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Methods to rank traffic rule violations resulting in crashes for allocation of funds

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ABSTRACT

Education, enforcement and engineering countermeasures are implemented to make road users comply with the traffic rules. Not all the traffic rule violations can be addressed nor countermeasures be implemented at all unsafe locations, at once, due to limited funds. Therefore, this study aims at ranking the traffic rule violations resulting in crashes based on individual ranks, such as 1) frequency (expressed as a function of the number of drivers violating a traffic rule and involved in crashes), 2) crash severity, 3) total crash cost, and, 4) cost severity index, to assist transportation system managers in prioritizing the allocation of funds and improving safety on roads. Crash data gathered for the state of North Carolina was processed and used in this study. Variations in the ranks of traffic rule violations were observed when individual ranking methods are used. As an example, exceeding authorized speed limit and driving under the influence of alcohol are ranked 1st and 2nd based on crash severity while failure to reduce speed and failure to yield the right-of-way are ranked 1st and 2nd based on frequency. To minimize the variations and capture the merits of individual ranking methods, four different composite ranks were computed by combining selected individual ranks. The computed averages and standard deviations of absolute rank differences between composite ranks is lower than those obtained from individual ranks. The weights to combine the selected individual ranks have a marginal effect on the computed averages and standard deviations of absolute rank differences. Combining frequency and crash severity or cost severity index, using equal weights, is recommended for prioritization and allocation of funds.

1. Introduction

Traffic fatalities are one of the leading causes of deaths in the United States. In 2013, 32,719 fatalities and 2.13 million injuries were reported on roads in the United States (National Highway Traffic Safety Administration, 2015). Per the National Safety Council (NSC), fatalities on United States roads are up by 14% in the first six months of 2015 compared to traffic deaths from January to June in 2014 (National Safety Council, 2015).

Aberrant driving behavior is a major reason for the occurrence of traffic crashes and fatalities (Sabey and Taylor, 1980). The aberrant driving behavior can be either unforced errors or intended deviations from practices that are to be followed by drivers to ensure safe movement on roads (Reason et al., 1990). A traffic rule violation could be either due to such an error or intended action. Penalty points, fines and revocation of license through enforcement practices are commonly adopted in various countries to make drivers comply with traffic rules. Besides enforcement, education and engineering countermeasures are implemented to reduce the traffic rule violations.

More than 70% of severe driver injuries occurred in crashes due to a traffic rule violation, while 51% of drivers involved in crashes committed a traffic rule violation (Penmetsa and Pulugurtha, 2017). Reducing such traffic rule violations may contribute significantly to crash and injury reduction (Factor, 2014). The contribution of a traffic rule violation to the number of crashes and injury severity may vary when compared to other traffic rule violations. However, not all the traffic rule violations can be addressed immediately and effectively through education, enforcement and engineering treatments. Further, they cannot be implemented at all unsafe locations, at once, due to limited funds. Therefore, the focus of this study is to research and evaluate methods to rank traffic rule violations and prioritize allocation of funds for implementing countermeasures. In this study, the traffic rule violations are ranked based on frequency (expressed as a function of the number of drivers violating a traffic rule and involved in crashes), crash severity, total crash cost and cost severity index. The findings from this study will assist trans-

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portation system managers to identify traffic rule violations that need to be immediately addressed to improve safety on roads. Additionally, policy makers can find the approach helpful in revisiting the existing driver's license penalty point system and fine amounts.

2. Literature review

The injury severity in crashes has been extensively studied in the past. Savolainen et al. (2011) summarized various methods that were used to assess crash severity. Regression models are the most common among the different methods to identify parameters that contribute toward injury severity. Campbell et al. (2003), Yamamoto and Shankar (2004), Yau (2004), Holdridge et al. (2005), Chang and Yeh (2006), Islam and Mannering (2006), Jung et al. (2010), Xie et al. (2012) and Kim et al. (2013) studied driver or crash severity in single vehicle crashes. Digges and Eigen (2004), Padmanaban et al. (2005), Conroy et al. (2006) and Brumbelow et al. (2009) examined rollover crash risks. Abdel-Aty and Keller (2005), Lee and Abdel-Aty (2005), Huang et al. (2008), Tay and Rifaat (2007), Wang and Abdel-Aty (2008), Haleem and Abdel-Aty (2010) and Moore et al. (2011) studied intersection crash severities. The effect of alcohol and drugs on injury severity was studied by Ramaekers et al. (2004), Smink et al. (2005) and Plurad et al. (2010). Other notable studies on crash severities are Abdel-Aty (2003), Singleton et al. (2004), Ulfarsson and Mannering (2004), Khorashadi et al. (2005), Hill and Boyle (2006), Savolainen and Mannering (2007), Newgard (2008), Yamamoto et al. (2008), Conroy et al. (2008), Fredette et al. (2008), Savolainen and Ghosh (2008), Nevarez et al. (2009), Pai (2009), Rana et al. (2010), Dupont et al. (2010), Geedipally et al. (2011), Lemp et al. (2011) and Rifaat et al. (2012).

Al-Ghamdi (2002) examined the effect of crash cause on severity of the crash. The crash causes evaluated in their study are speeding, running red light, following too closely, going wrong way, failure to yield, amongst others. Ayuso et al. (2010) examined injury severity due to involvement in traffic rule violation related crashes. Passing a stopped school bus, disregarding road marking, disregarding other road signs, driving under the influence of alcohol, driving under the influence of drugs, and improper lane use were not considered in their study.

Penmetsa and Pulugurtha (2017) evaluated the risk drivers pose to themselves and to other drivers by violating traffic rules. The primary intent of their study was to educate drivers about the risk associated with violating traffic rules. Other related example studies include the effect of driving under the influence of alcohol (Tay et al., 2011; Rifaat et al., 2012), speeding (Abdel-Aty, 2003; Rifaat and Tay, 2009; Yasmin et al., 2014), red light violation (Al-Ghamdi, 2002), etc. on crashes or injury severity. However, none of these studies compared one traffic rule violation with another traffic rule violation to rank for prioritization purposes.

Several researchers examined crash data to identify high crash locations through ranking methodology for allocation of resources. Tarko and Kanodia (2004), Cheng and Washington (2008), Montella (2010), Lim and Kweon (2013) and Washington et al. (2014) proposed methods to identify crash hotspots on roads. Sun and Manthena (2008), Washington et al. (2014), and Pour et al. (2015) used Equivalent Property Damage Only (EPDO) as the basis to rank high crash locations. Pulugurtha et al. (2007) researched and summarized different methods through which high crash locations can be identified and ranked. In addition to individual ranking methods, their study proposed the use of crash score method and compared it with the sum of the ranks method to combine the individual ranking methods. A similar methodology is adopted in this study to rank traffic rule violations.

The traffic rule violations can be ranked solely based on crash severity to allocate funds to critical traffic rule violations as well as locations. However, considering only crash severity would lead to allocation of funds to traffic rule violations that result in more fatal or severe injury crashes (example, exceeding authorized speed limit on low traffic volume roads). Traffic rule violations with typical higher number of minor injury, possible injury or property damage only (PDO) crashes would be ignored in this case. On the other hand, using crash frequency would lead to allocation of funds to traffic rule violations with more minor injury and PDO crashes (possibly, in high traffic volume and congested locations). The total crash cost and cost severity index may be correlated to either crash frequency, crash severity, or the number of drivers violating a traffic rule and involved in crashes.

Tay (2001) compared fatality versus social cost to prioritize road safety initiatives. Their study states that over-emphasis on fatal crashes may not result in optimal allocation of resources or funds. The optimal decision pertaining to allocation of resources should be based on marginal cost or related marginal effects (Tay, 2003, 2006).

The cost of traffic rule violations depends on crash frequency, crash severity, number of vehicles and individuals involved in crashes, amongst others. Using an appropriate or optimal combination of frequency, crash severity, total crash cost and/or cost severity index would therefore maximize the merits and potentially lead to more efficient utilization of limited funds. Therefore, this study focuses on evaluating the ranking of traffic rule violations based on 1) frequency, 2) crash severity, 3) total crash cost, and, 4) cost severity index as well as their combinations for prioritization purposes.

3. Data and methodology

Crash data was collected from the Highway Safety and Information System (HSIS) from 2009 to 2013 for the entire state of North Carolina. Five years of data was gathered to have a considerable number of crashes pertaining to all the traffic rule violations. HSIS uses four different files to provide adequate details pertaining to reported crashes; driver, crash, vehicle, road, and environmental characteristics, which can be joined using a unique case number. From 2009 to 2013, a total of 791,245 crashes involving 1,315,059 vehicles occurred on North Carolina roads. The crash data obtained from HSIS was modified such a way that each row represents a crash with all the required details (hereafter referred to as "modified crash data").

The crash severity defines the maximum injury severity that occurred in the crash; it may be of the occupants, the drivers or the other road users (pedestrians or bicyclists) who are involved in that crash. HSIS defines five levels of crash severity; fatal (K), incapacitating injury (A), non-incapacitating injury (B), possible injury (C), and PDO. In this study, the crash severity is reclassified into three categories; (i) severe injury crashes, obtained by combining K and A, (ii) moderate injury crashes, obtained by combining B and C, and, (iii) PDO.

The type of traffic rule violation that led to a crash is defined as contributing factor of the crash in HSIS data. HSIS provides 32 types of contributing factors. Only selected contributed factors (traffic rule violations) were considered in this study. A crash may have happened due to multiple traffic rule violations by a driver. As an example, a speeding drunk driver is involved in a crash. As the specific role of each such contributing factor in the crash is not clear from the database, only the reported primary contributing factor was considered for analysis.