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Analysis of driver injury severity in single-vehicle crashes on rural and urban roadways

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ABSTRACT

This study analyzes driver injury severities for single-vehicle crashes occurring in rural and urban areas using data collected in New Mexico from 2010 to 2011. Nested logit models and mixed logit models are developed in order to account for the correlation between severity categories (*No injury*, *Possible injury*, *Visible injury*, *Incapacitating injury and fatality*) and individual heterogeneity among drivers. Various factors, such as crash and environment characteristics, geometric features, and driver behavior are examined in this study. Nested logit model and mixed logit model reveal similar results in terms of identifying contributing factors for driver injury severities. In the analysis of urban crashes, only the nested logit model is presented since no random parameter is found in the mixed logit model. The results indicate that significant differences exist between factors contributing to driver injury severity in single-vehicle crashes in rural and urban areas. There are 5 variables found only significant in the rural model and six significant variables identified only in the urban crash model. These findings can help transportation agencies develop effective policies or appropriate strategies to reduce injury severity resulting from single-vehicle crashes.

1. Introduction

Single-vehicle crashes are frequently associated with a disproportionate number of serious and fatal crashes. In 2011, there were 19,092 fatalities caused by single-vehicle crashes nationwide, accounting for 59.0% of all motor vehicle fatalities (NHTSA, 2013). In the State of New Mexico, although single-vehicle crashes only accounted for 23.0% of total crashes, the proportion of fatal single-vehicles was as high as 55.2% in 2011 alone (NMDOT, 2013). These statistics illustrate that substantial research efforts are needed to better understand significant causal factors and their impacts on injury severities in single-vehicle crashes. Previous studies have compared single-vehicle crashes with multi-vehicle crashes and found substantial differences between these two types of crashes (Chen and Chen, 2011; Geedipally and Lord, 2010; Ivan et al., 1999; Martensen and Dupont, 2013; Rifaat and Chin, 2007; Ulfarsson and Mannering, 2004; Wu et al., 2013). For instance, in Ulfarsson and Mannering's study (2004), single-vehicle and two-vehicle crashes were modeled separately since their differences could not be accurately captured by one model. These previous findings indicate the necessity to analyze single-vehicle and multi-vehicle crashes separately in order to develop effective countermeasures and proper policies.

Furthermore, the different patterns of injury severities in rural and urban crashes were identified in previous studies (Chen et al., 2016b; Islam et al., 2014; Khorashadi et al., 2005; Lee and Mannering, 2002; Nordfjærn et al., 2010). According to New Mexico Department of Transportation (NMDOT) (NMDOT, 2013), there were 7599 crashes occurring in rural areas of New Mexico in 2011, which accounted for 17.6% of total crashes, while the proportion of fatalities in rural crashes was approximately 68.7%. Correspondingly, approximately 82.4% of all crashes statewide occurred in urban areas and resulted in 110 fatalities, accounting for 31.3% of total crash-related fatalities. These phenomena can be attributed to several factors, including driver behavior, demographic characteristics, and environmental and geometric features. Factors may vary between rural and urban areas, which may have different impacts on injury severities. Therefore, it is of practical importance to inves-

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tigate how these factors contribute to injury severities in rural and urban crashes distinctively.

In terms of methodology, a great number of discrete choice models have been developed in previous studies on single-vehicle crashes, of which the most widely used one is the multinomial logit model. However, standard multinomial logit models are developed based on the Independence of Irrelevant Alternatives (IIA) assumption that disturbances among the severity levels are assumed to be independent, which may not always hold in some situations(Hu and Donnell, 2011a; Lee and Mannering, 2002). If some injury severity levels share unobserved effects (e.g. correlated error components), the IIA assumption is violated and estimation results may lead to serious specification errors. Moreover, due to individual preferences (e.g. reaction time, driving experience, vehicle type, etc.), different drivers may result in different severity outcomes even they were involved in the same type of crashes under the same or similar situations. Models with fixed parameters may not accurately illustrate individual response heterogeneity in terms of environmental features, vehicle-infrastructure interactions, etc. Therefore, taking into account possible correlations among unknown or unobserved factors that may affect level of injury severities and random effects of some factors across observations, nested logit models and mixed logit models were developed to investigate and quantify their impacts on driver injury severities in single-vehicle crashes occurring in rural and urban areas. In order to better understand the quantitative impacts of significant factors on driver injury severities, elasticity analyses were also conducted. The model specifications and estimation results illustrate that significant differences exist between rural and urban single-vehicle crashes. The research findings are helpful to develop cost-effective countermeasures and policies to mitigate driver injury severities in single-vehicle crashes.

2. Literature review

To date, there have been a number of studies on single-vehicle crashes that analyzed contributing factors associated with crash frequencies and severities (Abe et al., 2010; Jung et al., 2010; Kim et al., 2013; Sandin and Ljung, 2007; Schneider et al., 2009; Zhu et al., 2010). For example, comparing with senior female driver (aged 65 or older), senior male drivers are more likely to be seriously or fatally injured in single-vehicle crashes (Islam and Mannering, 2006). Jung et al. (2010) assessed the effects of rainfall on severity of single-vehicle crashes and found that factors, including 15-min rainfall intensity, horizontal/vertical curve, female driver, were found to increase crash severities, and factors, such as wind speed and safety belt usage, were identified as contributing factors to decrease crash severities. In most previous studies, single-vehicle crashes were analyzed as a whole without considering the difference between crashes happening in rural and urban areas (e.g. Islam and Mannering, 2006; Jung et al., 2010; Kim et al., 2013). While some studies investigated single-vehicle crashes occurring only in rural areas (Hu and Donnell, 2011b; Rengarasu et al., 2007; Xie et al., 2012), the others focused on urban single-vehicle crashes (Rifaat et al., 2011). Also, other studies focused on a specific type of single-vehicle crash, such as rollover crashes (Chen et al., 2016a; Fréchède et al., 2011; Treacy et al., 2002), run-off-road crashes (Dissanayake and Roy, 2014), fixed-object crashes (Holdridge et al., 2005), and animal-related crashes (Savolainen and Ghosh, 2008). However, a limited number of studies on single-vehicle crashes do identify and compare the contributing factors that have different impacts on injury severities of single-vehicle crashes occurring in rural and urban areas. Although Islam et al. (2014) analyzed single- and multi-vehicle crashes on rural and urban roadways in Alabama, the focus of that study was given to large truck at-fault crashes only.

Numerous econometrical models have been conducted to identify and quantify contributing factors associated with crash injury severities (for comprehensive introduction, please see Savolainen et al., 2011). Ordered logit and probit models are used in the previous studies due to the ordinal injury outcomes (Kaplan and Prato, 2012; Li et al., 2012; Mohamed et al., 2013; Rifaat and Chin, 2007). However, their applications are limited because these models cannot fully address the non-monotonic impacts of some variables on driver injury outcomes. In order to release this ordinal constraint, multinomial logit models have been widely applied during the past decades (e.g. Hu and Donnell, 2011b; Savolainen and Ghosh, 2008; Shankar and Mannering, 1996). Multinomial logit models are associated with the constraint of the IIA property, which assumes that unobserved factors are independent across alternatives. Alternatively, nested logit models are employed for injury severity analyses in order to partially address this limitation (Abdel-Aty and Keller, 2005; Chang and Mannering, 1999; Lee and Mannering, 2002; Wu et al., 2015) by allowing correlation of unobserved factors among severity levels. Those models are helpful to provide a better understanding of contributing factors associated with injury severity outcomes. However, all parameters are estimated as constants across observations and thus incapable of capturing the individual heterogeneity among individual injury severities. Therefore, random parameter mixed logit models are used to analyze crash injury severities, allowing the impacts of variables on injury severities to vary randomly across drivers (Chen and Chen, 2011; Kim et al., 2013; Milton et al., 2008; Train, 2009; Wu et al., 2014). Another type of mixed logit model, the error component mixed logit model, can also capture correlations among severity levels without a random-coefficients interpretation, and is able to present similar results to the nested logit model (Train, 2009). To improve the accuracy of the model in investigating injury severities and provide cost-effective policies for mitigating injury severities, this study employs nested logit models, which allow potential correlations among injury severity outcomes, and mixed logit models, which can account for individual-level heterogeneity among drivers, to analyze driver injury severities. Both of these two models are expected to provide more accurate estimations of respective factors and lead to a better understanding about the contributing factors that affect injury severities in single-vehicle crashes in rural and urban areas. The model specifications and research findings are helpful in the development of proper countermeasures and policies for severe driver injury prevention.

3. Data description

In this study, data on single-vehicle crashes (omitting motorcycles, pedestrian crashes, and bicyclist crashes) are obtained from the NMDOT, Traffic Safety Division (TSD), and Division of Government Research (DGR) at the University of New Mexico (UNM) during the years 2010–2011. The data contains detailed information about single-vehicle crashes, including crash characteristics, environmental and geometrical features, as well as driver information. A total of 11,429 vehicles were involved in single-vehicle crashes in New Mexico from 2010 to 2011, of which 6304 single-vehicle crashes happened in rural areas and 5125 crashes occurred in urban areas. According to the NMDOT protocol (NMDOT Office of Programs Traffic Safety Bureau, 2011), driver injury severity outcomes are classified into 5 categories: *No apparent injury* (Class O), *Complaint of injury* (Class C), *Visible injury* (Class B), *Incapacitating injury* (Class A), and *Killed* (Class K). Of the total 11429 single-vehicle crashes reported, 8355(73.1%) resulted in *No apparent injury*, 1336 (11.7%) involved *Complaint of injury* (or *Possible*