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Analysis of injury severity of drivers involved in single- and two-vehicle crashes on highways in Ontario

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ABSTRACT

This study analyzes driver's injury severity in single- and two-vehicle crashes and compares the effects of explanatory variables among various types of crashes. The study identified factors affecting injury severity and their effects on severity levels using 5-year crash records for provincial highways in Ontario, Canada. Considering heteroscedasticity in the effects of explanatory variables on injury severity, the heteroscedastic ordered logit (HOL) models were developed for single- and two-vehicle crashes separately. The results of the models show that there exists heteroscedasticity for young drivers (≤30), safety equipment and ejection in the single-vehicle crash model, and female drivers, safety equipment and head-on collision in the two-vehicle crash models. The results also show that young car drivers have opposite effects between single-car and car–car crashes, and sideswipe crashes have opposite effects between car–car and truck–truck crashes. The study demonstrates that separate HOL models for single-vehicle and different types of two-vehicle crashes can identify differential effects of factors on driver's injury severity.

1. Introduction

Traffic crashes cause significant losses to society such as life and property losses, medical cost and traffic congestion, etc. In 2010, the numbers of motor vehicle fatalities and serious injuries in Canada were 2227 and 11,226, respectively (Transport Canada, 2012). In the same year, there were 579 fatalities and 2558 serious injuries in Ontario (Ministry of Transportation of Ontario, 2012). In particular, the cost of fatal traffic crashes is enormous. For example, although fatal collisions are less than 1% of reportable collisions in Ontario in 2004, they account for 64% of total social costs or $11 billion (Ministry of Transportation of Ontario, 2007).

In addition, collisions involving trucks usually result in more severe injuries. According to Transport Canada (2010), there was an annual average of 8,985 heavy truck casualty collisions in 2010. These collisions represent 7% of all collisions, 18% of fatal collisions and 15% ($3 billion) of the social costs (Transport Canada, 2010). Given this difference in injury severity between light and heavy vehicles, the type of vehicles should be considered as a factor in modeling of injury severity.

Furthermore, the effects of vehicle type on injury severity are likely to be different between single-vehicle and multi-vehicle crashes. This is because the impacts of collision with fixed objects on vehicles in single-vehicle crashes are different from the impacts of collision with other vehicles (mostly moving objects) in multi-vehicle crashes. Due to this difference, injury severity has been analyzed for single-vehicle crashes and multi-vehicle crashes separately (Wang and Kockelman, 2005; Savolainen and Mannering, 2007; Chen and Chen, 2011).

However, there were some limitations in the past studies. For two-vehicle crashes, most studies only considered the effects of one vehicle on driver's injury severity or the highest injury severity of two drivers. However, it is expected that driver's injury severity is not only affected by characteristics of his/her own vehicle, but also characteristics of a partner vehicle. This is because size and weight may differ between the two vehicles and this difference has differential impacts of collision on each vehicle. Also, there is a lack of study on the comparison of injury severity between single-vehicle crashes and different types of two-vehicle crashes to identify differential effects of the same explanatory variables.

Thus, the objectives of this study are to identify the factors that significantly influence on the injury severity of drivers involved in single- and two-vehicle crashes, and to investigate effects of these factors on injury severity using statistical models. This paper is organized as follows: The second section reviews the past studies

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on injury severity and identifies their limitations. The third section describes the data used in this study. The fourth section explains the methods. The fifth section discusses the results of the analysis. The last section draws conclusions based on the findings and makes recommendations.

2. Literature review

In order to analyze the effects of various factors on injury severity and predict different levels of injury severity based on the factors, researchers have applied various statistical models including a multinomial logit (MNL) model, a nested logit (NL) model, an ordered logit (OL) or ordered probit (OP) model, a heteroskedastic ordered logit (HOL) model, a generalized ordered logit (GOL) model, a mixed logit (MXL) model, a Bayesian ordered probit model, and a bivariate ordered probit model.

The past studies identified the factors affecting injury severity using the above models. The factors are categorized into the following five groups: (1) driver characteristics; (2) vehicle characteristics; (3) road geometric characteristics; (4) environmental characteristics and (5) impact speed.

First, driver characteristics include driver demographic factors such as age and gender. Zhang et al. (2000) reported that older drivers are more likely to be killed or seriously injured in traffic crashes than middle-age drivers. Harb et al. (2009) observed that drivers younger than 35 years old are more likely to have evasive actions that will prevent severe injury. In general, females are more likely to face fatal injury than males (Srinivasan, 2002; Kockelman and Kweon, 2002).

Some researchers found influence of driver conditions on injury severity. Nassiri and Edrissi (2006) found that driver fatigue increases the likelihood of more severe injuries in truck crashes for two-lane rural highways in Iran using OL model. Similarly, Zhu and Srinivasan (2011) reported that driver fatigue, illness, distraction and unfamiliarity with vehicle significantly increase injury severity. Moreover, Zajac and Ivan (2003) found that drinking and driving can significantly increase the risk of fatal crashes. Use of restraint devices is also associated with injury severity. Bedard et al. (2002) found that seatbelts or helmets significantly reduce injury severity. On the other hand, Srinivasan (2002) found that injury severity in a crash in which an air bag was deployed was higher than a crash in which an air bag was not deployed. This is because air bag is usually deployed at high impact speed where drivers are more likely to be severely injured. Vehicle rollover generally increases injury severity. Khattak et al. (2003) found that rollover leads to more severe injuries in single-truck crashes. Srinivasan (2002) claimed that tripped rollover will result in nearly eight time higher chance of fatal injury for moped riders, compared to non-rollover.

Some studies investigated influence of vehicle characteristics on injury severity. Harb et al. (2009) found that truck drivers are more likely to perform evasive actions to avoid crashes compared to passenger car drivers. In addition, since crash injury severity increases with the mass and speed of vehicles (Sobhani et al., 2011) and collision force (Wang and Qin, 2014), collisions with trucks increase injury severity than collisions with passenger cars (Duncan et al., 1998). Xie et al. (2009) found that drivers in SUV and van are less likely to be severely injured than passenger car drivers since larger vehicles can better protect the drivers. On the other hand, Yu and Abdel-Aty (2014) found that the drivers in passenger cars are more likely to be severe injured than the drivers in the other vehicle types. Model year of vehicles is another important factor associated with injury severity as it indirectly reflects vehicle technology. Khorashadi et al. (2005) developed MNL models using a four-year crash data in California and found that 1981 or older model years of cars are more likely to cause severe or fatal injury. Similarly, Kim et al. (2012) found that newer vehicles can reduce injury severity in single-vehicle crashes using MXL models. This is mainly due to the advance in vehicle and safety design for newer vehicle models.

The effect of road geometry on injury severity has also been examined. Chung (2013) found that fatality is associated with narrower median islands and the fixed object in the median islands increases injury severity. Moreover, Zhu and Srinivasan (2011) found that crashes on roadways with more number of lanes would result in less severe injury.

Some environmental factors such as lighting and road surface conditions are also found to be closely related to injury severity. Khorashadi et al. (2005) claimed that crashes in the morning (5:31–8:00) are less likely to result in severe or fatal injury in both urban and rural areas. Rana et al. (2010) found that driver injury severity was lower when crashes occurred on icy road surface than dry or wet road surface. Zhu and Srinivasan (2011) found that crashes in dark but lighted conditions lead to most severe injury, but the injury is less severe on wet road surface.

In fact, impact speed has the most dominant effect on injury severity. Krafft et al. (2009) reported that 10% speed reduction before impact can reduce fatal injury of car crashes by 30%. Similarly, Watanabe et al. (2012) and Seyer et al. (2000) also showed that the risk of injury increases with impact speed. However, actual impact speeds are not readily available in most crash reports. Thus, the other variables such as the posted speed limits have been used as proxy variables for impact speed. For instance, Stigson et al. (2011) found that fatal crashes occurred more frequently on the roads with higher speed limit. This is because vehicle speeds increase with speed limits. Martin et al. (2003) found that car weight is associated with the risk of injury since it reflects the speed capability. This indicates that vehicle weight can also be used as a proxy variable for impact speed in modeling of injury severity. Moskal et al. (2007) reported that the risk of injury is higher for motorcycle riders than moped riders due to difference in impact speed between the two wheelers. Thus, vehicle types indirectly reflect the effect of impact speed.

To identify unique characteristics of single-vehicle crashes, some studies focused on single-vehicle crashes only. The studies commonly found that injury severity in single-vehicle crashes is associated with driver's error or abnormal behavior such as distraction, alcohol/drug use, non-seat-belt use and speeding (Kim et al., 2012; Schneider et al., 2009; Xie et al., 2012; Anowar et al., 2012; Peng and Boyle, 2012; Jiang et al., 2013a).

On the other hand, some studies focused on two-vehicle crashes only. For instance, Duncan et al. (1998) investigated injury severity of truck-passenger car rear-end crashes using OP model. Zhu and Srinivasan (2011) analyzed injury severity of different collision types of car–truck crashes and found that injury severity was higher for head-on and sideswipe crashes. However, these studies did not report injury severity of the other types of two-vehicle crashes (e.g. car–car and truck–truck crashes). Recently, Abay et al. (2013) considered characteristics of both vehicles involved in two-vehicle crashes to estimate injury severity. The study found that lighter vehicle's driver is more likely to be severely injured than heavier vehicle's driver. However, it did not examine the difference in injury severity among different types of two-vehicle crashes. Qin et al. (2013) compared injury severity between car–truck and truck–truck crashes but could not find a significant difference in spite of differential impacts of collisions. Jiang et al. (2013b) found that light-truck-involved crashes produced less severe injury than car–car crashes but could not find a significant difference in injury severity between car–car crashes and heavy-truck-involved crashes. Torrão et al. (2014) reported that the engine size of the partner vehicle affects serious injury and fatality in the vehicle. However, the study only considered characteristics of two