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Cross Sectional Crash Severity Analysis among Various Vehicle Driver Characteristics

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Abstract

The current study evaluated road crashes in three categories of drivers: passenger car drivers, heavy vehicle drivers and pickup truck drivers. The crash data of road crashes that occurred from 2009 to 2012 in Iranian suburban roads were analysed. The crashes involved 194,041 damage, 9,677 injury and 1,303 fatality crashes. Because of the ordinal nature of crash severity, ordered logit model was selected for each vehicle driver category. In the passenger car driver category, the independent variables of driver's gender, driver's age and driver's educational level (uneducated, less than high school diploma, high school diploma) were obtained for modeling; in the heavy vehicle driver category, the independent variables of driver's age and driver's educational level (uneducated, less than high school diploma) were obtained for modeling, and in the pickup truck driver category, the independent variables of driver's age and driver's educational level (uneducated, high school diploma) were obtained for modeling. The variable of driver's gender with respect to passenger cars shows that crashes by female drivers are more severe than those involving male drivers in suburban roads. Regarding the variable of driver's age, if the driver's age increases in each vehicle driver category, the probability of occurrence of a severe crash will decrease. The variable of driver's educational level shows that the severity of crashes involving a driver that has a low level of education is more compared with a driver that has a high level of education.

Keywords: Driver Characteristics; Vehicle Categories; Crash Severity; Ordered Logit.

1. Introduction

Driver characteristics are important factors of road crashes in suburban roads. These characteristics may be different in drivers of different vehicle categories. Further, road safety situation is much worse in developing than developed countries and the costs of accidents in such countries as Iran are extremely high. This study evaluated road crashes involving three categories of vehicle drivers: passenger car drivers, heavy vehicle drivers and pickup truck drivers. Based on the research purpose, the focus of this literature review is on the effects of driver characteristics on crashes involving different categories of vehicles.

Shun Feng et al. studied the risk factors of fatal bus crashes involving different drivers in the United States by logistic model. The analysis indicates that some risk factors have the same effect on different drivers [1]. In another study, Chimba et al. also found that the size of the bus has a significant effect on the bus crash rate [2]. The results of a research on bus crashes, which investigated 9000 bus crashes in the United States, indicated that no connection exist between crashes and the basic driver characteristics such as age and gender [3]. A different research studied the effects of technical specifications of vehicles and characteristics of bus drivers on fatal crashes. The study evaluated the social and economic characteristics of drivers, speeding and bus suspension systems. The results of the study indicate that there is a significant relationship between these parameters and fatal crashes [4]. A study in Sri Lanka used case-control method

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to investigate the effects of long working hours and low salaries of bus drivers on crashes, and the results indicate that these parameters increase the risk of crashes [5].

A research by Thompson et al. studied the performance of old (86 years old) and middle-aged drivers (51 years old). The results of their study indicate that old drivers drive at lower speeds and decelerate differently compared with middle-aged drivers [6]. Also, another research in this field shows that driver characteristics such as gender, age and educational level have little effect on the rate of fatal crashes [7].

The results of a study of young drivers of 15-29 years showed that the main cause of death for young people aged 15-29 years is traffic crashes. Young drivers tend to violate traffic rules more than other groups and, therefore, are involved in more accidents [8-10].

Joon-Ki Kim et al. carried out a research on injury severity in single vehicle crashes in California using mix logit model. In their study, the effects of age and gender were considered. In more than half of the older drivers (over 65 years), the likelihood of a fatal crash was more compared with drivers within the age range of 25 to 64 years. With respect to gender, the average likelihood of a fatal crash involving male drivers was more compared with female drivers in newer vehicles. Several factors play significant roles in increasing the likelihood of a fatal accident, including male driver, driving while drunk, unsafe speed, older drivers (65+), older vehicles and darkness [11]. Meuleners et al. showed that older drivers over the age of 70 sustained serious injury rates more than twice as high as those of the 30–59-year-old drivers. Fragility increased with age, contributing between 47% and 95% for drivers above 65 years [12]. In another study for each age and gender group, deaths per driver involved in a crash (a marker of fragility) and drivers involved in crashes per VMT (a marker of excessive crash involvement) were computed. Compared with drivers ages 30–59, those younger than 20 and those 75 or older both had much higher driver death rates per VMT [13].

Zhang et al. investigated the effects of driver and environmental factors on single vehicle crashes and concluded that age is an important factor of crash severity. Their findings indicate that the likelihood of a fatal crash in older drivers is more compared with middle-aged drivers [14]. So, an increase in the driver's age could have a negative effect on traffic safety [15].

The driver's gender is a significant factor of crashes. Research showed that the behavior of male and female drivers is significantly different, causing differences in the severity of injuries resulting from crashes [16, 17]. Some of these differences are important; for example, fatal crashes in male drivers are more than fatal crashes in female drivers [18].

Morgan and Mannering studied the effects of the driver's age and gender on the severity of injury in single vehicle crashes under wet and dry conditions as well as icy road surfaces. The results of their study showed that significant differences exist in all age groups and gender under different road surface conditions and drivers understanding and reaction to surface conditions are different in the different genders and age groups [19].

Alver et al. evaluated the relationship between young drivers and crashes. In their study, data were collected by face to face interview of 2,057 young drivers (18-29 years old) in four different cities in Turkey. The main purpose of the study was to evaluate the relationship between demographic characteristics of young drivers and traffic violation crashes. Four hypothetical scenarios were considered for each violation of traffic rules, and the data from these scenarios were modeled with ordinal probit model. The data analysis showed that 23.9% of the drivers had been involved in at least one traffic crash in the past three years. Similarly, 38.3% of the drivers had been involved in at least one traffic violation in the past three years, while 47.4% of the drivers had been fined for not using safety belt in the past three years [20].

Ma and Yan studied the impact of driver's age on rear-end collisions. The results are as follows: First, the risk of been involved in rear-end collisions changes drastically with changing age. Second, the interaction between age and gender shows that the behaviors of male and female drivers are different in rear-end collisions. Third, the age impact changes according to the type of pre-crash action and the leading vehicle's behavior [21].

Because of their age and lack of experience, young drivers have less driving skills e.g. their speeding behavior [22]; also young drivers believe they have more driving skills than older and experienced drivers [23-25]. Age of drivers is more significant than their driving experience in safety [26] but the driving experience appears to be an important factor in traffic accidents [27-32]. Age at licensure and driving experience interact to influence crash rate and Experience driving as a requirement of obtaining a license may contribute to a reduced frequency of accidents involving vehicles [33].

Many studies have been conducted to evaluate the effects of the age of a driver. For example, Laurens et al. conducted multivariate analysis with correction for annual mileage, and Kim et al. investigated the heterogeneous effects of age [11, 34].

Amarasinghe and Dissanayake studied the effect of a young driver's gender on crashes. They used a logit regression model based on injury severity in their study. The effective parameters considered in the model include the following: different driver, environment, vehicle and road. The results showed that variables such as license validity, driving on a

weekend, avoidance or slow maneuvers at crash, collisions and rollover, and collisions with pedestrians are significant for female drivers in the crash severity model. Type of road, concrete and wet surfaces, collision with another vehicle, and rear-end collisions are significant for male drivers in the crash severity model [35].

Ozkan and Lajunen investigated the differences between male and female driving. A total of 131 young Turkish male drivers and 86 young Turkish female drivers participated in the survey. Analysis techniques such as reliability analysis, Pearson product-moment correlations and statistical distributions were used to analyze the primary data. The results showed that female drivers have negative performances in all active and passive crashes and positive performances in perceptual-motor and safety skills [36].

Weiss et al. studied crash severity in young drivers (15-24 years old) using discrete choice models. They did a comprehensive analysis of single and two vehicle crashes (damage, injury and fatal) in New Zealand between 2002 and 2011. The results showed that the behaviors of young drivers, passengers and involvement of vulnerable road users are the most important factors of injury severity in single vehicle and two vehicle crashes. Non-use of seatbelts, drinking alcohol and inexperience are the deadliest behavioral factors in single vehicle crashes, while fatigue, reckless driving and non-use of seatbelts are the deadliest behavioral factors in two vehicle crashes [37].

In the above-mentioned studies, drivers' characteristics such as age, gender, and experience have been evaluated. These characteristics showed different impacts in the studies. Furthermore, different vehicle categories have not been considered in the analyses, although the vehicle category may be influential on the relationship between drivers' characteristics and crash severity. Considering the drivers of various vehicles and comparing their demographic characteristics is the innovation of this research. The importance of this issue can be furthered in driving licensing policies, identifying high-risk drivers and organizing training courses on traffic safety for specific drivers. The current study aims at comparing the effects of age, education and gender on crash severity in three categories of vehicles: passenger cars, heavy vehicles, and pickup trucks.

2. Research Methodology

Crash severity is a dependent variable in this study. This variable was evaluated in three levels of severity: damage, injury and fatality. Because crash severity has an ordinal nature, ordered model is preferred to other models. Also, the stochastic components of the utility error follow the logistics distribution in crash models. Accordingly, ordered logit model was used for modeling in this study. NLOGIT statistical software was used for modeling and sensitivity analysis. This software provides the widest and deepest array of tools available anywhere for analysis of multinomial logit models, including nested logit, ordered logit, generalized mixed multinomial logit, heteroscedastic extreme value, multinomial probit, mixed logit and more. A unique simulation package that allows user to analyze alternative scenarios in the context of any estimated discrete choice model with any data set, whether used in estimation or as hold out data for examining model cross validity.

Modeling was based on backward format method. In this method, first, all independent variables are entered into the model then variables that were not significant were excluded from the model. The exclusion criteria of the variable is p-value greater than 0.05. In the final stage, sensitivity analysis was performed on the final variables. The flowchart of the study is shown in Figure 1.

The unobserved dependent variable was defined in the ordered logit model. This variable connected the actual dependent variable and cut point of the variable. Equation 1 and 2 show the relationship between dependent variables and cut points of the variables. Equation 3 shows the probability of a severe crash in the three categories of vehicle drivers.

$$y^* = \alpha x' + \varepsilon \quad (1)$$

$$M_i < {y^*}_{nm} \leq \mu_{i+1}, \ \mu_0 = -\infty, \ \mu_3 = +\infty, \qquad i = 0,1,2 \quad (2)$$

$$\Pr(\mu_i < {y^*}_{nm} \leq \mu_{i+1}) = \Pr(y_{nm} = i), \qquad i = 0,1,2, \qquad m = 1,2,3 \quad (3)$$

y^*: unobserved dependent variable; x': unobserved independent variable; α: coefficient of unobserved independent variable; ε: stochastic components of the utility error; μ_i: cut point of crash severity i; ${y^*}_{nm}$: unobserved dependent variable for crash number n and category of vehicle driver m; y_{nm}: actual dependent variable for crash number n and category of vehicle driver m.

The maximum log likelihood method was used to estimate the coefficients of models. Equation 4 shows this method for logit models. Because of the existence of cut point in ordered logit model, Equation 4 was converted to Equation 5. Equation 5 shows the maximum log likelihood method for ordered logit model.

$$LL(\alpha) = \sum_{n=1}^{N_m} \sum_{i \in S} \rho_{in} . Ln\ P_{in} \quad (4)$$

$$LL(\alpha) = \sum_{n=1}^{N_m} \sum_{i \in S} \rho_{in} . Ln \left(F(\mu_{i+1} - \alpha x) - F(\mu_i - \alpha x) \right) \quad (5)$$

N_m: Number of crashes in category of vehicle driver m; i: crash severity in S set; ρ_{in}: binary variable of crash number n and crash severity i; P_{in}: probability of occurrence of crash number n and crash severity i; x: actual independent variable.

Sensitivity analysis was used to accurately describe each variable. This analysis is different for discrete and continuous variables. Equation 6 and 7 show this analysis for discrete and continuous variables respectively (Train K., 2003).

$$E_{ix} = \frac{P_{1ix} - P_{0ix}}{P_{0ix}} \quad (6)$$

$$E_{ix} = \frac{\partial P_{in}}{\partial X_{in}} * \frac{X_{in}}{P_{in}} \quad (7)$$

E_{ix}: variation in the probability of crash severity i for a change in the independent variable x from 0 to 1; P_{1ix}: the probability that the independent variable x will be 1 in crash severity i; P_{0ix}: the probability that the independent variable x will be 0 in crash severity i; X_{in}: the independent variable for crash number n and crash severity i.

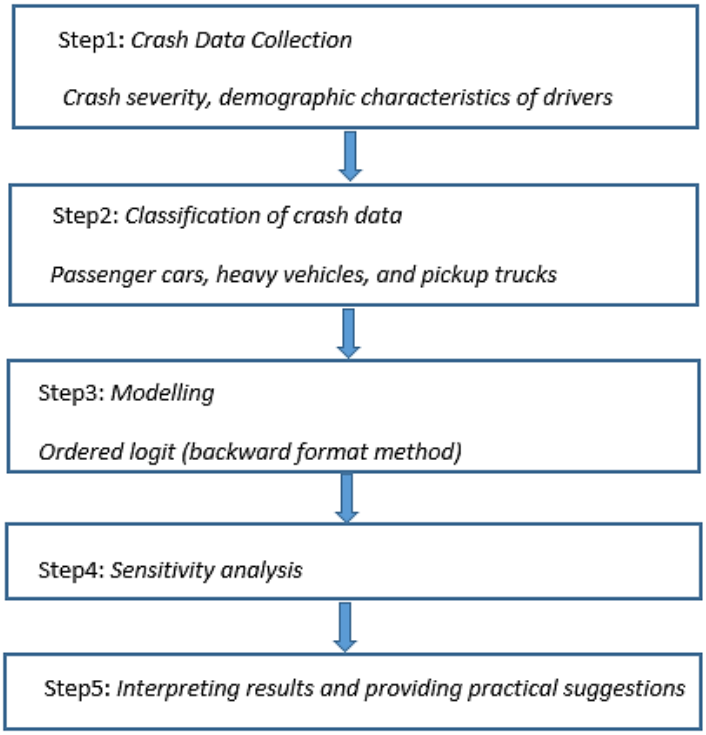


Figure 1. The steps followed in conducting the research

3. Data

The crash data comprise road crashes that occurred from 2009 to 2012 in Iranian suburban roads. These data considered the severity of the crashes and driver culpability. The crashes involved 194,041 damage, 9,677 injury and 1,303 fatality crashes. The drivers of three categories of vehicles that had been involved in crashes were evaluated: passenger car drivers, heavy vehicle drivers and pickup truck drivers. Table 1 presents the crash severity in each vehicle driver category. Since the age qualification, type of driving training and types of driving tests required to get a driver's license are different for these three vehicle categories, the drivers of these vehicle categories were selected for the current study.

Also, the driver characteristics used in this study are driver's gender, driver's age and driver's educational level.

Other driver characteristics, such as psychological factor, physical health factor, etc., could also have been used in the study, but the reported crash data doesn't contain these characteristics. The driver characteristics of both genders were proposed in only passenger vehicle drivers because female driver crashes have not been reported in heavy vehicles and pickup trucks. Table 2 to 4 shows the summary of the statistics of each vehicle driver category.

4. Modeling and Analysis

In this study, because of the ordinal nature of crash severity, the ordered logit model was selected for each vehicle driver category. N-Logit software was used for modeling and sensitivity analysis. Modeling was based on backward format method. In this method, the variables that were not significant were excluded from the model. The p-values of all the variables were lower than 0.05 in the final model. Table 5 shows the final model in each vehicle driver category.

Table 1. Crash severity in each vehicle driver category

Vehicle drivers categories	Crash Severity	Frequency	Percent	Cumulative
Passenger car driver*	Damage	124120	94.38	94.38
	Injury	6597	5.02	99.39
	Fatality	796	0.61	100.00
	Total	131513	100.00	
Heavy vehicle driver**	Damage	44258	96.28	96.28
	Injury	1445	3.14	99.42
	Fatality	267	0.58	100.00
	Total	45970	100.00	
Pickup truck driver***	Damage	25663	93.19	93.19
	Injury	1635	5.94	99.13
	Fatality	240	0.87	100.00
	Total	27538	100.00	

*Maximum capacity is 9 passengers

**Vehicle weight and carload are more than 6000 kilogram, and vehicle can carry more than 26 passengers

***Maximum vehicle weight and carload are 6000 kilogram

Table 2. Summary of the statistics of passenger car drivers

Driver characteristics	Mean	Std. Dev.	Min	Max	Category coding
Driver's gender	0.020	0.142	0	1	Male=0, female=1
Driver's age	35.70	10.66	12	97	-
age<25	0.132	0.339	0	1	(age<25)=1, others=0
25⩽ age<35	0.371	0.482	0	1	(25⩽ age<35)=1, others=0
35⩽ age<45	0.289	0.453	0	1	(35⩽ age<45)=1, others=0
45⩽ age<55	0.150	0.357	0	1	(45⩽ age<55)=1, others=0
55⩽ age<65	0.044	0.205	0	1	(55⩽ age<65)=1, others=0
65⩽ age	0.013	0.116	0	1	(65⩽ age)=1, others=0
Driver's education					-
Uneducated	0.171	0.376	0	1	Uneducated=1, others=0
Less than high school diploma	0.378	0.485	0	1	Less than high school diploma=1, others=0
High school diploma	0.316	0.465	0	1	High school diploma=1, others=0
University education	0.134	0.340	0	1	University education=1, others=0

Table 3. Summary of the statistics of heavy vehicle drivers

Driver characteristics	Mean	Std. Dev.	Min	Max	Category coding
Driver's age	35.58	11.39	12	94	-
age<25	0.148	0.355	0	1	(age<25)=1, others=0
25⩽ age<35	0.381	0.485	0	1	(25⩽ age<35)=1, others=0
35⩽ age<45	0.251	0.434	0	1	(35⩽ age<45)=1, others=0
45⩽ age<55	0.144	0.352	0	1	(45⩽ age<55)=1, others=0

55⩽ age<65	0.052	0.222	0	1	(55⩽ age<65)=1, others=0
65⩽ age	0.020	0.141	0	1	(65⩽ age)=1, others=0
Driver's education					-
Uneducated	0.216	0.411	0	1	Uneducated=1, others=0
Less than high school diploma	0.530	0.499	0	1	Less than high school diploma=1, others=0
High school diploma	0.218	0.412	0	1	High school diploma=1, others=0
University education	0.035	0.184	0	1	University education=1, others=0

In the passenger car driver category, the independent variables of driver's gender, driver's age and driver's educational level (uneducated, less than high school diploma, high school diploma) were obtained for modeling. The null hypothesis of variable coefficients was rejected, and the likelihood ratio was 0.0219.

The coefficient of the variable of driver's gender was 0.189 in the passenger car driver category model. This shows that crashes by female drivers of passenger cars are more severe than crashes by male drivers of passenger cars. This may be due to the inability of female drivers to effectively control the vehicle in suburban roads because they are more physically fragile (less muscle mass, lower bone density, etc.). The coefficient of the variable of driver's age was -0.010 in the passenger car driver category model. This shows that if the driver's age increases, the probability of occurrence of severe crashes will decrease. This may be due to cautious driving in old age. The coefficients of the variables of driver's educational level in the passenger car driver category model were as follows: uneducated = 1.289, less than high school diploma = 0.559 and high school diploma = 0.281. All the coefficients of educational level were positive and will be discussed in the discussion section.

Table 4. Summary of the statistics of pickup truck drivers

Driver characteristics	Mean	Std. Dev.	Min	Max	Category coding
Driver's age	35.58	11.39	12	94	-
age<25	0.148	0.355	0	1	(age<25)=1, others=0
25⩽ age<35	0.381	0.485	0	1	(25⩽ age<35)=1, others=0
35⩽ age<45	0.251	0.434	0	1	(35⩽ age<45)=1, others=0
45⩽ age<55	0.144	0.352	0	1	(45⩽ age<55)=1, others=0
55⩽ age<65	0.052	0.222	0	1	(55⩽ age<65)=1, others=0
65⩽ age	0.020	0.141	0	1	(65⩽ age)=1, others=0
Driver's education					-
Uneducated	0.216	0.411	0	1	Uneducated=1, others=0
Less than high school diploma	0.530	0.499	0	1	Less than high school diploma=1, others=0
High school diploma	0.218	0.412	0	1	High school diploma=1, others=0
University education	0.035	0.184	0	1	University education=1, others=0

Table 5. The final model for each vehicle driver category

Variable	Coefficient	Standard error	Z	$P>\|Z\|$	95% Confidence interval	
Gender	0.186	0.082	2.27	0.023	0.025	0.347
Age	-0.010	0.001	-9.01	0.000	-0.012	-0.008
Uneducated *	1.289	0.048	26.80	0.000	1.195	1.383
Less than high school diploma *	0.559	0.047	11.82	0.000	0.466	0.652
High school diploma *	0.281	0.049	5.71	0.000	0.184	0.377
Cut point 1	3.048	0.058			2.932	3.163
Cut point 2	5.339	0.067			5.206	5.472
Prob > *chi2* : 0 rejected null hypothesis			Pseudo R^2 : 0.0219			
Age	-0.004	0.002	-1.98	0.049	-0.009	0.000
Uneducated *	1.039	0.086	11.98	0.000	0.869	1.210
Less than high school diploma *	0.391	0.081	4.82	0.000	0.232	0.550
Cut point 1	3.588	0.111			3.369	3.807
Cut point 2	5.482	0.125			5.237	5.728
Prob > *chi2* : 0 rejected null hypothesis			Pseudo R^2 : 0.0119			

Age	-0.008	0.002	-4.13	0.000	-0.013	-0.004
Uneducated *	0.775	0.053	14.45	0.000	0.670	0.880
High school diploma *	-0.302	0.071	-4.25	0.000	-0.442	-0.163
Cut point 1	2.462	0.082			2.301	2.623
Cut point 2	4.590	0.101			4.390	4.790
Prob > *chi2* : 0 rejected null hypothesis			Pseudo R^2 : 0.0178			

* Dummy variable compared with the "University education" variable.

In the heavy vehicle driver category, the independent variables of driver's age and driver's educational level (uneducated, less than high school diploma) were obtained for modeling. The null hypothesis of variable coefficients was rejected, and the likelihood ratio was 0.0119.

The coefficient of the variable of driver's age was -0.004 in the heavy vehicle driver category model. This shows that if the driver's age increases, the probability of severe crashes will decrease. The coefficients of the variables of driver's educational level in the heavy vehicle driver category model were as follows: uneducated = 1.039 and less than high school diploma = 0.391. These coefficients of educational level were positive, and they show that the probability of a severe crash involving a driver that has a low educational level is more compared with a driver that has a high educational level. The high school diploma variable was not significant in the heavy vehicle driver category model.

In the pickup truck driver category, the independent variables of driver's age and driver's educational level (uneducated, high school diploma) were obtained for modeling. The null hypothesis of variable coefficients was rejected, and the likelihood ratio was 0.0178.

The coefficient of the variable of of driver's age was -0.008 in the pickup truck driver category model. This shows that if the driver's age increases, the probability of severe crashes will decrease. The coefficients of the variables of driver's educational level in the pickup truck driver category model were as follows: uneducated = 0.775 and high school diploma = -0.302. The coefficient of the uneducated variable of educational level was positive, and this shows that the probability of the occurrence of a severe crash involving a driver that has a low educational level is more compared with a driver that has a high education level. The coefficient of the high school diploma variable of educational level was negative and will be discussed in the discussion section.

Fig. 2 show the driver age effect on the severity of crash in three category. The coefficient of age variables is negative and the driver age effect in passenger cars drivers is more compared to other drivers.

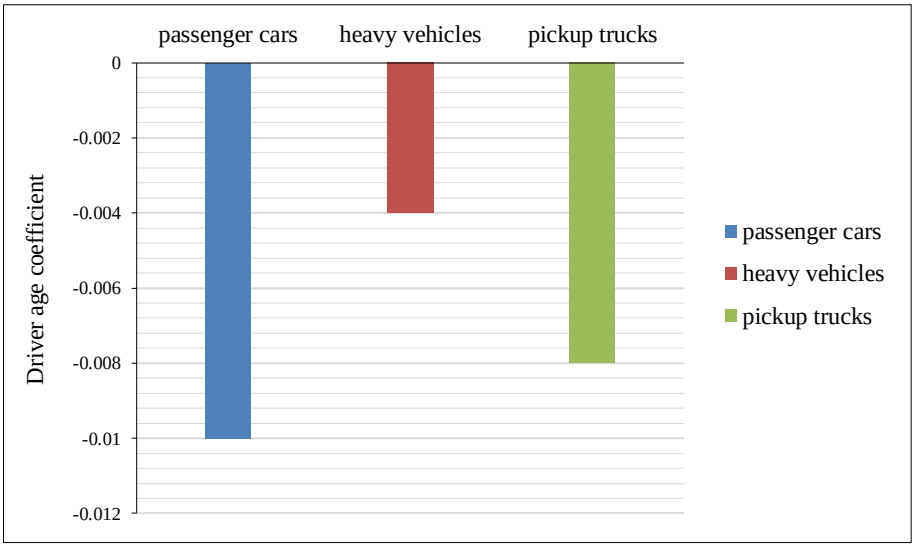


Figure 2. The driver age effect on the severity of crash

Figure 3 show the driver education effect on the severity of crash. The coefficient of "uneducated" variables is positive and the effect of this variable in passenger cars drivers is more compared to other drivers. The "less than high school diploma" is not significant in pickup truck drivers and the effect of this variable in passenger cars drivers is more compared to heavy vehicle drivers. The "high school diploma" variables obtained different result in each category of drivers.

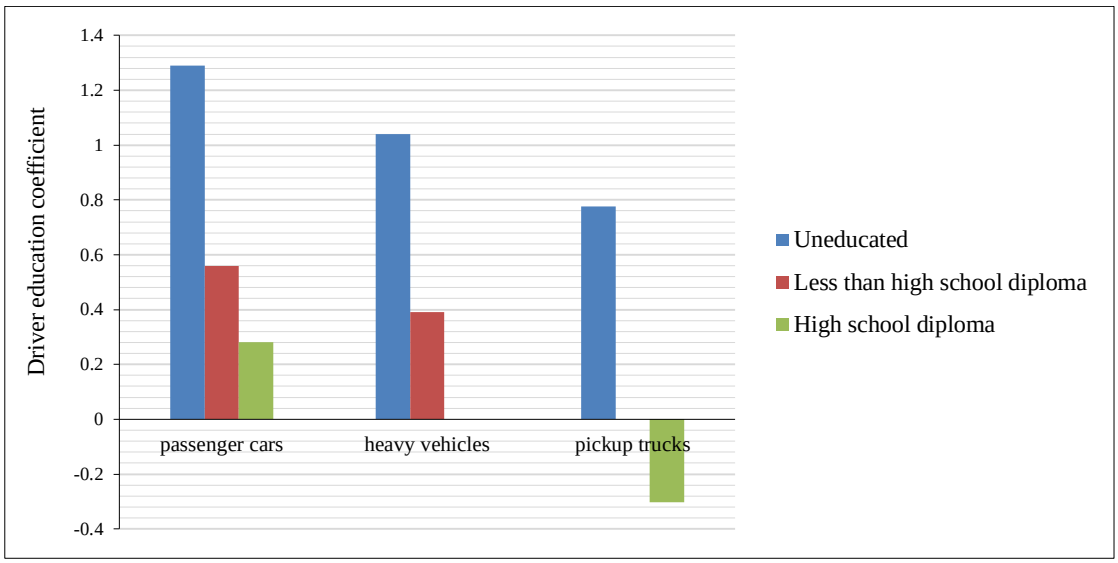
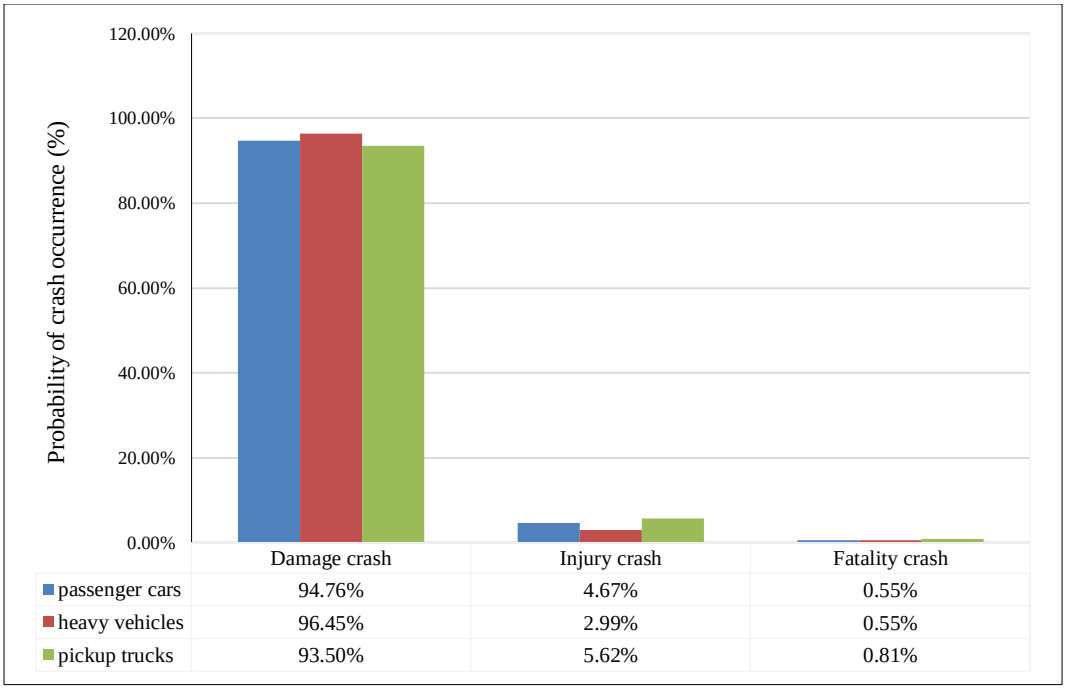


Figure 3. The driver education effect on the severity of crash

Sensitivity analysis was used to describe the variables after modeling. Table 6 to 8 shows the sensitivity analysis of the passenger car driver model, heavy vehicle driver model and pickup truck driver model respectively.

With respect to the passenger car driver model, the probability of occurrence of damage, injury and fatality crashes were 94.76%, 4.67% and 0.55% respectively. Similarly, regarding the heavy vehicle driver model, the probability of occurrence of damage, injury and fatality crashes were 96.45%, 2.29% and 0.55% respectively. Further, regarding the pickup truck driver model, the probability of occurrence of damage, injury and fatality crashes were 93.5 %, 5.62 % and 0.81 % respectively. Fig.4 show the probability of crash occurrence in three level of severity.

The final model had continuous and discrete variables in each vehicle driver category, and the sensitivity description of these two groups of variables was different. For example, regarding continuous variables, the differential of the variable of age in injury crash of passenger car driver model was -0.00046. It means that if the variable of the passenger car driver's age increases by 1%, the probability of an injury crash will decrease by 0.046%. Also, with respect to discrete variables, the differential of uneducated variable in injury crash of the pickup truck driver model was 0.049. This differential indicates that if the pickup truck driver is uneducated, the probability of an injury crash will be 4.9% more than other pickup drivers.



	Damage crash	Injury crash	Fatality crash
passenger cars	94.76%	4.67%	0.55%
heavy vehicles	96.45%	2.99%	0.55%
pickup trucks	93.50%	5.62%	0.81%

Figure 4. Probability of crash occurrence in three level of severity

Table 6. Sensitivity analysis for passenger car drivers

Variable	dy/dx	Standard error	*Z*	*P* > |*Z*|	95% Confidence interval	
Damage crash						
Gender	-0.01002	0.00478	-2.10	0.036	-0.01939	-0.00065
Age	0.00051	0.00006	9.05	0.000	0.00040	0.00063
Uneducated	-0.09610	0.00492	-19.55	0.000	-0.10574	-0.08647
Less than high school diploma	-0.02972	0.00268	-11.11	0.000	-0.03497	-0.02448
High school diploma	-0.01463	0.00268	-5.46	0.000	-0.01989	-0.00938
Y=Pr (Damage crash): 0.9476						
Injury crash						
Gender	0.00889	0.00424	2.10	0.036	0.00058	0.01720
Age	-0.00046	0.00005	-9.04	0.000	-0.00056	-0.00036
Uneducated	0.08456	0.00430	19.68	0.000	0.07614	0.09298
Less than high school diploma	0.02638	0.00237	11.11	0.000	0.02173	0.03103
High school diploma	0.01300	0.00238	5.46	0.000	0.00833	0.01766
Y=Pr (Injury crash): 0.0467						
Fatality crash						
Gender	0.00112	0.00054	2.07	0.038	0.00006	0.00219
Age	-0.00005	0.00001	-8.67	0.000	-0.00007	-0.00004
Uneducated	0.01154	0.00074	15.56	0.000	0.01008	0.01299
Less than high school diploma	0.00334	0.00032	10.31	0.000	0.00270	0.00398
High school diploma	0.00163	0.00031	5.34	0.000	0.00103	0.00224
Y=Pr (Fatality crash): 0.0055						

Table 7. Sensitivity analysis for heavy vehicle drivers

Variable	dy/dx	Standard error	*Z*	*P* > |*Z*|	95% Confidence interval	
Damage crash						
Age	0.00014	0.00008	1.99	0.049	-0.00002	0.00031
Uneducated	-0.04907	0.00532	-9.22	0.000	-0.05950	-0.03864
Less than high school diploma	-0.01284	0.00254	-5.05	0.000	-0.01782	-0.00786
Y=Pr (Damage crash): 0.9645						
Injury crash						
Age	-0.00012	0.00007	-1.98	0.049	-0.00026	0.00001
Uneducated	0.04096	0.00444	9.23	0.000	0.03227	0.04966
Less than high school diploma	0.01079	0.00214	5.04	0.000	0.00659	0.01499
Y=Pr (Injury crash): 0.0299						
Fatality crash						
Age	-0.00002	0.00001	-1.98	0.049	-0.00005	0.00000
Uneducated	0.00810	0.00101	8.00	0.000	0.00612	0.01009
Less than high school diploma	0.00205	0.00042	4.87	0.000	0.00122	0.00287
Y=Pr (Fatality crash):0.0055						

Table 8. Sensitivity analysis for pickup truck drivers

Variable	dy/dx	Standard error	*Z*	*P* > |*Z*|	95% Confidence interval	
Damage crash						
Age	0.00053	0.00013	4.14	0.000	0.00028	0.00078
Uneducated	-0.05715	0.00466	-12.27	0.000	-0.06628	-0.04803
High school diploma	0.01694	0.00368	4.60	0.000	0.00972	0.02416
Y=Pr (Damage crash): 0.935						

Injury crash						
Age	-0.00046	0.00011	-4.14	0.000	-0.00068	-0.00024
Uneducated	0.04922	0.00402	12.25	0.000	0.04134	0.05709
High school diploma	-0.01469	0.00320	-4.59	0.000	-0.02097	-0.00842
Y=Pr (Injury crash): 0.0562						
Fatality crash						
Age	-0.00007	0.00002	-4.02	0.000	-0.00010	-0.00003
Uneducated	0.00793	0.00082	9.72	0.000	0.00633	0.00953
High school diploma	-0.00224	0.00050	-4.47	0.000	-0.00323	-0.00126
Y=Pr (Fatality crash):0.0081						

5. Discussion

The final model is shown in Table 5 for each vehicle driver category. The pseudo R2 (likelihood ratio) for passenger car driver, heavy vehicle driver and pickup truck driver categories were 0.0219, 0.0119 and 0.0178 respectively. These amounts of R2 are not high because the models considered only driver characteristics, but many other factors influence crash severity, such as road factors, traffic condition, weather condition, etc.

The variable of the driver's age had a negative coefficient in each vehicle driver category. It means that if the driver's age increases, the probability of severe crashes will decrease. But the coefficient of the driver's age in the heavy vehicle driver model was less than those of other vehicle driver models. This may be due to the age limit in obtaining heavy vehicle driver's license in comparison with other vehicle driver's license.

The driver's education variables were different in each vehicle driver category. This difference was important in the high school diploma variable. This variable was not significant in the heavy vehicle driver model. It had a positive coefficient in the passenger car driver model and a negative coefficient in the pickup driver model. The following points should be noted:

High educational level does not have any effect on crash severity with respect to heavy vehicle drivers.

High and low educational levels increase the crash severity in passenger car drivers. However, the coefficient of high educational level was less than that of low educational level. This means that the probability of a severe crash involving a driver of passenger car with a low educational level is more compared with that involving a driver of passenger car with a high educational level.

High educational level in the pickup driver model was different from other driver models; in other words, if pickup drivers have a high educational level, the probability of severe crashes is decreased.

6. Conclusion

This study focused on the effects of driver characteristics on crash severity in various vehicles. In summary, the following conclusions were reached:

In the passenger car driver category, the independent variables of driver's gender, driver's age and driver's educational level (uneducated, less than high school diploma, high school diploma) were obtained for modeling. Similarly, in the heavy vehicle driver category, the independent variables of driver's age and driver's educational level (Uneducated, less than high school diploma) were obtained for modeling, and in the pickup truck driver category, the independent variables of driver's age and driver's educational level (Uneducated, High school diploma) were obtained for modeling. The p-values of all the variables were lower than 0.05, and the null hypothesis of variable coefficients was rejected.

The sensitivity analysis showed that the probability of occurrence of damage crash involving passenger car drivers was 94.76%; the probability of occurrence of injury crash was 4.67%, while that of fatality crash was 0.55%. Also, the probability of occurrence of damage crash involving heavy vehicle drivers was 96.45%; the probability of occurrence of injury crash was 2.29%, while that of fatality crash was 0.55%. Further, the probability of occurrence of damage crash in pickup truck drivers was 93.5%; the probability of occurrence of injury crash was 5.62 %, while that of fatality crash was 0.81 %.

The driver's gender variable was proposed only in passenger car drivers, and the coefficient of this variable was 0.189 in the final model. This shows that crashes by female drivers of passenger cars are more severe than crashes by male drivers of passenger cars. The sensitivity analysis indicates that if the passenger car driver is female, the probability of occurrence of a damage crash will be 1% less than that of male drivers; however, the probability of injury and fatality crashes will be 0.88% and 0.11% more than those of male drivers respectively.

The variable of the driver's age had a negative coefficient in each vehicle driver category (coefficient of -0.010 in passenger car driver, coefficient of -0.004 in heavy vehicle driver and coefficient of -0.008 in pickup truck driver). These coefficients show that if the driver's age increases in each vehicle driver category, the probability of a severe crash will decrease. Therefore, the age factor can be modified accordingly for getting driver's license.

The driver education variables show that the severity of crashes involving drivers with a low education level is more than those involving drivers with a high education level accordingly the education level factor can be considering in getting driver's license.

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