Transportation Research Part A 94 (2016) 558–572

Contents lists available at ScienceDirect

Transportation Research Part A

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

Crash analysis at intersections in the CBD: A survival analysis model

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ARTICLE INFO

Article history:
Received 7 November 2015
Received in revised form 30 July 2016
Accepted 24 October 2016

Keywords:
Crashes
Intersection
Midblock
Pedestrian
Survival analysis
Exponential
Weibull
Log-logistic

ABSTRACT

Enhancing the safety level of urban roads especially in CBDs is paramount. Due to a large number of intersections in what is usually a grid road system in the CBDs, we investigate crashes occurring in and around an intersection. The question of interest in this study is: does the nature of crashes at intersections differ from those of the roads at midblock? Stated more precisely, considering the intersection as a reference point, does the distance to the reference point (i.e. midblock locations on the roads) correlate with different types of crashes compared to that of the intersection? A right answer can lead traffic engineers and safety auditors to propose different safety measures at intersections and the midblock locations. As a pilot study, we collected the last 9 years crash data of the CBD of Melbourne, Australia. For the first time, we employ Survival Analysis models -including Exponential, Weibull, and Log-logistic- to investigate a space-dependent phenomenon (i.e. accidents at proximity to the intersection). Of the outcome, highlights are: (i) police presence at busy intersections during busy night outs and weekends highly improves the pedestrian safety (ii) raised crossings at midblock locations lower likelihood of crashes of pedestrians as well as cars, (iii) lighting conditions at intersections must be watched and kept at a high level. (iv) Severity, likelihood, and location have no known association with the level of congestion. In other words, safety is first, always and everywhere. The results can be of interest to traffic authorities and policy makers in reinforcing traffic calming measures in the cities. The codes developed in this study are made available to the research community to be used in further studies.

1. Introduction

Transportation plays a vital role in the prosperity of societies, for which safety comes first (Bagloee et al., 2012). Central business districts (CBDs) are the hearts of activities in the cities. Hence transportation in the CBDs is of the highest importance. By and large, the roads of CBDs form a grid system, that is, the roads are closely intersected to greatly connect the urban canyons (Siksna, 1998). Safety is paramount in transportation, therefore due to a large number of intersections in the CBDs, we investigate crashes occurring at and around an intersection. Based on the location, crashes are divided into two groups, crashes at the intersection, and crashes at midblock roads. The road geometry, traffic control, drivers' behaviour, light conditions, etc. at the intersection points are different from those at midblock locations. Hence, one may wonder about

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http://dx.doi.org/10.1016/j.tra.2016.10.019
0965-8564/

variation in the nature of crashes at different locations (in this study, intersection versus midblock). To this end, the question of interest in this study is: does the nature of crashes at intersections differ from the ones at midblock locations? Arriving at a right answer can lead traffic engineers or safety auditors to propose different, purpose-built safety measures at intersections and in their vicinity (Stutts et al., 1996).

As a pilot study, we collected the last 9 years police-reported crash data of the Melbourne's CBD which covers a range of information such as time, location, severity level, type of accident and weather conditions.

Dependent variable (y) is considered as the distance from the crash location to the intersection point, in which $y = 0$ for crashes occurred right at the intersection and $y > 0$ otherwise. We employ Survival Analysis models to relate the locations of the crashes to a variety of explanatory variables based on police-reported characteristics. Survival Analysis is a model widely used in the econometric analysis of time-dependent phenomena. In this study, for the first time –to the best of our knowledge- we are using such models for space-dependent phenomena (i.e. accidents at proximity to the intersection). Furthermore, in Appendix A, we also investigate the type of the crashes (pedestrian versus cars as well as rear-end versus sidewipe) using binary logit and probit models. The results provide a set of guidelines for traffic authorities to enhance safety level in the CBDs.

The remainder of this article is organized as follows. Section 2 provides a review of the relevant literature. Section 3 is dedicated to mathematical analysis underlying the survival analysis. The pilot study and numerical results are discussed in Section 4. Concluding remarks are extended in Section 5.

2. Literature review

With respect to whether a pedestrian is involved in a crash or not one can classify the crashes as follows: (i) crashes between cars and pedestrians, (ii) crashes between cars only. A large body of research is dedicated to the pedestrian-related crashes. This has pinpointed a variety of factors contributing to the pedestrian crashes:

- Pedestrian characteristics:
  - Age: older pedestrians are at high risk of fatal accidents due to their sluggish reactions (Al-Ghamdi, 2002; Fontaine and Gourlet, 1997; Jang et al., 2013; Lee and Abdel-Aty, 2005; Oxley et al., 1997; Tarawneh, 2001; Tarko and Azam, 2011; Zajac and Ivan, 2003; Zegeer et al., 1996). By the same token, children are also subject to high risk of crashes (Jang et al., 2013).
  - Lighting conditions: dark lighting conditions put pedestrians at high risk in the crashes (Jang et al., 2013; Mohamed et al., 2013; Zegeer et al., 1996).
  - Alcohol: alcohol-impaired pedestrians are more involved in crashes (Holubowycz, 1995; Jang et al., 2013; Miles-Doan, 1996; Öström and Eriksson, 2001; Zajac and Ivan, 2003).
- Vehicle characteristics:
  - Speed: a lower speed limit is associated with lower fatality rates (Anderson et al., 1997; Haleem et al., 2015; Oh et al., 2005; Tarko and Azam, 2011). A thorough review of the literature suggests that pedestrian casualty ubiquitously increases with vehicle speed (Rosen et al., 2011).
  - Vehicle type: the larger the size of vehicle the higher the risk of fatality (Haleem et al., 2015; Jang et al., 2013; Lefler and Gabler, 2004; Mohamed et al., 2013; Tarko and Azam, 2011).
  - Vehicle manoeuvres: pedestrians are largely involved in crashes due to the vehicle turning manoeuvres (Preusser et al., 2002; Zajac and Ivan, 2003).
- Road geometry: provision of median strips provides safety protection to the pedestrian (Bowman et al., 1995; Lee and Abdel-Aty, 2005). Wider roads are associated with higher risks for pedestrians (Zajac and Ivan, 2003).
- Vehicle driver: intoxicated drivers are prone to more crashes (Lee and Abdel-Aty, 2005), dark conditions impair drivers' visual cognition and hence they are correlated to an increased number of crashes (Jang et al., 2013; Lee and Abdel-Aty, 2005; Zajac and Ivan, 2003).
- Land use: the likelihood of pedestrian crashes in residential areas is lower than in the CBDs (Mohamed et al., 2013; Ukkusuri et al., 2012). Nonetheless, in some other studies, greater mixing of residences and commercial land uses is associated with higher pedestrian crash risk. Presumably, ceteris paribus, such access produces more potential conflicts between pedestrian and vehicle movements (Lee et al., 2015b; Wang and Kockelman, 2013; Wier et al., 2009). Miranda-Moreno et al. (2011) found that although the built environment has a significant association with pedestrians activity, but no significant association with pedestrian–vehicle collision frequency was found.
- Distraction: mobile phone usage by both pedestrian as well as drivers as a source of distraction has also been linked to high crash risks (Byington and Schwebel, 2013; Jang et al., 2013; Nasar and Troyer, 2013).
- Rainy weather is also reported as a crash-prone condition (Haleem et al., 2015; Jang et al., 2013).

In some studies, attributes pertaining to the built environment (surrounding land uses, amenity, lighting conditions, etc.), traffic conditions and the characteristics of cars, as well as geometric design, are also highlighted as crash-related factors. Lee et al. (2014) assert the crash occurrence is also affected by several demographic and socioeconomic characteristics of residence zones. More precisely, traffic crashes are a socio-economic problem related to the deprived socio-economic status and