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Modelling pedestrian crossing behaviour in urban roads: A latent variable approach

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ABSTRACT

As pedestrians are the most exposed and vulnerable road users to traffic accidents, urban planners frequently propose alternatives to improve their safety. However, some solutions, such as pedestrian bridges and crosswalks at signalized intersections, usually imply longer walking distances compared to the direct crossing alternative which, in its turn, involves a higher risk.

In this article, a hybrid framework is proposed to analyse the pedestrians' choice on how to cross an urban road where three crossing options are available: crossing directly, crossing by using a pedestrian bridge or using a crosswalk at a signalized intersection. The decision process is modelled as a discrete choice model incorporating latent variables to consider perceptions and psychological factors, using stated preference data coming from a survey applied in Bogotá, Colombia.

Results show that the latent variables security/safety and attractiveness of each crossing alternative are relevant to understand the pedestrian crossing behaviour. These latent variables are strongly determined by socioeconomic characteristics of the individual (age, gender, level of study) and conditioned by the circumstances of the trip (main mode of transport, walking or not with children). It was found that a longer walking distance to a pedestrian bridge or a signalized crosswalk increases the probability of direct crossing, having a more relevant effect in the case of the pedestrian bridge.

1. Introduction

Traffic accidents are a growing public health problem in most cities, which is even more critical in developing countries. In Colombia during 2013, for instance, 29.13% of traffic fatalities involved pedestrians, being only surpassed by motorcycle-related deaths which represented 34.1% (Instituto Nacional de Medicina Legal y Ciencias Forenses, 2012). In Bogota, the capital of Colombia, pedestrians represented about 62% of traffic fatalities (Cámara de Comercio de Bogotá, 2009). Because of their vulnerability to vehicles, pedestrians are the most exposed road users in traffic accidents, especially in urban contexts. Therefore, analysing their behaviour is very important to achieve the goal of reducing mortality rates in urban areas.

In particular, it is of great interest to analyse the causes of pedestrian injuries in cities. The highest incidence of these events occur mainly when the pedestrian crosses a road in non-authorized places; that is, pedestrians "illegally" crossing directly through the highway (Zhuang & Wu, 2011). However, the analysis is complex given that pedestrian crossing

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behaviour is influenced by multiple factors. They include aspects such as the road and traffic environment, socioeconomic and psychological characteristics of the individual, and the travelling conditions (Hamed, 2001; Papadimitriou, 2012; Sisiopiku & Akin, 2003; Taubman-Ben-Ari & Shay, 2012).

The road infrastructure (i.e. number and wide of lanes, the presence of signals for crosswalks, zebras, bridges and medians) and the purpose of the trip are two decisive factors for the pedestrians behaviour when they need to cross a road (Cambon de Lavalette et al., 2009). Other factors such as the composition of traffic flows passing through a pathway and the design of phases in the case of signalized intersections, can also affect the behaviour of pedestrians (Das, Manski, & Manuszak, 2005).

Some studies suggest that pedestrian crossing behaviour on a street could vary according to the age, gender, and whether the person is a driver or not. Holland and Hill (2007) found that women are less likely to cross when there is a high perception of risk. In other words, men are more likely to be risk takers when crossing streets. In general older pedestrians have a tendency to be more cautious than younger adults when accepting traffic gaps, and children are less able to make appropriate safe crossing decisions than teenagers or adults (Havard & Willis, 2012). Bernhoft and Carstensen (2008) conducted a study of the preferences and the behaviour of pedestrians and cyclists by age and gender in Denmark, and concluded that older respondents appreciate significantly safer facilities (zebras, signalized intersection, cycle paths) more than the younger respondents do. Also they found that older road users appear to be more influenced by the legality of their behaviour whereas the younger pedestrians were more focused on the fastest alternative.

Interesting literature reviews on topics related to conduct of pedestrians crossing roads and walking speeds can be found in Ishaque and Noland (2008), and Papadimitriou, Yannis, and Golias (2009). The former point out that their behaviour depends on their subjective value of time, risk attitudes and physical capabilities. The latter focus on the importance of considering the interdependence between route choices and crossing behaviour, which are usually modelled separately. It is possible to catch such interdependence by incorporating the attributes of the crossing options into the route choice model framework, and the route attributes into the behavioural models.

Several researchers have developed observational studies to analyse the crossing behaviour of pedestrians on urban roads. Sisiopiku and Akin (2003) found that the crosswalk location, relative to the origin and destination of the complete trip, was the most influential factor considered for pedestrians to decide whether or not to cross at a specific location. They also concluded that well designed traffic control devices encourage pedestrians to cross at safer proposed locations and moreover, physical environmental factors such as vegetation and concrete barriers also influenced the decision about whether or not to cross at a specific location. Havard and Willis (2012) performed a before and after study which evaluated the effect of installing a marked crosswalk and the perceptions of the environment. They concluded that the marked crosswalks encourage the use of a specific crossing location by pedestrians. They spent significantly less time waiting to cross, and walked more slowly after the zebra was installed when compared with before. Furthermore, pedestrians felt safer, less vulnerable and more confident when crossing the road after the zebra had been installed.

Taubman-Ben-Ari and Shay (2012) concluded that individuals in Israel who have a driveŕs license are more likely to take higher risks when walking than those who do not have it. They found strong positive correlations between various risky driving behaviours and the propensity for dangerous behaviour as pedestrians.

Cambon de Lavalette et al. (2009) identified and evaluated the influence of environmental factors on the propensity of pedestrians to violate traffic rules when crossing roads. They observed that the number of rule violations is significantly lower when crossing facilities are equipped with signals for pedestrians. The study also showed that it is more likely to observe prohibited crossings on roads equipped with central refuge islands, and those refuges encourage pedestrians to cross the road in prohibited zones. The former result is in line with an observational study of pedestrians performed at an unmarked roadway in China, which suggests that pedestrians prefer to cross a road actively in cautious ways rather than waiting passively (Zhuang & Wu, 2011). During crossing, most of the pedestrians looked at the oncoming vehicles and actively crossed the road. However, middle aged pedestrians and those walking within bigger groups presented safer behaviour as they looked at oncoming vehicles more repeatedly before crossing.

Econometric models, including discrete choice approaches founded on random utility theory, have been used to describe pedestrian behaviour in the context of urban travels. Zhou and Horrey (2010) proposed a hierarchical regression model for predicting adolescent pedestrians' behavioural tendencies to follow others in risky crossing situations. They conclude that personal attitudes, subjective norms, perceived behavioural control, and anticipated consequences of the action emerged as the most relevant predictors.

Yannis, Golias, and Papadimitriou (2007) developed hierarchical logit models and multiple linear regressions to model pedestrian crossing behaviour along an urban trip. They used a set of directly measurable geometric and traffic characteristics as explanatory variables (i.e. walking and crossing distances, traffic volume, and the presence of crossing control devices). They found that accident risk at a particular crossing location is influenced by previous crossing decisions, as they make certain crossings "inevitable" (named by the authors "deterministic crossing behaviour") while other crossings depends on behavioural parameters (named "probabilistic crossing behaviour"). The deterministic behaviour concerns crossings "along" the trip direction, whereas the probabilistic one concerns crossings "across" the trip direction.

The study conducted by Guo, Gao, Yang, and Jiang (2011) developed a hazard-based duration approach using data field collected by video cameras in China to investigate the effects that waiting duration, human factors and external environmental factors have on street-crossing behaviour. They found that the behaviour of pedestrians was time dependent and that even though environmental physical interventions had a positive effect in improving pedestrian safety, policies focussing