Building Tomorrow's Society
Bâtir la Société de Demain

Fredericton, Canada
June 13 – June 16, 2018/ *Juin 13 – Juin 16, 2018*

INVESTIGATING THE RISKS IMPOSED BY DIFFERENT DRIVER GROUPS ON OTHER ROAD USERS

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Abstract: Multi-vehicle traffic collisions usually result in increased injury severities to the more vulnerable drivers involved in those accidents. An obvious example is the case of an accident between a heavy vehicle and a motorcycle, which usually results in an increased injury severity to the motorcyclist. However, there is lack of quantified measures that estimate the level of risk imposed by different driver groups on other road users. As an example, there are no quantified measures available to estimate the level of risk imposed by impaired drivers on other road users. This paper provides a quantitative investigation regarding the level of risk imposed by different driver groups on other road users. The research is based on analyzing accident records from North Carolina for all two-vehicle collisions that occurred from January 1, 2012 until December 31, 2013. Different driver groups are investigated based on driver's gender, age, impairment and the age of the vehicle involved in the collision. To eliminate the random effect of the number of passengers in the vehicle, only driver's injuries are considered in the analyses. For each pair of groups, the number of collisions where the driver was at least visibly injured is compared between the two groups and based on that an estimate is made to the odds of every driver group to increase the severity of injuries for the other driver groups. The findings of this research may help decision makers identify driver groups that are more dangerous to other road users so that more resources might be allocated to improve awareness programs and licensing procedures dedicated to those groups. The findings of this research also provide quantified measures for insurance companies and law enforcement agencies regarding the potential liability imposed by different driver groups on other groups.

1 INTRODUCTION

Traffic collisions result in approximately 1.3 million deaths every year (World Health Organization 2015). For collisions involving two different types of vehicles, such as collisions between heavy vehicles and motorcycles, certain driver groups (in this case, the motorcyclist) are at more risk of being severely injured because of those collisions. However, there is lack of quantified measures that help us estimate the risk imposed by different driver groups on other road users, such as the risk imposed by impaired drivers on other road users. Daniels et al. (2010) examined risk externalities at roundabouts using logistic regression to analyze the severity level of drivers' injuries related to 1491 collisions that occurred at 148 roundabouts in Flanders-Belgium. They found that vulnerable road user groups (pedestrians, bicyclists, moped riders and motorcyclists) are more severely affected when colliding with other vehicle types. They also found that older road users (above the age of 45 years) are more severely injured when colliding with younger road users. There were other research studies that utilized logistic regression to investigate the significance of different factors that increase the severity of injuries in traffic collisions. Yau (2004) conducted a study to identify the various factors that can contribute to higher severity of single vehicle collisions in Hong Kong during the years 1999 and 2000. Factors pertaining to three types of vehicles, namely private vehicles, goods vehicles and motorcycles were identified using logistic regression models. Various factors such as vehicle age, gender of the driver, roadway lighting conditions, and seatbelt usage were found to be major contributors to the severity of collisions. Yan, et al. (2005) studied multi-vehicle rear-end collisions at signalized intersections in Florida for the year 2001 by using multiple logistic regression where they identified several factors that contributed to the severity of those collisions. Those factors include the number of lanes, road surface condition, driver's gender, speed limits, and alcohol/drug use.

Chang and Yeh (2006) analysed single vehicle crash data in Taiwan for the year 2000 and they were able to identify fatality risk factors for motorcyclists and non-motorcycle drivers. Based on the factors identified, they recommended several measures to reduce the fatality rates in collisions, including improving the quality of the roadway surface, proper speed management techniques, and enforcement of seatbelt use. Harb et al. (2008) analysed freeway work-zone crashes in Florida for the years from 2002 to 2004 and found that the geometry of the road, lighting conditions, driving under the influence, age, and gender are all factors associated with work zone crashes. Bham et al. (2012) analysed single vehicle and multi-vehicle collisions on urban U.S. highways. A multivariate analysis was used to identify various factors that result in collisions. Five types of collisions (angular, head-on, rear-end, sideswipe – same direction, sideswipe – opposite direction) were identified. Apart from this, various factors such as wet road conditions, poor lighting conditions, driving under the influence, driver's behaviour (decision making), and geometry of the road were found to increase collision severity. Another interesting study is the work done by Wenzel (2013), where he explored the possibilities of improved vehicle designs and their results in reducing accident fatalities. Various factors such as presence of side air bags, better alignment of light truck bumpers etc. were found to reduce the fatality rates during collisions. Yu et al. (2014) studied the effect of microscopic traffic, weather and road geometry on specific crash types on the freeway section I-70 in Colorado, USA. With the help of the automatic vehicle identification and weather detection systems installed in the corridor, the study provided valuable insights on how intelligent transport systems can give more focus on traffic safety improvement and effective traffic management. Dabbour (2017) analysed the effects of various factors on the severity of drivers' injuries in single-vehicle collisions involving light vehicles by using collision data from North Carolina during the period from 2007 to 2013. Factors related to the driver, the roadway, the vehicle, and the environmental conditions were identified, and temporal stability of these variables were also analysed.

This study provides a quantitative investigation on the level of the risk imposed by different driver groups on other road users. The research is based on analysing the accident data for all two-vehicles collisions that occurred in North Carolina from January 1, 2012 until December 31, 2013. To eliminate the random effect of the number of passengers in the vehicle, only driver's injuries are considered in the analysis. The results from this study could help decision makers identify those driver groups that increase the severity of injuries of other road users and this in turn can help in increasing the awareness among people and take necessary precautionary measures.

2 METHODOLOGY AND DATA COLLECTION

All two-vehicle collisions are analyzed to investigate the level of risk imposed by one driver group on other road users. Due to the significant differences between vehicle and driver characteristics of heavy vehicles and those of light vehicles, only collision data pertaining to light vehicles were considered for the analysis. The vehicle classes considered as light vehicles are passenger cars, pickup trucks, light trucks, panel trucks, sports utility vehicles, and vans.

The risk imposed by the driver groups is found out using logistic regression, which is a generalized linear model where the occurrence of an event is predicted by fitting the data to a logit function. The event is coded as a dichotomous outcome variable and its value is dependent on the various explanatory variables (Dabbour 2017). The logit function takes the general form:

[1] $f(z) = e^z / (1 + e^z)$

Where z denotes the logit function, and $f(z)$ represents the dichotomous variable which is assumed to follow Bernoulli distribution. This represents the probability that the driver is killed or seriously injured provided that the collision has occurred and has resulted in an injury to the driver. It can take a value of "1" if the driver injury is fatal or serious and "0" if it is a minor injury. The corresponding logit function can be represented as:

[2] $z = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k$

Where $x_1, x_2, \ldots x_k$ represent the explanatory variables, $\beta_1, \beta_2, \ldots \beta_k$ represent the regression coefficients and β_0 is the intercept. The collision data corresponding to the years 2012 and 2013 were collected from the Highway Safety Information System (HSIS). The HSIS is managed by the University of North Carolina Highway Safety Research Center under contract with the Federal Highway Administration. (University of North Carolina Highway Research Center, 2010). Explanatory variables related to both the driver and the vehicle were considered for the analysis. The different variables considered for the analysis are given below:

1. Driver-related variables: include driver's age, driver's gender and impairment level of driver; and

2. Vehicle-related variables: include vehicle's age.

The outcome variable is the injury level that is coded "1" if the driver is at least visibly injured, and coded "0" otherwise. The gender of the driver is coded "1" for female and "0" for male. The impairment level is coded "1" for impaired (which represents the impairment due to medications, drugs, alcohol) and "0" for not impaired. Once the explanatory variables were selected, those records which have incomplete/irrelevant data were eliminated. In this analysis, the odds ratio (OR) is used to interpret the significance of the different explanatory variables considered. Also, the 95% confidence interval (CI) is utilised to define the upper and lower limit values of the odds ratio with 0.05 significance level.

3 RESULTS AND DISCUSSION

Table 1 shows the frequencies and percentages of single-vehicle collisions, two-vehicle collisions, and collisions involving three (or more) vehicles. As shown in the table, two-vehicle collisions constitute more than 56% of the total collisions occurred; and hence it is worthwhile trying to understand the level of risk imposed by different driver groups on other road users in this category.

Table 1: Number [and percentage] of collisions based on the number of vehicle involved *

Number of vehicles involved	2012	2013
Single-vehicle collisions	57,789 [37.9%]	60,070 [37.8%]
Two-vehicle collisions	85,449 [56.1%]	89,386 [56.3%]
Collisions involving three (or more) vehicles	9,139 [6.0%]	9,374 [5.9%]
All collisions	152,377 [100%]	158,830 [100%]

*Note - Above percentages are obtained after eliminating outlier data pertaining to number of vehicles only.

Table 2 shows the coefficients associated with the developed logistic regression models along with the standard errors and the lower and higher 95% confidence intervals. The corresponding forest plot summary for the logistic regression performed is shown in Figure 1. All the explanatory variables considered for analysis (except the gender of the driver who is severely injured) were found to be significant during the analysis period at 0.05 significance level. Out of the different explanatory variables considered, impairment level was found to have the most significant coefficient with the highest odds ratio when compared to the other explanatory variables. Driving under the influence of alcohol or illicit drugs is therefore a significant factor that increases the risk of being seriously injured and also to cause severe injuries to other road users. As shown in Table 2, an impaired driver is five times more likely of getting injured when compared to other drivers. This result is similar to the findings of Behnood et al. (2014). The possible explanation for higher risk of injury for an impaired driver could be that the driver may not be reacting fast enough (for example normal driver might go to a bracing position faster at the time of accident compared to an impaired driver). Another finding which we see from Table 2 (related to impairment level) is that an impaired driver is 3.83 times more likely to increase the injury severity for other road users. This could possibly be explained by the fact that impaired drivers are less likely to adopt corrective maneuvers (in terms of braking or steering away) and correspondingly the impact speeds can be higher causing higher injury severities to the injured driver.

Table 2: Parameters of the developed logistic regression models

Explanatory Variable	Coefficient	Standard Error	Odds Ratio	95% CI	
				Low	High
Driver's age[a]	0.0067	0.0005	1.0068	1.0057	1.0078
Driver's age[b]	0.0025	0.0005	1.0025	1.0014	1.0035
Vehicle's age[a]	0.0175	0.0010	1.0177	1.0157	1.0197
Vehicle's age[b]	0.0107	0.0011	1.0108	1.0086	1.0130
Driver's gender[a]					
Female	NS[c]	NS[c]	NS[c]	NS[c]	NS[c]
Male (base category)	-	-	-	-	-
Driver's gender[b]					
Female	-0.2410	0.0190	0.7858	0.7571	0.8156
Male (base category)	-	-	-	-	-
Driver's impairment[a]					
Impaired	1.6302	0.0475	5.1051	4.6512	5.6033
Not impaired (base category)	-	-	-	-	-
Driver's impairment[b]					
Impaired	1.3428	0.0523	3.8298	3.4566	4.2432
Not impaired (base category)	-	-	-	-	-

[a] Characteristics of the driver who is more severely injured.

[b] Characteristics of the driver and the vehicle that caused more injury to the other driver.

[c] Not significant during the observation period (p value greater than 0.05)

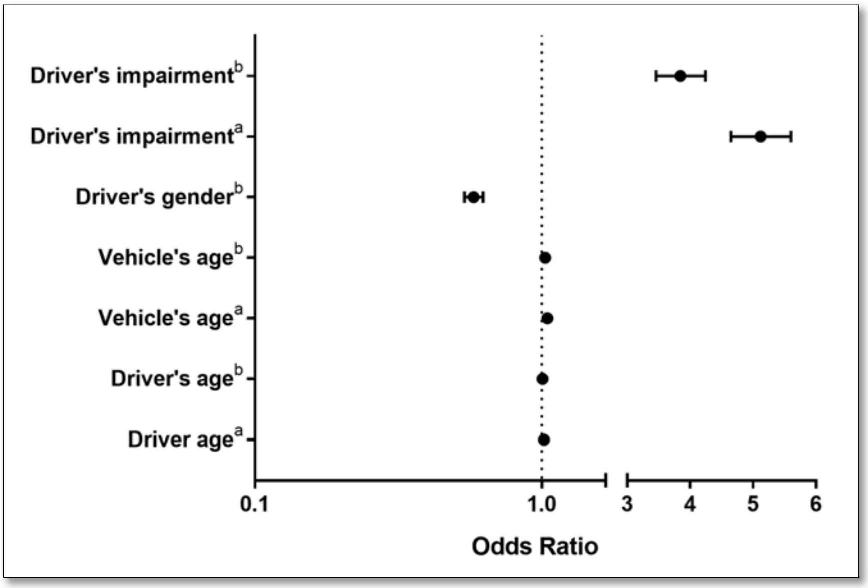

Figure 1: Forest plot of the parameters associated with the developed logistic regression models

When it comes to the gender of the driver involved in the accident, we see from Table 2 that female drivers are less likely to cause more serious injuries to other road users. This can be explained by the fact that women tend to be more cautious drivers compared to their male counterparts. Generally, aggressive driving behaviour, road rage etc. is exhibited more by males than female drivers. When we look at previous studies related with the gender of the driver, we see discussions related with "which gender is more severely injured?". Behnood and Mannering (2015) analysed the effect of male drivers on injury severity for the years 2004 to 2012, where they found that for the year 2007 and 2009, with regard to severe injuries, male drivers have a greater likelihood of severe injuries. In all the other years it was found that males have a less likelihood of severe injuries. Another study by Kim et al. (2013) showed that male drivers are associated with a greater probability of fatal injuries and it was attributed to the fact that male drivers are usually over-represented in the fatal injury category. Further analysis will be required to see if the variable "driver gender who is severely injured" is significant during other years and also check the temporal stability of the trends shown during the analysis period 2012-2013 for a greater period of time.

The ages of the colliding vehicles were also found to have significant influence on the severity of drivers' injuries. It can be seen that as the vehicle age increases by one year, the odds of being seriously injured increase by 1.77%. So, we can say that, using a 10-year old vehicle can increase the odds of serious injury by 17.7%. Another result related to vehicle's age is that as the age of the colliding vehicle increases by 1 year, it increases the odds of serious injuries by 1.08%. So, in short, the older the vehicle, the greater the injury severity for the injured driver. This result is similar to previous studies (Wenzel 2013) and it might be explained by the fact that modern vehicles have more safety features than older vehicles. Also, due to the higher safety standard requirements, modern vehicles are subject to more rigorous crash tests prior to being commercially available.

The age of the driver was also found to increase the odds of driver's serious injuries. We see that for an increase in the driver age by one year, the odds of being seriously injured increase by 0.68%. This is logical because an 80-year-old driver is more likely to be injured because the physical condition deteriorates as the years go by. Another result related with the driver age is that as the age of the driver of the colliding vehicle increases by 1 year, it increases the odds of serious injuries by 0.25%. This result is similar to previous studies (Kim et al. 2013) and it could be explained by the fact that the responses of an older driver (in terms of braking or steering away) could be slower when compared to a young driver and correspondingly it can result in greater injury severity for the injured driver.

By understanding the risk imposed by the different explanatory variables considered for the above analysis, it is important to look at what we can to do minimise the risks for different road users in the future.

As we saw earlier, driver impairment is the major factor that has to be targeted so as to make the roads safer for all road users. The first step is by proper enforcement of laws which eliminate drunk driving and also the enforcement of strict measures such as license suspensions/cancellations depending on the severity of the offense. Another method of law enforcement is by setting up sobriety checkpoints for breath checks to see if the driver is impaired or not. A third option is by installing ignition interlocks in vehicles. These are devices installed in vehicles that measure the driver's breath before each journey and if the driver is impaired, he/she won't be able to start the vehicle. Generally, these devices are installed in vehicles of drivers who have been convicted multiple times for driving under the influence (DUI). However, making it mandatory for all vehicles can act as a deterrent for people who drive while being impaired.

When it comes to the gender of the driver, we saw that female drivers are less likely to cause serious injury to the other driver compared to their male counterparts. The best option here is to educate drivers the significance of being calm behind the wheel and to take necessary precautionary steps to avoid aggressive driving. Usually, drivers get agitated when they are late. So, planning ahead and giving yourself enough time to reach your destination can definitely help. Traffic congestions is another reason for aggressive driving behaviour. So, the driver should identify alternate routes with less traffic and be ready to use them so as to avoid aggressive driving. Even though such precautionary measures are adopted, the drivers should come to terms with the fact that traffic congestions are part of driving and its best handled with a peaceful attitude.

When it comes to the age of the vehicle, we saw that as the age of the vehicle increases, the severity of injuries increases as well. The average life span of a passenger car ranges from 8 to 10 years. However, there are older/classic cars on the road which have been brought back to life by restorations. While performing restorations/improvements, importance should be given for the safety aspects as well. Many of these classic cars do not even have seatbelt provisions which is a disadvantage. Combine that with the lack of modern features like airbags and dedicated crumple zones during impact, older vehicles are far behind in terms of modern safety standards. Specific rules should be set apart for older vehicles such that at least the basic safety requirements are met during their restoration.

When it comes to the age of the driver, we saw that as the age increases, the chances of severe injury increases. We also saw that aged drivers can cause more injuries to the other driver. Frequent senior driver assessments can ensure that the senior drivers are physically and cognitively fit to be on the road. Vehicle related improvements can also be made by car manufacturers such that driver restraint systems like seatbelts, airbags etc. are designed specifically for senior citizens so as to reduce injuries. Road infrastructure changes such as better road lighting facilities can help senior citizens see vehicles better during night time driving reducing the chances of accidents. Improved educational and refresher courses related with driving should be made available to old drivers before their license renewals. All the above-mentioned measures can definitely help make our roads much safer.

4 Conclusions

Logistic regression was used to identify and quantify the effects of various explanatory variables that increase the risk of injury in drivers associated with two-vehicle collisions for light duty vehicles. The study was conducted by analysing the accident records of all collisions that occurred in North Carolina from January 1, 2012 to December 31, 2013. Explanatory variables related to the drivers as well as those related to the colliding vehicles were considered for the analysis and all variables taken into consideration (except the gender of the driver who is severely injured) were found to be statistically significant at 0.05 significance level. The explanatory variables related to the driver were the age of the injured driver, the gender and impairment levels of both colliding drivers. Vehicle's ages were the explanatory variables related to the vehicles. It was found that an impaired driver is most likely to be seriously injured and also to cause serious injuries to other road users. Female drivers were found to cause less injury to the injured driver compared to males. The age of the injured driver and the age of the driver in the colliding vehicle were found to increase the odds of serious injuries. The ages of the two colliding vehicles were also found to increase the odds of serious injuries.

Traffic collisions that result in serious injuries constitute a large burden on the healthcare system. Identifying various factors that increase the risk of drivers' serious injuries can help decision makers take necessary precautionary measures to reduce those risks or to improve legislative policies. The findings of this research can also help insurance firms and law enforcement agencies in estimating the potential liability imposed by different driver groups on other groups.

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