Accident Analysis and Prevention 97 (2016) 261–273

Contents lists available at ScienceDirect

Accident Analysis and Prevention

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

Analysis of injury severity of large truck crashes in work zones

Mohamed Osman[a], Rajesh Paleti[b], Sabyasachee Mishra[a,c,*], Mihalis M. Golias[a,c]

[a] Department of Civil Engineering, University of Memphis, 3815 Central Avenue, Memphis, TN, 38152, United States
[b] Department of Civil & Environmental Engineering, Old Dominion University, 135 Kaufman Hall, Norfolk, VA, 23529, United States
[c] Intermodal Freight Transportation Institute, University of Memphis, Memphis, TN, 38152, United States

ARTICLE INFO

Article history:
Received 15 December 2015
Received in revised form 11 October 2016
Accepted 13 October 2016

Keywords:
Large truck
Work zones
Injury severity
Multinomial logit
Ordered logit
Generalized ordered logit

ABSTRACT

Work zones are critical parts of the transportation infrastructure renewal process consisting of rehabilitation of roadways, maintenance, and utility work. Given the specific nature of a work zone (complex arrangements of traffic control devices and signs, narrow lanes, duration) a number of crashes occur with varying severities involving different vehicle sizes. In this paper we attempt to investigate the causal factors contributing to injury severity of large truck crashes in work zones. Considering the discrete nature of injury severity categories, a number of comparable econometric models were developed including multinomial logit (MNL), nested logit (NL), ordered logit (ORL), and generalized ordered logit (GORL) models. The MNL and NL models belong to the class of unordered discrete choice models and do not recognize the intrinsic ordinal nature of the injury severity data. The ORL and GORL models, on the other hand, belong to the ordered response framework that was specifically developed for handling ordinal dependent variables. Past literature did not find conclusive evidence in support of either framework. This study compared these alternate modeling frameworks for analyzing injury severity of crashes involving large trucks in work zones. The model estimation was undertaken by compiling a database of crashes that (1) involved large trucks and (2) occurred in work zones in the past 10 years in Minnesota. Empirical findings indicate that the GORL model provided superior data fit as compared to all the other models. Also, elasticity analysis was undertaken to quantify the magnitude of impact of different factors on work zone safety and the results of this analysis suggest the factors that increase the risk propensity of sustaining severe crashes in a work zone include crashes in the daytime, no control of access, higher speed limits, and crashes occurring on rural principal arterials.

1. Introduction

Work zone safety is a major concern for the Federal Highway Administration (FHWA), State Departments of Transportation (DOTs), and the public. Over the last 30 years, the total lane miles in the US have increased by 7.4% whereas the Vehicle Miles Travelled (VMT) increased by 86% (FHWA, 2012). With increased VMT, work zone fatalities and injuries have also increased. Nationally, there were 87,606 work zone crashes in 2010 which is approximately 1.6% of the total number of roadway crashes. More than 20,000 workers were injured in work zones in 2010. In the same year, work zone crashes resulted in 37,476 injuries which equates to approximately four injuries every hour. In 2010, there were 514 fatal crashes resulting in 576 fatalities in work zones, which equates to approximately one fatality every 15 h (FHWA, 2010). Work zones have unique traffic conditions that are different from other crash locations and thus warrant studies that focus exclusively on these locations instead of pooling them with other locations.

Another key segment of crashes, that is of major concern both to the transportation officials and the trucking industry, are those involving large trucks. In 2012 alone, there were 317,000 large truck crashes in the US that resulted in 3464 fatalities and 73,000 injuries (FHWA, 2014). In the same year, large trucks accounted for 8% of all vehicles involved in fatal crashes and 3% of vehicles involved in injury and property-damage-only (PDO) crashes (U.S. Department of Transportation, 2014). Although these percentages may not seem alarming at first glance, the economic impact could be substantial because large truck crashes incur high costs including high value goods, and higher travel delays associated with longer traffic incident durations. Moreover, the determinants of severity of crashes involving large trucks can be considerably different from crashes involving passenger cars and/or relatively smaller commercial fleet.

* Corresponding author at: Department of Civil Engineering, University of Memphis, 3815 Central Avenue, Memphis, TN, 38152, United States.
E-mail addresses: mosman@memphis.edu (M. Osman), rpaleti@odu.edu (R. Paleti), smishra3@memphis.edu (S. Mishra), mgkolias@memphis.edu (M.M. Golias).

http://dx.doi.org/10.1016/j.aap.2016.10.020
0001-4575/

So, it is important to focus exclusively on large truck crashes to understand the relative effect of different factors on their road safety.

The current study aims to contribute to the literature on work zone safety by exploring the characteristics of large truck crashes in work zones using a disaggregate-level analytical approach that focusses on each individual crash and associated set of potentially contributing factors. Specifically, the study examines the factors that impact the severity level of the most severely injured individual involved in the crash, which essentially marks the overall severity level of the crash. Understanding large truck crash severity characteristics in work zones will be a steppingstone in enabling practitioners, designers, and DOT officials to mitigate the severity of such type of crash. The findings of this study have important implications in the work zone safety field, education of motorists, training of truck drivers, and traffic regulation and control. Designers of roadway work zones will be able to implement effective safety measures that will allow DOT officials to better manage the safety of a work zone through learning about the important factors influencing crashes involving large trucks.

The remainder of this paper is structured as follows. A literature review is presented in the next section followed by the econometric framework describing the methodology of the different models developed in this paper. The data section discusses the dataset utilized and the final estimation sample assembly process. The empirical analysis section presents a detailed overview of the estimation results, statistical measures of fit, and elasticity effects. Finally, the conclusion section provides an overall summary of this research along with major findings and future scope of research.

2. Literature review

Several research studies have been conducted to analyze the severity of crashes involving large trucks (Chang and Mannering, 1999; Duncan et al., 1998; Islam and Hernandez, 2013a,b; Li and Bai, 2009; Pahukula et al., 2015; Qi et al., 2013; Wang and Shi, 2013; Wang et al., 2010). The overview of the literature indicates that there is a vast body of research examining the factors affecting the severity of large truck-involved accidents on both crash-level and occupant-level. The literature presented in this paper is primarily focused on injury severity of large trucks in work zones at the crash-level to obtain insights and to help to meet the goal of this research. However, occupant-level injury severity studies are imperative in the context of work zone safety and comprehensively presented in the literature (Chang and Chien, 2013; Chen and Chen, 2011; Dong et al., 2015; Khorashadi et al., 2005; Lemp et al., 2011; Mooradian et al., 2013; Wong et al., 2011; Zhu and Srinivasan, 2011a,b) and will not be reviewed herein.

The past literature can be grouped under three categories – (1) those that focus exclusively on large truck crash severity modeling, (2) those that focus on injury severity in the context of work zone safety, and (3) those that focus both on large truck crash severity and work zone safety combined. In this section we present a review of the crash-level literature that specifically pertained to injury severity of crashes involving large trucks, work zones, or both. The econometric framework comparisons utilized in this study have been recently used by other researchers in the context of injury severity analysis to evaluate alternate discrete outcome frameworks for modeling crash injury severity (Yasmin and Eluru, 2013). Sample size requirements were evaluated by comparing three commonly crash severity models (Ye and Lord, 2014). Another study has evaluated alternate discrete choice frameworks for modeling ordinal discrete variables but not necessarily in the context of injury severity (Eluru, 2013). A discrete choice model comparison was applied to investigate cyclist injury severity in automobile-involved bicycle crashes (Chen and Shen, 2016). Pedestrian Injury Severity in New York City was also examined using alternative ordered response frameworks (Yasmin et al., 2014). To our knowledge, this is the first application of such a comprehensive set of discrete choice models in the context of work zone safety. A brief overview of past literature in these three categories follows in the next three subsections.

2.1. Large truck crash severity

A variety of discrete choice models were used in the literature to analyze large truck crash severity. For example, assessing the severity of truck crashes on a freeway network using a hierarchical regression model indicated that the presence of ramp, freeway segment length, and weather conditions were important factors affecting truck safety performance (Wang and Shi, 2013). Utilizing nested logit models to investigate the severity in truck and non-truck crashes, risk factors that are unique to large trucks were identified. Variables that increased injury severity for large trucks were higher speed limits, vehicles making right or left turns, and rear-end collisions (Chang and Mannering, 1999). Using a random-parameter ordered probit model allowed the identification of the differences between random and fixed factors affecting the severity outcome. It was found that the severity level is highly influenced by complex interactions between factors, and that the effects of some variables can vary across observations (Islam and Hernandez, 2013a,b). Investigating rear-end large truck crashes using an ordered probit model indicated that darkness, high speed differential between vehicles and trucks, higher speed limits, wet surfaces on a grade, a car struck to the rear, and alcohol increased crash severity while snow and ice, congested roads, and station wagon decreased the likelihood of a severe crash (Duncan et al., 1998). An exploratory study utilized a mixed logit model to analyze injury severity of crashes involving large trucks on Texas highways which revealed that time-of-day (12–6 a.m.), summer time (June-August), clear weather, rural areas, and 4-lane roadways were all contributing factors to higher likelihood of higher injury severity levels (M. Islam and Hernandez, 2013a,b). Another study also used mixed logit models to estimate the effect of time of day on injury severity of large truck crashes in urban areas (Pahukula et al., 2015). The study uncovered major differences both in the combination of variables and their magnitude of impact on the severity outcomes across different time periods. Among different explanatory variables used in the study, the effects of traffic flow, lighting road surface conditions, time of year, and percentage of trucks were found to vary by time period (Pahukula et al., 2015). In recent years, mixed logit models have generally gained attention within the discrete choice modeling literature due to their flexibility in allowing variations over data observations as compared the restrictions imposed by standard logit models. This modeling technique has been utilized in previous large truck literature, but not necessarily within the context of injury severity (Romo et al., 2014).

2.2. Work zone crash severity

A work zone crash is defined as a crash that occurred in an area comprising a work zone as per defined by the Manual of Uniform Traffic Control Devices (MUTCD). Specifically, for the purpose of this study, a work zone extends from the “advanced warning area” until the “termination area”. There is some literature that focused specifically on crashes in work zones. For instance, one study used the ordered probit model to analyze severity of rear-end crashes in work zones. The study found that alcohol, night hours, pedestrians, roadway defects, truck-involvement, and the number of vehicles involved increased crash severity, while careless backing, stalled vehicles, slippery surfaces, and misunderstanding flagging signals