Injury Risk of Traffic Accidents Involving Emergency Vehicles in Alberta

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Abstract

Emergency vehicles (ambulances, police cars and fire trucks) are deployed for rescuing people in an emergency. Crash statistics for Alberta, Canada indicate that more than 300 road traffic accidents every year involve at least one emergency vehicle. The aim of this study is to identify the factors that may have an influence on the probability of injury in crashes involving emergency vehicles in Alberta from 2004 to 2007. The results from our binary logit model show that these crashes are less likely to be injurious during off-peak hour, when it is a single-vehicle accident, or when the driver is male. The risk of injury increases when the drive violates a stop or yield sign, disobeys a traffic signal or when the vehicle hits a fixed object.

Keywords: Emergency Vehicle, Injury Risks, Logistic Model

Introduction

Road safety is a serious issue in Alberta and around the world. Every year, nearly 400 people die and more than 27,000 people are injured in the over 112,000 motor vehicle collisions in Alberta (Alberta Traffic Safety Plan, 2006). The direct social cost of motor vehicle collisions to Albertans is as much as $4.68 billion or 2.4% of Alberta's gross domestic product (GDP).

Among these accidents Emergency Vehicles (EV) are involved in only 0.2% of the total accidents in Alberta and these vehicles include police vehicles, ambulances, fire-fighting vehicles and vehicles used by a gas disconnection unit of a public utility. Emergency services ensure the delivery of vital services during a crisis and are deployed for rescuing people in an emergency. Emergency service personnel must travel day and night, encountering various hazardous weather, road, and traffic conditions. The drivers are often traveling under stressful conditions, at high speed, and in vehicles with poor high-speed manoeuvrability.

For EVs to fall victims to road traffic accidents would be more unfortunate than a regular crash because help cannot be rendered to others in need. Though EV collisions represent a small percentage of the total road crashes, the risk of a EV crash resulting in injury is considerably higher although any collision involving EV is a cause for concern, whether the collision is a minor one or the one with tragic outcome. Hence, to ensure greater safety of our EV operation, it is necessary to identify the factors that contribute to the injury risk in EV accidents.

Literature review

The Firefighter Fatality Retrospective Study 2002 illustrates that the third leading cause of fatal injury for firefighters who died in 2001 was vehicle collisions. The same study indicates that this cause is usually the second most common cause of firefighter fatalities.

Ray and Kupas (2005) found that driver error is the primary cause of up to 93% of emergency vehicle crashes in urban environments and 75% in rural environments. Comparing the characteristics of crashes involving ambulances with those not involving emergency vehicles, road surface and weather conditions at the time of the crash were found to be similar among the vehicle groups while ambulance crashes were more likely to occur at intersections, particularly where traffic signals were present. Ambulance crashes were also found to occur more frequently during evening and weekend hours.

Maio et al (1992) and Kahn et al (2001) identified the errors made on the part of non-emergency vehicle drivers who fail to yield the right-of-way to approaching emergency vehicles at intersections as the contributory factor of EV crashes. However, Clarke et al (2009) found that fatal injuries were more likely to result in the cases where the emergency driver was judged to be at fault and nearly all the drivers were male and that crash involvement peaked in the 26 to 30 year old age group.

Becker et al (2003) and Auerbach et al (1987) found that the use of safety restraint devices significantly reduced the likelihood of being killed or seriously injured. Becker et al (2003) found that restrained ambulance occupants involved in a crash were significantly less likely to be killed or seriously injured than unrestrained occupants. Ambulance rear occupants as well as occupants traveling in non-emergency were significantly more likely to be killed than front-seat and traveling emergency occupants.

Ray and Kupas (2007) compared urban and rural ambulance crashes and found that time of day, lighting conditions, and road type were generally similar between the urban and rural environments. Operator error was found to be the most common cause of crashes, particularly in urban areas. Urban crashes were more pronounced at intersections, particularly stop-controlled and signalized intersections.

Objective and scope of the study

The objective of this research is to identify critical factors associated with injury outcomes in crashes involving emergency vehicle crashes in Alberta. Since no previous study pertaining to the EV related collision of Alberta was found, this research aims to provide valuable insights to transportation professionals in identifying the problem areas and assist them to make decisions that will enhance roadway safety.

Logistic Regression Model

In this research, the dependent variable (injury or non injury outcomes in an emergency vehicle crash) is a dichotomous outcome which facilitates the application of binary logistic regression. The conditional probability π of a positive outcome (injury or death) is determined in the following equation:

(1) $$\pi(x) = \frac{\exp(g(x))}{1+\exp(g(x))}$$

where x is a vector of contributing factors. In our model, the logit g(x) can be interpreted as the index of collision severity which is a latent variable.

(2) $$g(x) = \ln[\frac{\pi(x)}{1-\pi(x)}] = \beta_0 + \sum_{j=1}^{I} \beta_j x_j$$

where β is a vector of coefficients to be estimated and I is the number of independent variables. The likelihood function is given by:

(3) $$l(\beta) = \prod_{i=1}^{n} \pi(x_i)^{y_i}(1-\pi(x_i))^{1-y_i}$$

where *n* is the number of observations and y_i denotes the ith observed outcome, with the value of 0 for a non injury outcomes and 1 for an injury outcome. The best estimate of β could be obtained by maximizing the log likelihood function:

(4) $$LL(\beta) = \sum_{i=1}^{n}\{y_i \ln(\pi(x_i)) + (1-y_i)\ln(1-\pi(x_i))\}$$

The STATA program, LOGIT, was used for model development and the hypothesis testing.

Data description

For this study, a sample of collision data in Alberta from 2004 to 2007 was used and 1169 Emergency Vehicle (EV) related accidents were reported within this period. Among these crashes, only 10.6% resulted in injuries to the emergency vehicle occupants, whereas only 0.17% (2 cases) was fatal. More than 93% of the accidents occurred in urban areas, of which only 824 were identified as crashes with all attributes compiled in the data set. The observations with few or no attributes in the dataset were excluded from the analysis.

The severity of a crash was determined by the person with the most severe injury and a crash was considered as fatal if at least one person involved in the crash died within 30 days of collision. A crash was considered to be an injury crash if at least one person was injured and a property damage crash was defined as a crash associated with no injury but only damages to properties over $1000. Since, the number of fatality was very small, fatal and injury outcomes were combined into one category for analysis.

Based on the information available in the dataset, 10 variables were selected for analysis. These factors include crash characteristics, vehicle characteristics, environmental conditions, traffic control, operational characteristics and driver characteristics. The descriptions and summary statistics of these variables are given in Table 1.

Table 1: Summary Statistics of Variables

Variables	**Mean**	**Std Dev**
Time of day		
Night Time	0.417	0.493
Off-peak period	0.335	0.472
Peak period	0.248	0.432
Number of vehicle involved in the accident		
Single vehicle	0.222	0.416
Two vehicles	0.726	0.446
More than two vehicles	0.052	0.223
Primary event		

Run-off-Road	0.032	0.175
Right-angle	0.176	0.381
Passing	0.049	0.215
Sideswipe	0.132	0.340
Backing	0.163	0.369
Rear-end collision	0.098	0.298
Others	0.350	0.477
Gender of driver		
Male	0.888	0.315
Female	0.358	0.480
Lighting condition		
Daylight/ sun glare	0.625	0.484
Dark and lighting unknown	0.081	0.273
Dark and unlighted	0.051	0.220
Dark but lighted	0.245	0.430
Driver action		
Driving properly	0.676	0.468
Stop sign/yield sign/signal violation	0.132	0.339
Parked vehicle	0.166	0.373
Improper lane change/passing/turn	0.087	0.283
Others	0.542	0.498
Point of impact		
Broad side	0.640	0.480
Back side	0.291	0.455
Front side	0.501	0.500
Others	0.040	0.196
Weather condition		
Clear	0.807	0.395
Rain/ Hail/ Sleet	0.057	0.232
Snow	0.095	0.293
Others	0.041	0.199
Surface condition		
Dry	0.592	0.492
Wet	0.117	0.321
Snowy	0.258	0.438
Others	0.033	0.178
Safety equipment used		

Lap or shoulder belt	0.291	0.455
Lap and shoulder belt	0.718	0.450
No safety equipment	0.127	0.334
Other safety equipment	0.034	0.181

Since all the contributing factors were categorical in nature, several dummy variables were introduced for each factor and one of the variables was used as the reference in the estimation. From the calibrated model, the effects of these identified factors on the injury risk of the emergency vehicle occupants were examined by comparing the β values of the dummy variables against the reference case (no coefficient estimated).

Results and Discussions

The logistic regression analysis identified significant factors that are directly associated with injury risk of emergency vehicle (EV) occupants in traffic accidents in Alberta. Table 2 lists the model estimates (β values), standard errors and p-values.

Table 2: Estimation Results of injury risk of EV occupants

Variables	Beta	Std Err	P-values
Time of Day (Reference: Night time)			
Off-peak period	-0.847	0.445	0.057
Peak period	-0.358	0.413	0.386
Number of Vehicle (Reference: Two vehicle)			
Single vehicle	-2.669	0.731	<0.001
More than two vehicle	0.776	0.474	0.101
Primary Event (Reference: Rear-end collision)			
Run-off-Road	0.937	0.895	0.295
Right-angle	1.132	0.490	0.021
Passing	0.634	0.652	0.331
Sideswipe	0.308	0.584	0.598
Backing	-1.948	1.132	0.085
Others	0.171	0.477	0.72
Gender of Driver (Reference: Female)			

Male	-1.062	0.399	0.008
Lighting condition (Reference: Dark but lighted)			
Daylight/ sun glare	0.731	0.455	0.108
Dark and lighting unknown	1.094	0.531	0.040
Dark and unlighted	1.416	0.571	0.013
Driver Action (Reference: Driving properly)			
Stop/yield/signal violation	0.775	0.397	0.051
Parked vehicle	-0.960	0.515	0.062
Improper lane change/ passing/turn	0.858	0.471	0.068
Others	-0.039	0.332	0.907
Point of impact (Reference: Back side)			
Broad side	-0.254	0.396	0.522
Front side	1.201	0.379	0.002
Point of impact others	1.335	0.731	0.068
Weather condition (Reference: Clear)			
Rain/ Hail/ Sleet	1.900	0.645	0.003
Snow	-0.286	0.510	0.575
Others	-0.082	0.639	0.898
Surface condition (Reference: Snowy)			
Dry	-0.064	0.361	0.859
Wet	-1.430	0.595	0.01
Others	-0.171	0.714	0.811
Safety equipment used (reference: Lap or shoulder belt)			
Lap and shoulder belt	0.140	0.290	0.629
No safety equipment	1.052	0.321	0.001
Others	1.809	0.534	0.001
Constant	-1.269	0.960	0.186
Number of observation = 824 Log likelihood = -225.16901 Chi-square = 174.46 P-value < 0.0001 Pseudo-R-Square = 0.2792			

It should be noted that some of the variables within a factor are not statistically significant but are retained in the model as long as at least one of the variables for the same factor is statistically significant. Kockelman and Kweon (2002) suggested that variables with low statistical significance may also be retained in the model if they belong to factors that have some significant effect on injury severity. This approach may reduce the efficiency of the estimates but it is adopted for ease of comparison and interpretation of the estimates. This potential decrease in efficiency has been adjusted by using a more liberal confidence level of 90% instead of the traditional 95%.

Our study found that time of day had a significant effect on the injury risk of EV occupants. Probability of an injury outcome was higher during the night time compared to off-peak period. The reasons for this might include the more prevalent use of alcohol by drivers at night, the effects of fatigue on the driving task and the risk associated with reduced visibility. Moreover, higher speed and lower volume of vehicle on road during night time might increase the probability of more severe outcomes.

Our results showed that the injury risk of EV occupants was less when the accident was a single vehicle accident. The result could be explained by the fact that EV drivers would be better trained in skid control and would be more cautious in driving than the other drivers, thus resulting in a less severe outcome.

Our analysis showed that right-angle collisions posed higher injury risk for EV occupants than rear-end collisions. The angular collisions would have greater impact forces than rear-end collisions. Thus, angular collisions would impose more severe injuries than rear-end collisions (Tay and Rifaat, 2007).

Our estimates showed that the age of the drivers had no significant effect on the injury risk whereas the injury risk was significantly higher if driver was female. This finding could be explained by the hypothesis that males would generally more skilful and able to perform difficult manoeuvre than female driver (Al-Balbissi, 2003). Massie et al. (1997) found that the injury accidents involvement rate of women are 1.3 to 2 times higher than men of the same age, because male driver had more lifetime driving experience and began accumulating it at an earlier age (Stamatiadis et al., 1995).

The model estimates showed that the injury risk of EV occupants was significantly higher during unlighted dark period than in lighted dark period. Darkness impaired drivers' vision thereby reducing the reaction distance and increasing the impact speed. Elvik and Vaa (2004) summarised evidence from 38 studies that evaluated the effects of providing lighting on previously unlit roads and concluded that road lighting reduce fatal accidents in the dark by 64% and injury accidents by 30%.

As expected, crashes that occurred while an emergency vehicle driver was attempting to pass another vehicle, change lanes, or avoiding another vehicle or other obstacle, were more likely to result in injuries. Also, our results showed that stop sign, yield sign and signal violations were causing more injuries in accidents than in normal driving practice. The results were consistent with the findings of Maio et al (1992), Kahn et al (2001), Savolainen and Datta (2009) and Clarke et al (2009).

Our results showed that if the initial impact point was the front of EV, the injury risk was higher than if it was at the back. The result was in line with the findings of Weiss et al (2001). The probability of head and neck injury would be higher for frontal point of impact than back point of impact, which might lead to the higher injury risk.

As expected, we found that the injury risk of EV occupants was higher during adverse weather condition, like rain/ hale/ sleet, than in normal weather condition. Adverse weather condition reduced visibility and friction of road surface, and hence were expected to decrease safety. Andrey and Yagar (1993) in their temporal analysis of rain-related crash risk of Calgary and Edmonton concluded that accident rates were increased by 70% when it was raining. Andrey et al (2003) also found an increase in road accidents and injuries due to precipitation by using data from mid-sized Canadian cities.

We also found that the injury risk of EV occupants in accidents was lower when the surface was wet compared to covered by snow. The roadway friction on the snowy surface would be much lower than in the wet surface (Willman and Åström, 2001). Thus, due to the lower friction, skidding would be more prevalent on the snowy surface, resulting in higher injury risk in accidents on snowy surface condition than on wet surface.

One of the most critical errors committed by emergency vehicle drivers and occupants would be the failure to use appropriate safety restraint devices. Our analysis showed that drivers and the occupants of EV were less likely to be injured in a crash when they used either lap or shoulder belt or both together. Lap, shoulder belt and air bags protect the occupants from serious head and neck injury. The results were consistent with the findings of Becker et al (2003) and Auerbach et al (1987).

Conclusion and Recommendation

This study examines the factors associated with injury risk of EV occupants. A binary logit model was applied to a sample of EV accident data from Alberta, which was based on police-reported collision data, from 2004 to 2007. Our model showed that emergency vehicle crashes were less likely to result in injury during off-peak hour, when it was a single-vehicle accident, or when the driver was male. The risk of injury increased when the driver violated stop or yield sing or traffic signal, or when the vehicle hit a fixed object.

Due to the lack of data, we were unable to examine several interesting issues. Further research could be done to differentiate those factors associated with emergency vehicle crashes occurring during emergency runs versus crashes involving out-of-service emergency vehicles, and to identify differences between crashes involving police cars, fire trucks, and ambulances.

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