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Injury severity analysis in taxi-pedestrian crashes: An application of reconstructed crash data using a vehicle black box

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ABSTRACT

In-vehicle recording devices have enabled recent changes in methodological paradigms for traffic safety research. Such devices include event data recorders (EDRs), vehicle black boxes (VBBs), and various sensors used in naturalistic driving studies (NDSs). These technologies may help improve the validity of models used to assess impacts on traffic safety. The objective of this study is to analyze the injury severity in taxi-pedestrian crashes using the accurate crash data from VBBs, such as the time-to-collision (TTC), speed, angle, and region of the crash. VBB data from a two-year period (2010–2011) were collected from taxis operating in Incheon, South Korea. An ordered probit model was then applied to analyze the injury severity in crashes. Five variables were found to have a greater effect on injury severity: crash speed, crashes in no-median sections, crashes where the secondary impact object of pedestrians was the crash vehicle, crashes where the third impact object of pedestrians was another moving vehicle, and crashes where the third impact region of pedestrians was their head. However, injuries were less severe in crashes where the first impact region on the pedestrian was their leg, crashes with the car moving in a straight line, and crashes involving junior high school students.

1. Introduction

There have been various efforts to identity factors that affect the severity of pedestrian injuries in vehicle-pedestrian crashes using datasets collected from crashes. Traffic accident data have typically been collected by the police. The police record accident information based on estimation through engineering methods using post-crash trajectories and skid marks at the accident scene, as well as from witnesses and the people involved (Loo 2006; Chung et al., 2014; Moes, 2014). However, such data may include errors.

Technological developments in in-vehicle recording devices are enabling new methodological paradigms in traffic safety research. Such devices include event data recorders (EDRs), vehicle black boxes (VBBs),[1] and various sensors used in naturalistic driving studies (NDSs). VBBs in particular feature high-resolution cameras with a wide lens that can record clear color images from the front of the vehicle. They also have global positioning system (GPS) devices that provide location and time information anywhere on the Earth (Moes, 2014). VBBs were initially introduced for use as legal evidence for traffic accidents (Koo et al., 2013). VBBs also enable the collection of internal driving information, such as the braking start time, crash time, speed, crash angle, and crash region of the vehicle or a pedestrian.

These technologies may reduce the human error involved in collecting accident data and help improve the validity of models used to assess impacts on traffic safety. The objective of this study is therefore to analyze the injury severity in taxi-pedestrian crashes using the accurate crash data from VBBs. VBB data were collected for two years from taxis operating in Incheon, South Korea. Injury severity is categorized into ordinal scales as “fatal injury,” “incapacitating injury,” “visible injury,” and “complaints of pain.” Thus, an ordered probit model was applied in this study since it is appropriate for analyzing the different impacts of particular factors on the injury severity levels (Duncan et al., 1998).

2. Prior studies

2.1. Taxi-pedestrian crashes

Relatively few studies have examined the risk factors and injury severities in taxi-pedestrian crashes, and those available are all based on data collected by survey or driving simulations. Dalziel and Job (1998) reported that increased anger expression and risk-taking among taxi drivers contribute to a greater likelihood of crash involvement. They also indicated that taxi drivers with sleeping problems are more likely to have fallen asleep while driving than other drivers. Stewart et al. (2005) studied various taxi drivers’ driving behaviors in taxi-

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[1] A more detailed description of VBBs can be found in a previous study (Chung and Chang, 2015).

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Table 1
Examples of prior studies on injury severity in vehicle-pedestrian crashes.

Author	Crash data	Methodology	Key findings
Zegeer et al. (1993)	Police-recorded data	Simple comparison analysis by age groups	- Older pedestrians (65+) have a much higher likelihood of being killed than younger age groups (under 25).
Fontaine and Gourlet (1997)	Police-recorded data	Multiple correspondence analysis	- The fatality rate of older pedestrians (65+) is higher than those of all other ages. - Pedestrians are killed less often when they are facing the traffic.
Jensen (1999)	Police-recorded data	Simple comparison analysis by groups	- More severe injury severity groups are identified with elderly pedestrians, drunk pedestrians, and pedestrians in darkness.
Kim et al. (2008)	Police-recorded data	Heteroskedastic logit model	- Higher pedestrian age, male driver, and intoxicated driver contribute to greater probability of fatality. - Traffic signs, commercial areas, and darkness contribute to greater probability of fatality. - Two-way divided roadways, speeding, motorists turning or backing up, and both driver and pedestrian faults lead to increasing the probability of fatal pedestrian injury. - Crashes on a curved roadway decrease the probability of a fatal injury.
Damsere-Derry et al. (2010)	Police-recorded data	Multinomial logistic regression	- Risk factors associated with pedestrian fatality include being hit by heavy vehicles, speeding, and roadside activities such as street hawking, jaywalking and nighttime walking
Kim et al. (2010)	Police-recorded data	Mixed logit model	- Higher pedestrian age, darkness regardless of streetlights, speeding, and pedestrian fault increase the probability of fatal injury for pedestrians.
Moudon et al. (2011)	Police-recorded data	Binary and ordinal logistic regression	- Crossing intersections without signals increases the likelihood of being severely injured or dying. - Vehicles moving straight along the roadway and making a right turn have a negative association with injury severity. - Having two or more pedestrians involved in a collision increases the risk of severe injury or death.
Aziz et al. (2013)	Police-recorded data	Random parameter logit model	- Darkness and unlit roads increase the fatality in a pedestrian–vehicle crashes. - Pedestrian crashes involved with left turning vehicles are more likely to be fatal. - Middle aged (45–55 years) and older adults (65+) are more likely to have fatal crashes.
Mohamed et al. (2013)	Police-recorded data	A latent class with ordinal scale models	- Pedestrian age and lighting conditions influence the likelihood of fatal crashes.
Zhang et al. (2014)	Police-recorded data	Logistic regression	- Crashes with pedestrians at fault, crashes with pedestrians aged 45 or older, drunk driving, other illegal driving, and speeding increase the probability of severe injuries or fatality
Yasmin et al. (2014)	Police-recorded data	Ordinal logit model	- Pedestrians aged 18 and less have reduced injury severity. - Pedestrians aged 65+ increased injury severity.
Koopmans et al. (2015)	Police-recorded data	Multivariate logistic regression	- Pedestrians aged 5–19 sustain less fatal injuries than older pedestrians.
Haleem et al. (2015)	Police-recorded data	Mixed logit model	- Crashes at signalized intersections, at higher speed limits, with pedestrian age 80+, with at-fault pedestrians, and in dark lighting conditions are associated with higher pedestrian severity risk.
Oikawa et al. (2016)	Police-recorded data	Statistical tests between different groups	- Pedestrians age 60+ face a higher risk of fatality.
Pour-Rouholamin and Zhou (2016)	Police-recorded data	Ordered response model	- Older pedestrians (65+) and darkness contribute to more severe injuries. - Crossing the street at crosswalks and presence of traffic control devices decrease the probability of severe injuries.
Prato et al. (2017)	Police-recorded data	Linearized spatial logit model	- Older (60+) and intoxicated pedestrians and roads with higher speed limits are related to severe injuries.
Tulu et al. (2017)	Police-recorded data	Mixed logit model	- Crashes on roads with higher speed limits, at intersections, and in darkness increase the probability of fatal pedestrian injury.

pedestrian crashes. They found that taxi drivers are more likely to violate traffic rules to deliver passengers on time, which correlated with a higher likelihood of crashes. In addition, taxis tend to occupy busy areas where there are many people, including passengers, who also tend to dash out to hail a passing taxi. As a result, pedestrian crashes are more common for taxis than other cars. Moreover, there are more distractions for taxi drivers than for other drivers due to the passengers and various on-board electronic devices.

Rowland et al. (2007) investigated taxi drivers' attitudes and road safety perceptions, and they found that taxi drivers perceived drunk driving to be the most serious driving behavior. Other behaviors that they perceived as unacceptable were aggressive driving behaviors such as risky overtaking and following closely, but attitudes toward speeding were more lenient. To understand the factors associated with the crash risk among taxi drivers, La et al. (2013) identified that in Hanoi, Vietnam, the crash risk increases significantly for drivers who work part-time, are young, and have low income, and who had a traffic rule violation within the past 12 months.

Unlike other studies, Wu et al. (2016) analyzed the discrepancy in driving performance between taxi drivers and non-professional drivers based on a driving simulation experiment. They found that taxi drivers had a higher rate of running red-light than non-professional drivers. In addition, when facing a potential collision, taxi drivers were more likely to turn the steering wheel, while non-professional drivers had more abrupt deceleration behaviors. Moreover, taxi drivers had better performance in terms of crash avoidance at intersections.

2.2. Injury severity in vehicle-pedestrian crashes

There has been rapid development in road safety research to understand factors that affect injury severity in vehicle crashes (Mannering and Bhat, 2014). Injury severity data are generally represented by ordinal categories such as "fatal injury," "incapacitating," "non-capacitating," "possible injury," and "property damage only." Thus, a family of discrete outcome models have become the prevailing analytical techniques (Savolainen et al., 2011). More sophisticated models have been developed as a result of the efforts by traffic safety researchers to determine the influence of injury severity factors more precisely. Examples include simple binary outcome models, ordered discrete outcome models, and unordered multinomial discrete outcome models. However, the actual data applied in these models do not seem to have evolved much in terms of quality and content.