Accident Analysis and Prevention 81 (2015) 14–23

Contents lists available at ScienceDirect

Accident Analysis and Prevention

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

Analyzing pedestrian crash injury severity at signalized and non-signalized locations

Kirolos Haleem [a,*], Priyanka Alluri [b,1], Albert Gan [c,2]

[a] Transportation Safety Consultant, AgileAssets, Inc., 3001 Bee Caves Road, Suite 200, Austin, TX 78746, USA
[b] Lehman Center for Transportation Center, Department of Civil and Environmental Engineering, Florida International University, 10555 West Flagler Street, EC 3680, Miami, FL 33174, USA
[c] Department of Civil and Environmental Engineering, Florida International University, 10555 West Flagler Street, EC 3680, Miami, FL 33174, USA

ARTICLE INFO

Article history:
Received 13 August 2014
Received in revised form 21 April 2015
Accepted 22 April 2015
Available online 2 May 2015

Keywords:
Pedestrian safety
Injury severity
Mixed logit model
Countermeasures

ABSTRACT

This study identifies and compares the significant factors affecting pedestrian crash injury severity at signalized and unsignalized intersections. The factors explored include geometric predictors (e.g., presence and type of crosswalk and presence of pedestrian refuge area), traffic predictors (e.g., annual average daily traffic (AADT), speed limit, and percentage of trucks), road user variables (e.g., pedestrian age and pedestrian maneuver before crash), environmental predictors (e.g., weather and lighting conditions), and vehicle-related predictors (e.g., vehicle type). The analysis was conducted using the mixed logit model, which allows the parameter estimates to randomly vary across the observations. The study used three years of pedestrian crash data from Florida. Police reports were reviewed in detail to have a better understanding of how each pedestrian crash occurred. Additionally, information that is unavailable in the crash records, such as at-fault road user and pedestrian maneuver, was collected. At signalized intersections, higher AADT, speed limit, and percentage of trucks; very old pedestrians; at-fault pedestrians; rainy weather; and dark lighting condition were associated with higher pedestrian severity risk. For example, a one-percent higher truck percentage increases the probability of severe injuries by 1.37%. A one-mile-per-hour higher speed limit increases the probability of severe injuries by 1.22%. At unsignalized intersections, pedestrian walking along roadway, middle and very old pedestrians, at-fault pedestrians, vans, dark lighting condition, and higher speed limit were associated with higher pedestrian severity risk. On the other hand, standard crosswalks were associated with 1.36% reduction in pedestrian severe injuries. Several countermeasures to reduce pedestrian injury severity are recommended.

1. Introduction

Pedestrian safety is of particular concern to Florida as one in every five traffic-related fatalities in the state is a pedestrian (Fatality Analysis Reporting System "FARS", 2012). According to the National Highway Traffic Safety Administration (NHTSA, 2009), Florida had the highest pedestrian fatalities per capita in the United States (U.S.) based on the 2009 statistics of 2.51 pedestrian fatalities per 100,000 population. Another recent study by Transportation for America (T4A, 2011) has ranked Florida as the most dangerous state in the U.S. for pedestrians. The same study ranked 52 large metropolitan areas with over 1 million population. In this ranking, the top four regions were located in Florida. This ranking was given based on the Pedestrian Danger Index (PDI), which computes the rate of pedestrian deaths relative to the amount of walk-to-work trips in an area.

As pedestrian crashes typically involve injury, one way to analyze a pedestrian safety issue is to identify the significant factors affecting pedestrian crash injury severity in order to select the appropriate countermeasures. This paper identifies significant factors affecting pedestrian injury severity at signalized and unsignalized intersections using three years of pedestrian crash data (2008–2010) from Florida. The paper focuses on the relative risk of pedestrian injury severity rather than the absolute risk of a vehicle–pedestrian crash. The analysis was performed separately for signalized and unsignalized intersections to identify and compare the significant factors affecting pedestrian injury severity.

* Corresponding author. Tel.: +1 321 276 7889.
E-mail addresses: kirolos60@hotmail.com (K. Haleem), palluri@fiu.edu (P. Alluri), gana@fiu.edu (A. Gan).
[1] Present address: Department of Civil and Environmental Engineering, Florida International University, Miami, FL 33174, USA. Tel.: +1 305 348 1896.
[2] Tel.: +1 305 348 3116.

http://dx.doi.org/10.1016/j.aap.2015.04.025
0001-4575/

The mixed logit (or random parameters logit) modeling approach was applied, which accounts for the influence of unobserved factors, such as pedestrian physical health and driver behavior. This approach allows the parameter estimates to randomly vary across the observations to yield more reliable parameter estimates.

2. Prior research

This section reviews the literature on pedestrian injury severity analysis. It specifically focuses on studies that explored the risk factors affecting severity of pedestrian crashes and those that applied the mixed logit approach.

Zajac and Ivan (2003) used the ordered probit model to evaluate the effect of roadway features on pedestrian crash injury severity in rural Connecticut. The significant variables included roadway width, vehicle type, alcohol involvement, and pedestrian age. Using the same approach, Mohamed et al. (2013) used two pedestrian injury severity datasets from New York City, U.S. (2002–2006) and Montreal, Canada (2003–2006) and applied the ordered probit and multinomial logit models to analyze severity of pedestrian crashes. Several common variables, such as presence of heavy vehicles, absence of lighting, and prevalence of mixed land use, were found to increase the probability of fatal pedestrian crashes in both cities.

Oh et al. (2005) identified the significant factors affecting the probability of pedestrian fatalities in Korea using a logistic regression model. They found that the collision speed was the most significant factor, where a higher speed was associated with a pedestrian fatality increase. This result was consistent with Garder (2004), and was confirmed by Strandroth et al. (2011) and Zhao et al. (2013). Sarkar et al. (2011) also developed binary logistic regression models to identify pedestrian fatality risk factors along Bangladesh's roadways using crash data from 1998 to 2006. The authors found an increased likelihood of a fatality risk among elderly pedestrians (i.e., older than 55 years) and young pedestrians (i.e., younger than 15 years). A higher risk of fatality was observed for pedestrians who crossed the road compared to those who walked along the road. Pedestrian crashes involving trucks, buses, and tractors had a higher fatality risk compared to cars. Furthermore, pedestrian crashes occurring at locations with no traffic control or stop control had a higher fatality risk than those occurring at signalized intersections.

Tarko and Azam (2011) linked both police and hospital crash injury data to identify significant injury risk predictors by applying the bivariate probit model. The authors found that male and older pedestrians were more prone to severe injuries compared to other groups. Rural and high-speed urban roadways were found to be more dangerous for pedestrians, especially for pedestrians crossing the roadways. The most dangerous pedestrian behavior was identified to be crossing a road between intersections (i.e., at midblock locations). In addition, the size and weight of the vehicle involved in a pedestrian crash were significant predictors of pedestrian injury level. Similar findings were observed by Al-Shammari et al. (2009) who investigated risk factors of pedestrian injury severity in Riyadh, Saudi Arabia over three-year period. Results showed that men were at a significantly greater risk than women in pedestrian crash involvement and two-thirds of pedestrians were struck while crossing the road.

Nasar and Troyer (2013) hypothesized that pedestrians could experience reduced awareness of surroundings, distraction, and engage in unsafe behavior while talking or texting on their mobile phones. Using data from the U.S. Consumer Product Safety Commission on injuries in hospital emergency rooms from 2004 to 2010, they found that mobile phone-related injuries among pedestrians increased relative to total pedestrian injuries. Moreover, pedestrian injuries related to mobile phone use were higher for males and for people under 31 years of age. Similarly, Byington and Schwebel (2013) concluded that pedestrian behavior was considered riskier while simultaneously using mobile internet and crossing the street than when crossing the street with no distraction.

Several studies, including Lee and Abdel-Aty (2005) and Jang et al. (2013), analyzed both frequency and severity of pedestrian crashes. Lee and Abdel-Aty (2005) analyzed the frequency and injury severity of vehicle–pedestrian crashes at intersections in Florida using four years of data from 1999 to 2002. Some of the significant factors affecting crash injury severity included pedestrian age, weather and lighting conditions, and vehicle size. For example, the authors found that pedestrian injuries involving a large vehicle were more severe than those involving a passenger car.

Jang et al. (2013) used six years of pedestrian crashes from 2002 to 2007 in San Francisco, California to identify risk factors that affect the frequency and severity of pedestrian crashes. They used an ordered probit model and found that alcohol involvement, cell phone use, and age (either below 15 years or above 65 years) increased pedestrian injury severity. Environmental characteristics that were associated with high pedestrian severity included nighttime, weekends, and rainy weather. The authors also found that larger vehicles such as pickups, trucks, and buses were associated with greater pedestrian injury severities compared to passenger cars.

Roudsari et al. (2005) evaluated the association between the manner of collision and the severity of pedestrian injuries. For passenger cars, they found that colliding with the hood surface and windshield in pedestrian–vehicle crashes is the major scenario contributing to pedestrian injuries. A similar study was performed by Roudsari et al. (2006), who evaluated the impact of pre-crash maneuver on pedestrian severity. They found that vehicles going straight and striking pedestrians were associated with relatively more pedestrian fatalities.

To more accurately identify significant risk predictors of crash injury severity, the mixed logit models have been implemented in recent injury severity studies. The mixed logit model is characterized by its capability to account for unobserved predictors in severity studies due to the difficulty in quantifying some features, such as the pedestrian and driver behavior at the time of the crash (Kim et al., 2011). The application of the mixed logit model in injury severity studies can be found in Gkritza and Mannering (2008), Milton et al. (2008), Pai et al. (2009), Moore et al. (2011), Kim et al. (2011), Haleem and Gan (2013), and Shaheed et al. (2013). One study that applied the mixed logit approach to analyze pedestrian injury severity was performed by Kim et al. (2010). The authors used four-year police-reported crashes in North Carolina from 1997 to 2000. They found several predictors to the probability of fatal (or severe) injuries. Examples of these predictors include darkness without streetlights, trucks and sport utility vehicles, speeding involvement, freeway sections, and increase in pedestrian age.

The above-discussed review suggests that there is a relatively large amount of pedestrian risk literature. However, there is no study that emphasizes many of the contributing factors included in this study that affect pedestrian crash injury severity at signalized and unsignalized intersections. Some of these factors, such as the at-fault road user and crosswalk type, have not been studied. One reason may be because these data are not typically available in the crash and roadway databases. This study was made possible through a major data collection effort including detailed review of police reports and collection of roadway conditions through satellite and roadway images and Google Street View. The police sketches and illustrations were reviewed to have a better understanding of how each pedestrian crash occurred.