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Statistical modeling of total crash frequency at highway intersections

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ABSTRACT

Intersection-related crashes are associated with high proportion of accidents involving drivers, occupants, pedestrians, and cyclists. In general, the purpose of intersection safety analysis is to determine the impact of safety-related variables on pedestrians, cyclists and vehicles, so as to facilitate the design of effective and efficient countermeasure strategies to improve safety at intersections. This study investigates the effects of traffic, environmental, intersection geometric and pavement-related characteristics on total crash frequencies at intersections. A random-parameter Poisson model was used with crash data from 357 signalized intersections in Chicago from 2004 to 2010. The results indicate that out of the identified factors, evening peak period traffic volume, pavement condition, and unlighted intersections have the greatest effects on crash frequencies. Overall, the results seek to suggest that, in order to improve effective highway-related safety countermeasures at intersections, significant attention must be focused on ensuring that pavements are adequately maintained and intersections should be well lighted. It needs to be mentioned that, projects could be implemented at and around the study intersections during the study period (7 years), which could affect the crash frequency over the time. This is an important variable which could be a part of the future studies to investigate the impacts of safety-related works at intersections and their marginal effects on crash frequency at signalized intersections.

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1. Introduction

Intersection-related crashes are associated with high proportion of accidents involving drivers, occupants, pedestrians, and cyclists. A significant portion of total fatal crashes usually occur at intersections. In order to enhance the safety of intersections, significant attention is needed to ensure safe movement of road users. In general, the purpose of

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intersection safety analysis is to determine the impact of safety-related variables on pedestrians, cyclists and vehicles, so as to facilitate the design of effective and efficient countermeasure strategies to improve safety at intersections.

In the U.S., Illinois is one of the states with considerable number of crashes. For example, in 2010, 927 persons were killed, and 88,937 people were injured in crashes. Out of the total fatal crashes, 25.6% occurred at intersections. Besides, in the previous three years (2007, 2008, and 2009), an average of over 26% fatalities occurred at intersections on average (IDOT, 2013).

Although, urban intersections have been received significant attention in terms of signals' timing optimization to minimize vehicles' delay (Dong et al., 2014c; Nesheli et al., 2009) or to simultaneously minimize the delay of both vehicles and pedestrians (Roshandeh et al., 2014). Ignoring the expected safety effects may not yield the overall performance-based benefits. Compared with vehicle drivers, pedestrians and cyclists are much more vulnerable in intersection crashes due to their interactions with vehicles (Dong et al., 2014a; Zhou et al., 2014). Evidently, pedestrians comprise more than 22% of the 1.24 million people killed in traffic accidents worldwide (World Health Organization, 2014).

In order to investigate contributing factors on total crash frequency at intersections, this study intends to analyze effects of traffic, environmental, intersection geometric and pavement-related characteristics using a 7-year crash data from 357 randomly selected intersections in Chicago.

Over the past years, several studies have been conducted on intersection safety analysis. Agbelie and Roshandeh (2015) applied a random-parameters negative binomial model to investigate the impacts of signal-related factors on crash frequency. The results showed that increasing the number of signal phases and traffic volume at an intersection would increase crash frequency, whereas, increasing the number of approach lanes and the maximum green time would also lead to an increase in crash frequency at many intersections. Wu et al. (2013) used intersections crash data, all with intersection approaches having signal-warning flashers, to estimate a random-parameter negative binomial model of crash frequency. The estimation results revealed that a 5 mi/h speed-limit reduction decreases the frequency of crashes in some cases, whereas in other cases, it increases crash frequency. Oh et al. (2010) used a traffic conflict technique to evaluate traffic safety at signalized intersections and analyzed traffic conflicts that occurred at the time of a signal violation. By using image procedure technology, traffic images from two intersections in South Korea were analyzed and found that serious and dangerous conflicts took place at the time of signal violation. Gomes et al. (2012) applied Poisson-gamma modeling framework to develop predictive models for estimating safety performance of signalized and unsignalized intersections in Lisbon, Portugal. They put forward that highway geometric characteristics affect crash severity occurring at urban three- and four-leg intersections. Zhou et al. (2013) proposed a root cause degree procedure to measure intersection safety in Shanghai and found that clearance time, safety education, enforcement, trajectory inside the intersection, crossing a refuge island, speeding, and the right turn control pattern affect crash frequency. Wang and Abdel-Aty (2006) used the generalized estimating equations with the negative binomial link function to model rear-end crash frequencies at signalized intersections to investigate the crash temporal or spatial correlation among the data. Results showed that intersections with heavy traffic, more right and left-turn lanes, large number of phases per cycle, high speed limits, and in high population areas are more likely to have higher rear-end crashes. Das and Abdel-Aty (2011) applied genetic programming technique to analyze rear-end crash counts and found that crashes decreased with an increase in skid resistance during morning peak hours, whereas the crashes increased in the afternoon peak period. Dong et al. (2014a) investigated the contributing factors on crash frequency at urban signalized intersections and found that compared with the univariate Poisson-lognormal (UVPLN) and multivariate Poisson (MVP) models, the multivariate Poisson-lognormal (MVPLN) model better identifies significant factors and predicts crash frequencies. Their analysis suggests that traffic volume, truck percentage, lighting condition, and intersection angle significantly affect intersection safety. Park and Lord (2007) employed a new multivariate approach for modeling data on crash counts by severity based on MVPLN models. The method was applied to the multivariate crash counts from 451 intersections in California obtained in 10 years. It showed that the new MVPLN regression approach could address both overdispersion and a fully general correlation structure in the data. El-Basyouny and Sayed (2013) used a dataset corresponding to 51 signalized intersections in British Columbia to investigate the relationship between conflicts and collisions. A lognormal model was employed to predict conflicts and a conflicts-based negative binomial (NB) safety performance function was then used to predict collisions. Data on collision frequency, average hourly conflicts, average hourly volumes, area type (urban/suburban), the number of through lanes and the presence of right and left turn lanes were used as explanatory variables. The results showed that the effects of conflicts on collisions are nonlinear with decreasing rates. Dong et al. (2014b) employed a multivariate random-parameters zero-inflated negative binomial model for crash frequency modeling, which showed that this method performed better than Poisson, negative binomial, and Poisson-lognormal models. In another study, Dong et al. (2014c) used a Bayesian a multivariate zero-inflated Poisson model and proved that it would address correlations among various crash severity levels and properly handles observations with zero crashes.

The existing literature have extensively accounted for impacts of different variables on crash frequency at intersections. However, in order to investigate contributing effects of pavement condition and intersection's work zones on crash frequency, further research is still required. As such, this study endeavors to fill this gap and analyze impacts of pavement condition, intersection's work zone, traffic and environmental characteristics on total crash frequency at intersections.

The dataset available for the present study includes crash data of 357 intersections in Chicago, collected from 2004 to 2010. For the purpose of investigating safety impacts at these

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