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A time of day analysis of crashes involving large trucks in urban areas

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ABSTRACT

Previous studies have looked at different factors that contribute to large truck-involved crashes, however a detailed analysis considering the specific effects of time of day is lacking. Using the Crash Records Information System (CRIS) database in Texas, large truck-involved crashes occurring on urban freeways between 2006 and 2010 were separated into five time periods (i.e., early morning, morning, mid-day, afternoon and evening). A series of log likelihood ratio tests were conducted to validate that five separate random parameters logit models by time of day were warranted. The outcomes of each time of day model show major differences in both the combination of variables included in each model and the magnitude of impact of those variables. These differences show that the different time periods do in fact have different contributing factors to each injury severity further highlighting the importance of examining crashes based on time of day. Traffic flow, light conditions, surface conditions, time of year and percentage of trucks on the road were found as key differences between the time periods.

1. Introduction

1.1. Motivation

Large truck crashes have a considerable impact on society and the economy. It has been estimated that the average cost of no injury crashes (i.e., property damage only), non-fatal injury crashes, and fatal crashes involving large trucks are $15,114, $195,258 and $3,604,518, respectively (Zaloshnja and Miller, 2006). These estimates include medical costs, emergency services costs, property damage costs, lost productivity and monetized value of the pain, suffering and quality of life lost due to death or injury. The estimated cost of large truck crashes between 1997 and 1999 exceeded US$ 19.6 billion (Zaloshnja and Miller, 2004). From the perspective of moving freight, in 2010 it was estimated that large trucks carried roughly 68% of freight tonnage in the U.S totaling approximately 12,500 millions of tons (Federal Highway Administration, 2013). The National Highway Traffic Safety Administration (NHTSA) reports that tonnage is expected to increase by 1.4% per year till 2040 (Federal Highway Administration, 2013). Currently this tonnage is being moved continuously day and night and as the tonnage grows so will the daily distribution of the freight movements required to haul this extra tonnage. This has raised concerns especially in large populated urban areas where congestion is only getting worse, where large truck crashes at various times of the day have created havoc to commutes. The added congestion to these urban commutes is the equivalent of 1.9% of the $14.96 trillion U.S. gross domestic product (GDP) in 2010 (Kilcarr, 2014). Evidently, efforts to improve our understanding of the factors that influence large truck-involved crashes are needed especially from a time of day perspective.

Although there have been several efforts to understand large truck-involved crashes, the relationships between crash related factors, crash severity and time of day effects are still not completely understood. A reason for this stems from the availability of sufficient data to capture the complex interactions of multiple factors under a single framework for various times of day scenarios. Recent studies conducted by (Islam and Hernandez, 2013a,b,b) developed random parameters models to predict injury severity of large truck-involved crashes with data from the Texas Crash Records Information System (CRIS), but considered time of day as a contributing factor. To better understand the relationships of crash related factors and crash severity by time of day separately, the CRIS database is utilized for this study.

In order to clearly identify injury related large truck crash factors, the data set will be divided by land use (i.e., rural and urban) and then further divided into time periods. Khorashadi et al. (2005) identified significant differences between urban and rural crashes due to differing driver, vehicle, environmental, road geometry and traffic characteristics. Additionally, time of day

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has been identified as a significant factor in previous studies (Islam and Hernandez, 2013a,b,b). Past works capture the impact of time of day by using indicator variables representing various times of day as independent variables in regression models. However there is a complex interaction between variables in these types of models. For example, traffic patterns, light conditions and driver behavior can vary throughout the day. The impact of traffic levels in urban areas during morning time period and afternoon time period on truck injury severity may potentially be different. With this in mind, this study aims to analyze injury crash severity of large truck-involved crashes under an urban land use context and varying time of day scenarios through an econometric modeling approach by developing separate models for five time of days – early morning, morning, mid-day, afternoon and evening. Separate models for different time of day can help pinpoint specific issues.

The random parameters logit (or mixed logit) model is utilize here to gain a better understanding of the complex interactions between those factors found in the dataset and those unobserved factors that may be influencing (i.e., through unobserved heterogeneity). A latent class approach can also account for possible unobserved heterogeneity without having to make an assumption about the parameter distribution which may not always be consistent across all observations. Latent class models can account for possible unobserved heterogeneity by assuming that observations come from distinct classes based on common characteristics. However, one drawback of this approach is the number of classes is usually quite small so there is a coarse approximation of the distribution of heterogeneity (Behnood, 2014). Xiong and Mannering (2013) and Shaheed and Gkritza (2014) have identified another drawback that latent class models do not account for potential variation within a class. Xiong and Mannering (2013) further point out the difficulty in determining the statistically superior model which can vary by dataset. The random parameters approach will be utilized to this dataset to account for the unobserved heterogeneity. To the best of the authors' knowledge, this is the first attempt at modeling injury severity for large truck-involved crashes using a random parameters logit approach on urban freeways by separating crashes by time of day on three injury severity levels (serious injury, minor injury and no injury).

The remainder of the paper is organized as follows. First, a review of the current literature is presented followed by a discussion of the empirical settings and descriptive statistics. Next, the methodological approach is explained and the results are summarized. Finally, implications of the findings and the conclusion are presented.

1.2. Background

Although not the focus of this study, the following references provide valuable insights on time-of-day and its relation to crash rates and injuries sustained during crashes involving large trucks. According to the Fatality Facts provided by Insurance Institute for Highway Safety, highest incidence of deaths due to large truck crashes, nearly 19%, occur between the noon to 3 p.m. period (Fatality Facts 2004: Large Trucks, 2004). Blower and Campbell (1998) analyzed the Fatality Analysis Reporting System (FARS) data set from 1993 to 1995 and found that the higher fatalities occurred during daylight hours. However when fatality rates were calculated, a higher probability of fatality given the occurrence of a crash was observed during night time. An analysis of the General Estimates System (GES) data set for the same period revealed that while there were fewer crashes between midnight and 7 a.m., the chances of severe injuries were higher if a crash occurred during that period. It is important to note here that not all transportation facilities experience the same amounts of vehicular flows, thus exposure to higher traffic volumes may produce varying results with regards to maximum injury severity potential. Other possible exposure variables such as night-time hours of driving, truck-miles traveled, or ton-miles when considered could provide additional information on severity rates of large-truck involved crashes. In future work, the authors are examining methods that take into account exposure based data and crash analysis techniques for large-truck crashes.

Curnow (2002) analyzed the Australian Truck Crash Database and found that articulated truck crash incidents were spread evenly throughout the 24 h period whereas majority of the rigid truck crashes occurred during the day. Ghariani (2001) studied ten years of truck crash data from 1991 to 1999 obtained from Texas Department of Public Safety and found that a significant majority of the crashes occurred during day time. Similar trends were found in the rural freeways of Wyoming and Nebraska for the year 2000–2009 (Offei and Young, 2014). Knipling and Bocanegra (2008) analyzed the frequency of crash occurrence of combination unit trucks and single unit trucks from the truck crash causation study data (LTCCS) and found that the majority of the crashes occurred during the day and especially during rush hours. The percentage of crashes was found to be higher under dark conditions for combination unit trucks compared to single unit trucks. A majority of the above insights which focus on frequencies and distribution of crash occurrence based on time of day can be explained by the fact that most truck operations occur during the day.

Duncan et al. (1998) used an ordered probit model to understand the factors affecting truck–car rear end collisions based on highway safety information system data in North Carolina from 1993 to 1995. Injury severities were found to be higher during night time. Chang and Mannering (1999) analyzed the accidents in King County using a Nested Logit Model and found that for truck involved accidents there is a 50% higher chance of an injury or fatality if the accident occurred during night time and a 37% decrease in the probability of a possible injury if the accident occurred during night time.

Khorashadi et al. (2005) used a multinomial logit structure to understand the differences in factors affecting the severities of large-truck involved accidents in urban and rural areas using four years of crash data from 1997 to 2000 maintained by California Department of Transportation. The multinomial logit specifications were preferred to several nested logit specifications. Darker driving conditions were found to increase the probability of severe or fatal injury crashes. The probability of severe or fatal injury crashes decreased during rush hour with the decrease more prominent in the morning rush hour. Zhu and Srinivasan (2011) used an ordered probit model on the LTCCS data and found that crashes which occurred between 7:30 p.m. to 6:00 a.m lead to more severe crashes.

Lemp et al. (2011) used the heteroskedastic ordered probit model on the LTCCS dataset to study the impact of vehicle, environmental, and crash level variables on vehicle based and crash based maximum injury severity and found that non-bright conditions increased the probability of fatality. Chen and Chen (2011) studied the impact of driver, vehicle, environmental, roadway, temporal, and accident characteristics on single vehicle and multiple vehicle accidents involving large trucks using the highway safety information system data set for the state of Illinois from 1991 to 2000. Mixed logit specification was found to be better than the multinomial logit model. The probability of possible injury/non-incapacitating injury was found to increase during rush hour in single vehicle model. Non-bright conditions were found to significantly increase the probability of injury or fatality in multi-vehicle accident case.

Islam and Hernandez (2013b) used a random parameter ordered probit specification to study the impact of human, vehicle,