: the first section provides a brief background about existing statistical models developed in Portugal and elsewhere in Europe, the second section describes the methodology used for the construction of the accident database in the GIS; the third section presents the characteristics of the data used in this study; the fourth section focuses on the estimation of the APMs; the fifth section summarizes the modelling results; and the last section provides a summary of the study and of the advantages of the use of these APM in intervention methods in the planning and management of road networks.

2. Background on APM

The development of accident prediction models is not new in the road safety research. Several authors, all around the word have published their work in this scope. Different types of models have been developed, according to level of disaggregation of the variables used: aggregated and disaggregated models.

Aggregate models allow the description of general safety trends on the regional or national level, making possible the development of short-term safety estimations, as a function of traffic and macro-economic variables. For instance, Washington et al. (2006) developed accident prediction models for several accident desegregations using a log linear regression model with variables regarding: population, road length, vehicles kilometres travelled, intersections density, average income and number of housing units.

* Tel.: +351 218443528; fax: +351 218443029.
E-mail address: sandravieira@lnec.pt

0001-4575/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.aap.2013.02.042

Disaggregated models may be used to represent the effect of changes in specific parts of the transportation system or in the safety of specific user groups. They are used in the evaluation of safety policies and in road safety estimations, being therefore considered an important instrument to road safety management at a macroscopic level (regional or national). The usual types of disaggregation are by transport mode, age group, sex and type of road (Cardoso, 2007; EC, 2004).

In this section, a special focus is given on the desegregated type of accident prediction models applied to urban areas, as it relates to the work of the present paper. Total accident frequency is the most common response variable in accident modelling. Several authors developed mathematical functions to explain total accident occurrence at intersections. The common explanatory variables used were also motorized vehicles and pedestrian volumes, sometimes disaggregated by major and minor legs. Commonly, distinct models are developed for intersections and road links, as the type of variables involved are somehow different.

Mountain and Fawaz (1996) created APMs using data from 662 intersections with different types of traffic control systems in the UK. The authors developed models relating accidents with traffic flows and other variables, namely: method of control, road class, carriageway type (single or dual), number of arms and speed limit. The authors concluded that only the method of control had a significant effect on accident occurrence, although the best fitted models were ones with traffic flow as the only explanatory variable.

Sayed and Rodriguez (1999) develop accident prediction models for urban unsignalised intersections of Greater Vancouver Regional District and Vancouver Island, British Columbia, as a function of the traffic volumes on both major and minor roads and the type of intersection: three or four arm.

Mountain and Fawaz (1996) developed models for different types of intersections in the United Kingdom: signal-controlled intersections, roundabouts and major–minor priority, using as explanatory variables intersection characteristics (method of control, road class, highest standard of carriageway (single or dual), number of arms and speed limit) and traffic flow on major and minor road.

Accident prediction models in road links were also the scope of several authors, mainly in what concerns total accidents. Motorized vehicle traffic volumes were the basic explanatory variables used, but other variables like road length, driveway density, number of minor intersections, pedestrian traffic volumes, road width, number of lanes and traffic speed were also used:

Greibe (2003) developed APMs for road segments and urban intersections with three or four legs and with or without traffic signals in Denmark. The estimated accident prediction models for road links were capable of describing more than 60% of the systematic variation ('percentage-explained' value) while the models for junctions had lower values. The significant variables found in the study were: speed limit, road width, number of exits per km, number of minor side roads per km, parking and land use.

Turner et al. (2003) developed accident prediction models for urban road sections in New Zealand, using only the traffic volume as an explanatory variable.

Mountain et al. (1996) developed models for roads with minor intersections, in which the number of minor junctions in a road section is included as a variable. As stated by the authors, models of this form can be used on roads where traffic counts on the minor arms of intersections are not available. The explanatory variables included in the models were road type, carriageway type and speed limit.

Bonneson and McCoy (1997) created a model which predicts the annual number of accidents on urban arterial streets according to specified median treatments: raised-curb median, flush median delineated as a two-way left-turn lane (TWLTL) and undivided cross section. The explanatory variables included in the model were AADT, number of lanes, section length, cross section width, median with, speed limit, land use information, the driveway density and the unsignalised public-street-approach density.

Some authors have developed accident prediction models specifically for pedestrian accidents, which included in their variables the pedestrian traffic flow.

Turner et al. (2006) developed several accident prediction models regarding specifically pedestrians in intersections (signalized intersections, roundabouts and T-junctions). They disaggregated their multiplicative models by type of movement and used specific variables associated with conflicting movements.

Leden (2002) studied the pedestrian safety at intersections, considering different types of conflicts between road users. Four different ways of estimating hourly flows for left- and right-turning vehicles were explored. The author concluded that left-turning vehicles caused higher risks for pedestrians than right-turning vehicles. At low vehicular flows right turns and semi-protected left turns seemed to be equally safe for pedestrians. Another conclusion relates the risk decreased with increasing pedestrian flows and increased with increasing vehicle flow.

Pedestrian accidents at intersections were modelled by Maher and Summersgill (1996) and Gårder (2004) (for roundabouts). Both of them used multiplicative models which only included motorized vehicles and pedestrian volumes as explanatory variables.

The development and application of accident prediction models for various types of highway safety analyses in Portugal is very recent, but highly justified, as discussed in Vieira Gomes and Cardoso (2008). In this study, international accident prediction models were applied to some intersections of Lisbon, to evaluate their adjustment. The comparison between the observed accident frequencies and the estimated ones evidenced the inadequacy of the models to the Portuguese urban road context, since the estimated values were higher than the observed ones.

To fulfil this need, Vieira Gomes (2010) developed models to estimate the frequency of accidents on urban networks, according to different desegregations: according to the road element – at intersections (three legs, four legs and roundabouts) and in segments; according to type of accident – accidents involving pedestrians and other victims; and according to the inclusion of explanatory variables related to the road environment – simplified (only with the exposure variables) and global (with all potential explanatory variables).

This section provides a summary on accident prediction models applied to intersections and road links in urban areas. Accident prediction models are mathematical functions that describe the relation between the road safety and explanatory variables, such as traffic, road length and carriageway width, number of intersections, etc. Its most common form is expressed as the following multiplicative expression: $A = \alpha \times T_1^{\beta} \times T_2^{\beta} \times e^{\sum \gamma_i \cdot x_i}$, where A is the expected number of accidents, which is a function of traffic volumes (T_i) and with other factors (X_i). The effect of traffic in the accident's occurrence is modelled through the power β. The effect of the several risk factors that usually influence accident frequency is modelled through an exponential function of base e and raised to the sum of the product of the γ_i coefficients by the risk factors, x_i.

The accident prediction models developed in this study aim to contribute to the scientific knowledge of accidents phenomenon in Portugal, with detailed and accurate information on the factors affecting its occurrence.

3. Geocoded accident database

Geocoding accidents on digital road networks have great advantages for safety studies, namely the quick visualization of their