Accident Analysis and Prevention 102 (2017) 93–100

Contents lists available at ScienceDirect

Accident Analysis and Prevention

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

An empirical analysis of run-off-road injury severity crashes involving large trucks

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A R T I C L E   I N F O

Article history:
Received 8 November 2016
Received in revised form 22 February 2017
Accepted 24 February 2017

Keywords:
Large-truck safety
Run-off-road crashes
Ordered random parameter probit model
Injury severity
Unobserved heterogeneity

A B S T R A C T

In recent years, there has been an increasing interest in understanding the contributory factors to run-off-road (ROR) crashes in the US, especially those where large trucks are involved. Although there have been several efforts to understand large-truck crashes, the relationship between crash factors, crash severity, and ROR crashes is not clearly understood. The intent of this research is to develop statistical models that provide additional insight into the effects that various contributory factors related to the person (driver), vehicle, crash, roadway, and environment have on ROR injury severity. An ordered random parameter probit was estimated to predict the likelihood of three injury severity categories using Oregon crash data: severe, minor, and no injury. The modeling approach accounts for unobserved heterogeneity (i.e., unobserved factors). The results showed that five parameter estimates were found to be random and normally distributed, and varied across ROR crash observations. These were factors related to crashes that occurred between January and April, raised median type, loss of control of a vehicle, the indicator variable of speed not involved, and the indicator variable of two vehicles or more involved in the crashes. In contrast, eight variables were found to be fixed across ROR observations. Looking more closely at the fixed parameter results, large-truck drivers who are not licensed in Oregon have a higher probability of experiencing no injury ROR crash outcomes, and human related factor, fatigue, increases the probability of minor injury. The modeling framework presented in this work offers a flexible methodology to analyze ROR crashes involving large trucks while accounting for unobserved heterogeneity. This information can aid safety planners and the trucking industry in identifying appropriate countermeasures to help mitigate the number and severity of large-truck ROR crashes.

1. Introduction

In recent years, there has been an increasing interest in understanding the contributory factors to run-off-road (ROR) crashes in the US, especially those where large trucks are involved (Davis et al., 2006; Lee and Mannering, 2002; McLaughlin et al., 2009; Peng and Boyle, 2012; Roy and Dissanayake, 2011). One reason for this is that in 2010, approximately 57% of all fatal crashes were ROR crashes, whereas nonfatal crashes accounted for 16% (Blincoe et al., 2015). Accordingly, those crashes led to roughly $64 billion in economic costs and $298 billion in comprehensive costs, accounting for 27% of all economic costs and 36% of all societal harm (Blincoe et al., 2015). Although, statistically, the number of large-truck-involved crashes has decreased over the past two decades, there is still a higher fatal crash involvement rate per 100 million vehicle miles traveled compared to passenger cars (1.34 versus 1.08 for the year 2014) (Federal Motor Carrier Safety Administration, 2016). As a result, several state agencies have today developed and/or have adopted mitigation programs to reduce the number and severity of these crashes. For example, in Oregon, where nearly 66% of all fatal crashes were due to ROR crashes in 2010, the Oregon Department of Transportation (ODOT) partnered with the Federal Highway Administration (FHWA) to implement appropriate and low-cost countermeasures with the goal of reducing the number of ROR fatalities by 20%. However, the implemented countermeasures focused primarily on reducing ROR crashes for passenger cars, with little focus on large trucks (gross vehicle weight rating [GVWR] greater than 10,000 pounds). With this in mind, there is a clear need for continued research into identifying and/or developing cost-effective countermeasures to reduce the number and severity of ROR crashes involving large trucks.

Various methodological models have been used in analyzing severity and frequency of crashes. The selection of an appropri-

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http://dx.doi.org/10.1016/j.aap.2017.02.024
0001-4575/

ate statistical model depends primarily on the nature of the crash data. In this study, the injury severity sustained by trucks' drivers are the main interest. Therefore, only previous works that examined the crash severity will be reviewed. The current study has aimed to examine the impact of contributory factors on the run-off-the-road (ROR) crashes that involved large trucks. In terms of the risk factors, several studies have been conducted to investigate the effect of some possible factors on ROR crash severity. In general, these factors can be summarized into three main groups, human factors, highways' geometric design and environmental factors, and roadside factors. In terms of human factors, Davis et al. (2006) reviewed the previous works that studied the effect of speed on ROR crashes on rural two-lane highways. They collected data from Australia and Minnesota for their study and used Bayesian relative risk regression. In their study, they found that high speed was associated with higher fatality risk. McGinnis et al. (2001) used Fatality Analysis Reporting System (FARS) data for years 1975,1980, 1985, 1990, 1996, and 1997 to investigate the contributory factors that might affect ROR crashes. They found that around half of ROR crashes occurred due to intoxicated drivers, particularly male drivers whose age between 20 and 39 years. They also found that severity of ROR crashes that involved male drivers were higher than ROR crashes that involved female drivers.

Turning to statistical approaches, several models have been used to determine the relationship between the potential contributory factors and ROR crash severity. Liu and Subramanian (2009) conducted a univariate analysis with Chi-square tests and logistic regression to analyze FARS crash data for the period from 1991 to 2007. In their study, they attempted to capture the effect of various factors on ROR crashes such as roadway and environmental factors, driver characteristics, and traffic-related factors. They stated that some variables were statistically significant and affected ROR crashes such as the presence of horizontal curves on the roadway, alcohol impairment, number of lanes, inclement weather, and driver age. Roy and Dissanayake (2011) developed a Bayesian statistical approach to compare ROR with non-ROR crashes in Kansas by using crash data for crashes that occurred in the period between 1999 and 2008. They found some variables were highly associated with ROR crashes rather than non-ROR crashes. These variables included road surface condition (i.e., wet and icy surfaces), time of the day (i.e., nighttime), rural area, inclement weather conditions, horizontal curve sections, higher speed, and fatigue and drowsiness. Dissanayake (2003) conducted a study to identify the contributory factors that affect the severity of ROR crashes involving young drivers with age from 16 to 25 years. In this study, Dissanayake obtained a crash data from Florida traffic crash database. He categorized the injury severity into five injury outcomes and then developed four sequential binary logistic regression models. He concluded that some factors were highly influencing the severity of young drivers involved in ROR crashes such as gender, lighting condition, area type, and roadway alignment.

The majority of the aforementioned studies primarily focused on analyzing the injury severity of passenger cars involved ROR crashes. However, works that study the injury severity of drivers involved in large trucks ROR crashes are sparse. Some studies in recent years have specifically studied large-truck-involved crashes from various perspectives. Some of this work has dealt with understanding the risk and human-related factors of ROR crashes caused by speed, driver characteristics, driving under the influence of alcohol and/or drug impairments, fatigue or drowsiness, roadway characteristics, vehicle characteristics, and environmental factors (Aram, 2010; Compton and Berning, 2009; LeRoy et al., 2008; McGinnis et al., 2001; Neuman et al., 2003; Peng and Boyle, 2012; NHTSA, 2012). Other studies have focused on identifying the contributory factors to large-truck-involved crashes through econometric and statistical models. In those studies, ROR crashes are represented as an indicator variable for crashes related to urban settings, rural versus urban, time of day, manner of collision, and vehicle type (Cerwick et al., 2014; Chang and Mannering, 1999; Chen and Chen, 2011; Duncan et al., 1998; Islam and Hernandez, 2013a,b, 2015; Islam et al., 2014; Khorashadi et al., 2005; Lemp et al., 2011; Pahukula et al., 2015; Romo et al., 2014).

Although there have been several efforts to understand large-truck crashes, the relationship between contributory factors and severity of ROR crashes is not clearly understood. One reason for this stems from the lack of detailed crash data to capture the complex interactions of multiple factors under a single framework for ROR crashes. Therefore, the purpose of this research is to develop statistical models that provide additional insight into the effects that various contributory factors related to the person (driver), vehicle, crash, roadway, and environment have on ROR injury severity. This is done by analyzing the Oregon Statewide Crash Data System, which is an extensive database collected and maintained by ODOT. The findings of this study can provide information that can aid safety planners and the trucking industry in identifying appropriate countermeasures to help mitigate the number and severity of large-truck ROR crashes. To the best of the authors' knowledge, these are the first attempts at developing these types of models for ROR crashes.

The rest of the paper is organized as follows. In Section 2, the crash data used in the analysis and their descriptive statistics are described. Section 3 presents details of the proposed econometric modeling framework. In Section 4, estimation results along with discussions are presented. Section 5 provides conclusions and suggestions for future research.

2. Data description

This study utilizes data collected from the Oregon Statewide Crash Data System provided by ODOT. The data obtained represents seven years of large-truck-involved crashes, from 2007 to 2013; large-truck-involved crashes for the seven-year period comprised 13,364 records. However, since ROR crashes are the main interest of this study, only crashes belonging to this category are considered, bringing the sample size down to roughly 2486 observations (data filtered by ROR indicator). Each ROR observation represents the maximum level of injury severity sustained by the driver following the National Safety Council (NSC) injury severity scale, KABCO. The KABCO injury severity scale characteristically consists of five injury categories: fatality (K), incapacitating (A), non-incapacitating (B), possible injuries (C), and non-injury (O) or property damage only (PDO). For this study, any recorded incidents that showed an injury severity of "not reported" or "unknown" were rejected because the severity of those injuries could not be satisfactorily determined. As was the case with other studies (Anarkooli and Hosseinlou, 2016; Haleem and Abdel-Aty, 2010; Haleem and Gan, 2013; Pahukula et al., 2015; Quddus et al., 2002), because of low data observations for the higher injury severity outcomes, the full KABCO scale was reduced to three injury categories. These categories are severe injury (KA- fatal and incapacitating), minor injury (BC- non-incapacitating and possible injury), and no injury (O- property damage only or PDO).

Turning to the data, overall severe injury, minor injury, and no injury accounted for 2.6% (N = 65), 24.6% (N = 612), and 72.8% (N = 1809), respectively. Table 1 illustrates the descriptive statistics of key variables for large-truck-ROR crash severity. These variables were selected according to their statistical significance and minimal correlation.

In terms of the driver-related factors, injury statistics, shown in Table 1, show that 2.4% of truck drivers who were involved in