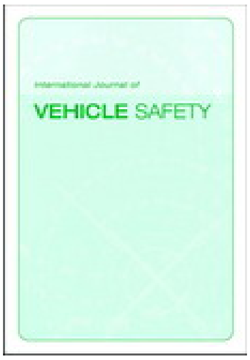

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Impact of vehicle-related factors on speed selection and accident severity rates

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Abstract: We investigated the impact of vehicle-related factors on speed at which accidents occur and accident severity rates. To achieve the objectives of the study, incident rate ratio effects were considered. The data was collected from the Ghana Police Motor Transport and Traffic Department accident database, vehicle owners, garages of auto-mechanics and welders in Ghana. The result shows that engine capacity, vehicle type and type of drive had significant impact on rates of accident severity. Additionally, the effect of engine capacity, vehicle age, vehicle type and type of drive on the speed at which accidents occur was also highly significant. An increase in speed and accident severity rates was explained primarily by high-engine capacity, 4WDs, AWDs and the size of vehicles. Again, an increase in vehicle age increased injuries. Therefore, it is important for authorities to strengthen the enforcement of traffic rules to control drivers' aggression speed and reduce accidents.

Keywords: vehicle factors; speed; accident severity rates; negative binomial regression; Ghana.

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1 Introduction

Road traffic accidents have received attention by researchers and governments around the world over the years because of their impact on the socio-economic development of nations (Nanjunda, 2021; Naqvi et al., 2020; Wijnen et al., 2019). Road accidents generally have far-reaching effects on individuals in different ways. On a global scale, road traffic accidents claim the lives of many with a majority of cases involving the youth in developing countries (Ivers et al., 2017). According to a recent Editorial Commentary, children and persons below the age of 35 years accounted for over 60% of the death toll resulting from road accidents (Blankson and Lartey, 2020). Further, while

72 persons out of a total Ghanaian population of 100,000 were injured as a result of road accidents over a 10-year period, a total number of 8 persons out of the same population died as a result of road traffic accidents. By extension, out of a total Ghanaian population of approximately 32 million people, approximately 23,040 people died of road crashes over a decade. Regardless of the number of lives claimed by the COVID-19 pandemic in recent times, road accidents account for a good number of deaths in Ghana. Road accidents are receiving increasing attention in Ghana as the death toll increases. The road accidents between the months of January and March, 2021 alone outweighed the number of deaths due to the COVID-19 pandemic since its outbreak in 2019. According to a Ghanaian online news outlet, a total number of 771 persons have died as a result of road accidents during the first quarter of 2021 as opposed to a total number of 752 deaths attributed to the outbreak of the novel Coronavirus disease (Darko, 2021).

The severity of a road accident is generally defined in terms of the number of deaths and the number of injuries which is also influenced by a number of factors (Casado-Sanz et al., 2020). In order to mitigate the effects of road traffic accidents, it is important to understand the factors that influence their occurrence so that this could inform policy formulation. A number of studies have been carried out in the past involving the factors that influence the severity of road accidents (Benlagha and Charfeddine, 2020; Casado-Sanz, et al., 2020; Ditcharoen et al., 2018; Eboli et al., 2020; Li et al., 2019; Makarova et al., 2020; Potoglou et al., 2018; Rovšek et al., 2017).

While there are two types of metrics for defining road accident severity as stated earlier, the study by Potoglou et al. (2018) investigated factors affecting injuries incurred during accidents only. It was established that injuries incurred were dependent on factors including vehicle speed, driver age, and time of the year when the accidents occurred. The relationship between injuries and influencing factors was established through the use of a logistic regression model. Another study reported the use of the Functional Resonance Analysis Method (FRAM) in an attempt to explain factors influencing accidents (Hlaing et al., 2019). The study by Hlaing et al. (2019) also used a machine learning model based on a Naive Bayesian Classifying Algorithm for estimating the probability of severity level of accident-causing factors. Time of accident, cause and vehicle type were reported by the aforementioned study as important factors that affect the severity of road accidents. Unlike the study conducted by Potoglou et al. (2018), another research conducted by Benlagha and Charfeddine, (2020) focused on road accident severity in terms of fatalities by investigating driver, vehicle and insurance cover factors. The study used ordinary least squares regression, quantile regression and extreme value theory to show that the driver factor (gender) significantly affected accident severity specifically for males. While previous studies focused on investigating factors, a recent study by Eboli et al. (2020) investigated factors leading to different types of crashes. Like previous studies, the study used logistic regression for determining the severity level of factors and revealed that road-related factors influenced the type of crash with gender not being a significant accident-causing factor.

Against the background of previous studies investigating factors that influence the severity of accidents, it has not been established clearly how vehicle-related factors affect the speed at which a road accident occurs and by extension, the severity of an accident. The current study used a negative binomial regression model for investigating the relationship between vehicle-related factors and how it affects the vehicle speed at which road accidents occur and the rates of accident severity.

2 Methodology

Observation and interviews were used to collect data for the study. At the initial stage of the data collection, permission was sought from the Ghana Police Motor Transport and Traffic Department (MTTD) to observe the accident vehicles in their premises where data on vehicle type, drive type, engine capacity, vehicle age, and vehicle registration numbers were collected. After the observation, the Police Officer in charge of accident records was interviewed and data on the speed at which the accidents occurred, the number of persons injured and killed were retrieved from the accident reports. At the end, data was collected on 356 accident vehicles. However, the Police could not provide information on speed, the number of persons injured and killed for 64 of the accident vehicles observed. Therefore, the 64 vehicles were excluded from the study with 292 vehicles from the Police finally being used for the study.

To increase the sample size, accident vehicles parked or under repairs at the garages of Auto Mechanics and Welders were included in the study. In Ghana, most of the vehicles involved in accidents are sent to garages of Auto Mechanics and Welders for maintenance and repairs. At these garages, permission was sought from the master of the shop (i.e., head of artisans) to observe the accident cars identified, and data on vehicle age, vehicle type, and type of drive was collected. The telephone numbers and house addresses of the owners of the accident cars were requested from the head of artisans. The head of artisans sought permission from the vehicle owners and the telephone numbers as well as residential addresses of those who agreed to partake in the study were given to the researchers. Through the telephone numbers and the residential address, the owners of the accident cars were traced and data on speed at which the accidents occurred, the numbers of persons injured and killed from the accident were gathered. In all, eight hundred (800) vehicles were identified from the sampled garages. Of the 800, majority (748) of the accident car owners agreed to partake in the study. Some of the car owners agreed to provide the answers to the interview questions on phone while some also requested face-to-face interviews. At the end of the data collection, 1040 cases were used. A simple random sampling method was used for selecting the garages. This method was adopted because it ensured that each workshop had an equal and independent chance of being selected.

2.1 Data analysis

The numerical data collected was analysed using StataMP version 13. Descriptive statistics was used to calculate the mean and the standard deviation of the variables. Correlation analysis was conducted to assess the relationship between the vehicle features, speed, and accident severity rates. To avoid false results, a validity test was carried out to choose a suitable regression technique. The relationship between the variance and mean was examined to understand the nature and distribution of the dependent variable. The conditional variance was larger than the conditional mean value of the variables, suggesting the existence of over-dispersion (Okamura et al., 2012). Therefore, the Negative Binomial Regression was used as the best technique for examining the impact of vehicle features on speed and accident severity rates. Finally, the difference between the categories of vehicle factors on speed selection and accident severity rates was examined.

2.3 Mathematical model

The Negative Binomial Regression is a fundamental model for determining accident severity rates. Accident data is usually a count data and a negative regression model is the best way to deal with such data (Ver Hoef and Boveng, 2007). The negative binomial regression model formula for accident severity rates can be expressed as:

$$\varphi_{ik} = \exp\left(\beta_{\mu k} X_{\mu k} + \varepsilon_{ik}\right) \tag{1}$$

where φ_{ik} refers to the speed at which accident occurs and accident severity rates for the *k*-th vehicle factor i . $X_{\mu K}$ is a set of explanatory variables for *k*-th vehicle factor. $\beta_{\mu k}$ represents the conforming regression parameters to be estimated for the *k*-th vehicle factor. ε_i is the error term, which follows the Gamma distribution, with a mean value of 1 and a variance of α , 2. So, the variance of speed and accident severity frequency distribution is given by

$$VAR\left[y_{ik}\right] = E\left[y_{ik}\right]\left[1 + \alpha E\left[y_{ik}\right]\right] = \varphi_{ik}\left(1 + \alpha\varphi_{ik}\right) \tag{2}$$

where y_{ik} represents the speed and the rates of accident severity for the *k*-th vehicle type *i*, $VAR\left[y_{ik}\right]$ represents its variance, and $E\left[y_{ik}\right]$ is the expected speed at which an accident occurs and accident severity rates. The likelihood density function of the negative binomial regression model was formulated as follows:

$$P\left(y_{ik}\right) = \frac{\tau\left(y_{ik} + \left(\frac{1}{\alpha}\right)\right)}{\tau\left(y_{ik} + 1\right)\tau\left(\frac{1}{\alpha}\right)} \left(\frac{\alpha\varphi_{ik}}{1 + \alpha\varphi_{ik}}\right)^{yk} \left(\frac{1}{1 + \alpha\varphi_{ik}}\right)^{\frac{1}{\alpha}} \tag{3}$$

The Gamma function is denoted by $\tau(\cdot)$. The negative regression model is identical to the poison regression model when $\alpha = 0$. When $\alpha > 1$, the data deviation is high and when $\alpha > 1$, the data deviation is low.

2.3.1 Model evaluation

To specify the suitability of the model, the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) were used to evaluate the model by using the maximum likelihood method. AIC and BIC are defined as follows:

$$AIC = -2\log k\left(\mu \middle| \beta_{uk}\right) + 2t \tag{4}$$

$$BIC = -2\log k\left(\mu \middle| \beta_{uk}\right) + t\log(2) \tag{5}$$

where $k\left(\mu \middle| \beta_{uk}\right)$ is the probability function with t representing the number of parameters.

R^2 was added to define the model's accuracy, with values ranging from 0 to 1. The model fit is better when the magnitude of R^2 is larger.

$$R^2 = \left(\frac{\sum_{1-1}^{n} \left(\varphi_{ik} - \widehat{y_{ik}} \right)^2}{\sum_{i-1}^{n} \left(y_{ik} - \widehat{y_{ik}} \right)^2} \right) \tag{6}$$

where $\hat{y}_{ik}$ is the observed average speed and accident severity rates for the *k*-th vehicle and factor *i*.

3 Results and discussions

In recent times, the issue of road traffic safety is becoming a relevant topic because of the increasing number of road traffic crashes and its impact on social life. For this reason, it is very important to analyse the rates of accident severity and the factors influencing it (Eboli et al., 2020) in order to suggest countermeasures aimed at improving road safety. The causes of road traffic crashes have been largely linked to human, environmental, and vehicle factors. It is also important to note that previous studies have not touched on the influence of vehicle factors on speed and accident severity rates. In addition, because the factors influencing crash risk are much more complex, it is still relevant to analyse accident severity rates and the factors influencing it. Therefore, the research investigated the impact of vehicle factors (i.e., engine capacity, vehicle age, vehicle type and drive type) on the speed at which road accidents occur and by extension, accident severity rates (i.e., number of persons injured and the number of persons killed).

3.1 Descriptive statistics analysis of vehicle characteristics

The results in Table 1 indicate that out of the 1040 cases, 516 persons sustained injuries and 296 were killed. Most of the vehicles (54.23%) were within the bracket of salon cars. The majority of the vehicles (38.85%) had an engine capacity of 2.00 to 2.80 cc and were between the age 11 and 20 years. The majority of the vehicles (51.15%) were Front-wheel drive and most accidents (45.38%) occurred at speeds in the range of 81 to 120 km/h.

The mean and standard deviation of the independent variables (vehicle features) and dependent variables (speed and accident severity rates) are also displayed in Table 1. It shows that the majority of the vehicles sampled had a mean engine capacity of 2.1 cc with a mean age of 13.6 years. This implied that the majority of the vehicles involved in accidents were over-aged cars and these cars had an appreciable engine capacity. These findings corroborate the results of a previous study which found that the majority of cars in Ghana are over-aged cars (10 years and more) (Sulemana, 2012). Regarding the vehicle drive type and vehicle type, the mean was 1.66 and 2.50, respectively, suggesting that the majority of the sampled vehicles were within the bracket of four-wheel drive and salon car type of vehicles. It was clear that the average mean speed of the vehicles was 62 km/h, representing the speed at which the majority of accidents occur. In other studies, it was found that 40–60 km/h was the commonest speed range just before the accidents occurred (Gras et al., 2007; Pathak et al., 2014). The findings also show that for every accident, at least one person is injured and, in some instances, deaths were recorded.

Table 1 Descriptive analysis of vehicle features

Variable	*Frequency*	*Percentage (%)*	*Mean*	*Std. Dev.*
Engine capacity			**2.123**	**1.073**
0.15–0.25 cc	100	9.62		
1.00–1.80 cc	256	24.62		
2.00–2.80 cc	404	38.85		
3.00–3.70 cc	260	25.00		
4.00 cc and above	20	1.92		
Vehicle age			**13.679**	**9.955**
1–10 years	260	25.00		
11–20 years	456	43.85		
21–30 years	308	29.62		
31years & above	16	1.54		
Drive type			**1.664**	**0.821**
Front Wheel Drive (FWD)	532	51.15		
4-Wheel Drive (4WD)	368	35.38		
Rear Wheel Drive (RWD)	88	8.46		
All-Wheel Drive (AWD)	52	5.00		
Vehicle type			**2.498**	**1.001**
Pick-ups	80	7.69		
saloon cars	564	54.23		
minibus/bus	284	27.31		
Heavy Good Vehicle (HGV)	12	1.15		
Three-wheeler	100	9.62		
Speed			**61.892**	**28.711**
20–50 km/h	224	21.54		
51–80 km/h	332	31.92		
81–120 km/h	472	45.38		
121 km/h and above	12	1.15		
Number of persons killed	**296**	**28.46**	**0.247**	**0.642**
Number of persons injured	**516**	**49.62**	**1.239**	**1.432**

3.2 Correlation analyses

Spearman's rho correlation analysis was used to explore the strength and direction of the linear relationship between vehicle factors and the speed at which accidents occur and the accident severity rates. In Table 2, a significant positive correlation between predictors and the outcome variables indicated an increase in speed and the rates of accident severity whereas a negative direction indicated a decrease in speed and accident severity rates. The result shows that engine capacity positively correlated with the speed at which accidents occur (r = 0.305, p< 0.001), number of persons injured (r = 0.270, p< 0.001) and number of persons killed (r = 0.199, p< 0.01). This suggests that engine capacity was the most important risk factor (Langley et al., 2000; Quddus et al., 2002) that could motivate drivers to select a particular inappropriate speed and by extension contribute to accident severity. It is possible that the speed at which the vehicles were driven was strongly associated with the severity of accidents because, the result shows that speed correlated positively with both the number of persons injured ($r = 0.288$, $p < 0.001$) and the number of persons killed ($r = 0.139$, $p < 0.05$). These findings confirmed the results of a previous study by Clifton et al. (2009) which found that the probability of serious injuries and deaths increased with increases in vehicle speed. Another study has also established that speed was the main contributor to the rate of fatality on roads (Atombo et al., 2016).

Table 2 Correlation matrix of vehicle factors, speed and accident severity

Variables	*Engine capacity*	*Vehicle age*	*Drive type*	*Vehicle type*	*Speed*	*No killed*	*No injured*
Engine capacity	**1.000**						
Vehicle age	–.026	**1.000**					
Drive type	.207***	–.444***	**1.000**				
Vehicle type	.031	–.324***	.440***	**1.000**			
Speed	**.305*****	.046	.021	**–.108***	**1.000**		
No. of persons killed	**.199****	.082	–.057	**.194****	**.139***	**1.000**	.
No. persons injured	**.270*****	.006	**.183****	.107*	**.288*****	**.411*****	**1.000**

Notes: ***p<0.001; **p<0.01; *p<0.05.

Additionally, the vehicle type had a negative significant correlation with the speed at which accidents occur. This implied that speed selection decreased with vehicle type. In the work of Panis et al. (2006) it was found that saloon cars were driven at higher speeds than other vehicles. However, vehicle type had a positive significant correlation with number of persons injured ($r = 0.194$, $p < 0.01$) and number of persons killed ($r = 0.107$, $p < 0.05$). This result aligns with the findings of a previous study (George et al., 2017). Further, type of drive positively correlated with the number of persons injured ($r = 0.183$, $p < 0.01$). This finding is consistent with that of a previous study conducted by George et al. (2017) that the number of persons injured increased with the type of drives.

3.3 The impact of vehicle factors on accident severity rates and driver speed

A negative binomial regression was run to examine the speed at which accidents occur and accident severity rates based on vehicle-related factors. The interpretation of the result largely took into consideration the significant variables. The result was based on estimated rate ratio for a unit of a variable increase or decrease in a standardised test score, given that the other variables are held constant in the model. The pseudo R^2-values were moderate, however, according to El-Habil (2012) even though the pseudo R^2 statistic is best, the classification coefficients are preferred over pseudo R^2. The result also showed that the p-values of the model chi-square were significant, less than the level of significance 0.05. Therefore, the relationship between the explanatory variables and the response variable was supported. The Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) also indicated that all the models tend to have its fitted values close to the true outcome probabilities.

3.3.1 Impact of vehicle factors on speed

In Table 3, it could be observed that when engine capacity, vehicle age, and type of drive increase by one point, the rate ratio for speed at which accident occurs would increase by a factor of 1.104, $p< 0.001$ (95% CI, 1.088 to 1.19); 1.002, $p = 0.044$ (95% CI, 1.000 to 1.003) and 1.062, $p <0.001$ (95% CI, 1.040 to 1.085), respectively. However, when vehicle type increases the test score by one point, the vehicle rate ratio of speed would be expected to decrease by a factor 0.924 (95% CI, 0.907 to 0.941) with $p = 0.007$ significance level. In relation to previous studies, the results imply that engine capacity, vehicle age and type of drive significantly influence driver's speed (National Highway Traffic Safety Administration, 2013; Quddus, 2013; Quddus et al., 2002). This means that speed is likely to increase with an increase in engine capacity, vehicle age and type of vehicle drives (Quddus et al., 2002). However, the speed could decrease with different types of vehicles.

Table 3 Impact of vehicle factors on speed

Vehicle factors	*IRR*	*Std. Err.*	*z*	*P>z*	*[95% Conf. Interval]*	
Engine capacity	1.103823	.0081924	13.31	0.000	1.087882	1.119997
Vehicle age	1.001747	.0008693	2.01	0.044	1.000045	1.003452
Drive type	1.062287	.0114705	5.60	0.000	1.040042	1.085008
Vehicle type	.9236909	.008705	–8.42	0.000	.906786	.9409109
McFadden's R^2:	0.110		*Cragg & Uhler's* R^2*: 0.191* Pseudo R^2: 0.110			
Max. Likelihood R^2:	0.191		AIC: 2441.891			BIC: 2463.232

Note: Log-Lik Full Model: –1214.945.

3.3.2 *Impact of vehicle factors on number of person injured*

The result in Table 4 indicates that for every increase in vehicle engine capacity by one point, 1.320 (95% CI, 1.211 to 1.440) times more persons were injured with a statistically significant result of $p< 0.001$. Again, when the type of vehicle drives on roads increases by one point, 1.182 (95% CI, 1.017 to 1.373) times more persons are likely to be injured with a statistically significant result of $p< 0.029$. In relation to a previous study, the results implied that engine capacity and type of drive had a significant impact on the number of persons injured (Laapotti and Keskinen, 1998). This explained the fact that the number of persons sustaining injuries is likely to increase with an increasing engine capacity and type of vehicle drive.

Table 4 Impact of vehicle factors on number of persons injured

Vehicle factors	*IRR*	*Std. Err.*	*z*	*P>z*	*[95% Conf. Interval]*	
Engine capacity	1.320271	.0583978	6.28	0.000	1.210635	1.439837
Vehicle age	1.004249	.0062127	0.69	0.493	.992146	1.0165
Drive type	1.181673	.0905424	2.18	0.029	1.016895	1.37315
Vehicle type	1.035912	.0666693	0.55	0.584	.9131482	1.175181
McFadden's R^2:	0.135	*Cragg & Uhler's* R^2: 0.205			Pseudo R^2: 0.1346	
Max. Likelihood R^2:	0.200	AIC: 776.382				BIC: 797.723

Note: Log-Lik Full Model: –382.191.

3.3.3 Impact of vehicle factors on number of persons killed

The result in Table 5 indicates that when engine capacity and vehicle type increase its test score by one point, the vehicle rate ratio for number of persons killed would be expected to increase by a factor of 1.523 (95% CI, 1.292 to 1.796) and 1.842 (95% CI, 1.337 to 2.538) with a statistically significant result of $p<0.001$. This explained the fact that, higher engine capacity vehicles and different vehicle types had a significant effect on the number of persons killed during accidents (George et al., 2017). This means that, higher engine capacity vehicles and different vehicle types have the probability of increasing the risk of accident severity. However, when type of drive increases the test score by one point, the vehicle rate ratio for number of persons killed would be expected to decrease by a factor 0.492 (95% CI, 0.293 to 0.826) with $p = 0.007$ at a significant level. This suggested that the frequency of persons killed is likely to decrease with an increase in different vehicle drive configurations (National Highway Traffic Safety Administration, 2013).Type of vehicle drive increases the number of persons sustaining injuries, but reduced the number of deaths.

Table 5 Impact of vehicle factors on number of person killed

Vehicle factors	*IRR*	*Std. Err.*	*z*	*P>z*	*[95% Conf. Interval]*	
Engine capacity	1.522964	.1279721	5.01	0.000	1.291708	1.795621
Vehicle age	1.006646	.0143608	0.46	0.642	.9788893	1.03519
Drive type	.4920144	.1301666	–2.68	0.007	.2929444	.8263621
Vehicle Type	1.842285	.3010232	3.74	0.000	1.337437	2.5377
McFadden's R^2:	0.172	*Cragg & Uhler's* R^2: 0.219			Pseudo R^2: 0.1720	
Max. Likelihood R^2	0.184	AIC: 304.962			BIC: 326.3034	

Note: Log-Lik Full Model: –146.481.

3.4 Different category of vehicle factors on speed and accident severity rates

The impact of the various aggregated vehicle-related factors on speed and accident severity rates has successfully been examined. However, it was not clear which specific category of vehicle-related factors contributed to the prediction of speed and the rates of accident severity. Therefore, the engine capacity was categorised into 5 groups such as 1 – (0.15 to 0.25 cc), 2 – (1.00 to 1.80 cc), 3 – (2.00 to 2.80 cc), 4 – (3.00 to 3.70 cc) and 5 – (4.00 to 6.70 cc). The vehicle age was grouped as 1 – (1 to 10 years), 2 – (11 to 20 years), 3 – (21 to 30 years) and 4 – (31 years and above). The drive type was coded as 1 – Front-wheel drive, 2 – Four-wheel drive, 3 – Rear-wheel drive, and 4 – All wheel drive. Finally, the vehicle type was classified as follows 1 – Pickup, 2 – Saloon car, 3 – Minibus/bus, 4 – Heavy good vehicle and 5 – Three-wheeler.

3.4.1 Impact of vehicle factors on speed at which accidents occur

The result in Table 6 shows that all the engine capacities included in the model had a significant impact on the speed at which accidents occur. The result revealed that the rate ratio of high-engine capacity is expected to increase the driver speed compared to vehicles with low-engine capacity (0.15 to 0.25 cc). This supports the findings of previous studies as the results illustrate that aggression speed is positively related to high-engine capacity (Chen and Chen, 2011; Javid and Al-Hashimi, 2020; Javid et al., 2021). Further, the result shows that the rate ratio of higher vehicle age is expected to decrease the driver speed selection behaviour compared to a vehicle with lower age between 1 year and 10 years. This means that drivers of new vehicles were more likely to speed than older vehicles (Ogle, 2005; Williams et al., 2006).

Table 6 Impact of vehicle factors on driver speed selection

Vehicle factors	*IRR*	*Std. Err.*	*z*	*P>z*	*[95% Conf. Interval]*	
Engine capacity						
2 (1.00–1.80 cc)	1.463	.053	10.46	0.000	1.362	1.571
3 (2.00–2.80 cc)	1.663	.060	14.20	0.000	1.550	1.784
4 (3.00–3.70 cc)	1.797	.064	16.43	0.000	1.676	1.927
5 (4.00–6.70 cc)	1.688	.115	7.68	0.000	1.477	1.929
Vehicle age						
2 (11–20 years)	.859	.018	–7.36	0.000	.825	.894
3 (21–30 years)	.994	.021	–0.29	0.768	.953	1.036
4 (31 years & above)	.723	.060	–3.88	0.000	.614	.851
Drive type						
2 (4WD)	1.100	.027	3.86	0.000	1.048	1.155
3 (RWD)	.539	.042	–8.00	0.000	.463	.627
4 (AWD)	1.355	.047	8.84	0.000	1.267	1.449
Vehicle type						
2 (salon cars)	.887	.030	–3.54	0.000	.830	.948
3 (minibus/bus)	.919	.028	–2.79	0.005	.867	.975
4 (HGV)	1.229	.097	2.60	0.009	1.052	1.435
5 (three-wheeler)	0.951	.081	0.65	0.516	.904	1.222

The result further demonstrated that a four-wheel drive and all-wheel drive, when compared to front-wheel drive, the 4-wheel drive and all-wheel drives were more likely to have a respective rate ratio of 1.100 (95% CI, 1.048 to 1.155) and 1.355 (95% CI, 1.267 to 1.449) increase in driver speed selection behaviour. This supports the finding that drivers of four-wheel drives select high speed compared to other cars (Bener et al., 2008). It was evident that 4WDs and AWDs might deliberately be breaking the driving rules and, consequently, ignore safe speed limits. Usually, the physical size and engine size of four-wheel vehicles are large. Therefore, it can be assumed that these features might influence risky driving behaviours. However, rear-wheel drive vehicles were more likely to decrease the rate ratio of driver speed selection behaviour when compared to front-wheel drive vehicles.

It is also evident that when saloon cars and minibuses/buses are compared with pickup trucks, the rate ratio of driver speed selection behaviour is expected to decrease by their corresponding factor 0.887 (95% CI, 0.830 to 0.948) and 0.919 (95% CI, 0.867 to 0.975). In contrast with a previous study by Bener et al. (2008) this means that pickup trucks reported higher speeding than small cars and buses. However, heavy goods vehicles were more likely to increase the rate ratio of driver speed selection behaviour when compared with that of pickup trucks.

3.4.2 Impact of vehicle factors on number of persons injured

The result in Table 7 shows that all the various engine capacities included in the model had a significant impact on the number of persons injured. The result revealed that the rate ratio of higher engine capacity significantly increased the number of persons injured compared with vehicles with low-engine capacity ranging between 0.15 cc and 0.25 cc. This result supports the findings of a previous study that the risk of an injury crash increases with increasing engine capacity (Langley et al., 2000).

Table 7 Impact of vehicle factors on number of persons injured

Vehicle factors	*IRR*	*Std. Err.*	*z*	*P>z*	*[95% Conf. Interval]*	
Engine capacity						
2 (1.00–1.80 cc)	3.726	1.483	3.31	0.001	1.708	8.129
3 (2.00–2.80 cc)	2.484	.828	2.73	0.006	1.293	4.773
4 (3.00–3.70 cc)	2.916	.974	3.20	0.001	1.515	5.612
5 (4.00–6.70 cc)	7.923	4.998	3.28	0.001	2.302	27.277
Vehicle age						
2 (11–20 years)	1.266	.176	1.98	0.045	.964	1.663
3 (21–30 years)	1.233	.182	1.96	0.052	.924	1.647
4 (31 years & above)	.9933	.091	–0.62	0.783	.983	1.016
Drive type						
2 (4WD)	2.040	.258	5.63	0.000	1.592	2.614
3 (RWD)	.799	.238	-0.75	0.450	.446	1.431
4 (AWD)	1.686	.430	2.05	0.041	1.022	2.781
Vehicle type						
2 (saloon cars)	.451	.125	–2.88	0.004	.262	.775
3 (minibus/bus)	1.376	.282	1.56	0.018	.922	2.055
4 (HGV)	.225	.205	–1.64	0.101	.038	1.339
5 (three-wheeler)	.804	.004	–0.03	0.875	.367	1.543

Additionally, when a vehicle aged between 11 years and 20 years and 21 years and 30 years is compared to the 1 to 10 years, the age between 11 years and 20 years and 21-year-old and 30-year-old vehicles were expected to have a rate ratio of 1.266 (95% CI, 0.964 to 1.663) and 1.233 (95% CI, 0.924 to 1.647) times greater for number of persons injured, respectively. Vehicles with the age of 10 years and above are considered over-aged in Ghana. A study found an association between older vehicles and mechanical failure as a contributing factor in crashes (Lécuyer and Chouinard, 2006). Therefore, the result suggests that an increasing accident and injuries on Ghanaian roads could be attributed to over aged cars which are more likely to develop mechanical failures. Allouch and Ouni (2020) assessed the probability of four levels of injury severity sustained by vehicle occupants and also found that the probability of serious injuries and deaths increased with increases in the age of the vehicles. Another study compared the relative risk of fatal crashes between vehicles aged 0–2 years and 15–29 years in

Malaysia and found that vehicles within the age bracket of 0–2 had a 55% lower risk than those in the 15–29 age bracket. More so, a report has estimated that when fatal crashes occur, drivers who drive vehicles aged 18+ years are 71% more likely to be seriously injured as compared with vehicles aged below 3 years (National Highway Traffic Safety Administration, 2013).

It is also clear that when saloon cars are compared with pickups, the rate ratio of saloon cars significantly decreased the number of persons injured by a factor of 0.451 (95% CI, 0.262 to 0.775). The minibuses/buses increased the number of persons injured by a factor of 1.373 (95% CI, 0.922 to 2.055). This could be because buses carry a large number of passengers, the number of persons sustaining injuries increases when an accident occurs. In consonance with the findings of a previous study, this implied that over the years minibuses/buses have been the leading vehicles primarily responsible for accident injuries compared with other types of vehicles (Akama et al., 2007).

The result further shows that a 4WDs and AWDs, when compared with FWD, the 4WD and AWD vehicles were more likely to have a respective rate ratio of 2.040 (95% CI, 1.592 to 2.614) and 1.686 (95% CI, 1.022 to 2.781) increase in number of persons injured. This means that the drivers and passengers of four-wheel and all-wheel drive vehicles were more vulnerable to injuries. The result confirmed the findings of a previous study conducted in the State of Qatar which found that four-wheel drivers contributed nearly 40.3% to road traffic accident severity (Bener et al., 2008).

3.4.3 Impact of vehicle factors on number of persons killed

The result in Table 8 shows that the rate ratio for higher engine capacity is expected to increase the number of persons killed when compared to vehicles with lower engine capacity (0.15 to 0.25 cc). However, except for engine capacities between 3.00 cc and 3.70 cc and 4.00 cc and 6.7 cc that had a significant impact on the number of persons killed, the rest of the groupings had no significant impact. This explained that the number of persons killed is largely linked to vehicles with high-engine capacities. This is in agreement with the findings of a previous study which suggested that the number of persons killed through road accidents increases with an increase in the engine cubic capacity and this becomes the most important risk factor (Quddus et al., 2002). The result could also be attributed to the fact that drivers of vehicles with high-engine capacities tend to engage in speeding and as result, more people are killed during accidents (Chen and Chen, 2011; Javid and Al-Hashimi, 2020; Javid et al., 2021). The result further explains that none of the vehicle age groupings had a significant impact on the number of persons killed during accidents. This could be due to the fact that since the increase in age is related to decreased speed selection by drivers, the occupants only sustained injuries but were not killed in the event that an accident occurs. This finding confirms the results of previous research which found that low speed resulted in injuries but not deaths (Tefft, 2013).

Table 8 Impact of vehicle factors on number of persons killed

Vehicle factors	*IRR*	*Std. Err.*	*z*	*P>z*	*[95% Conf. Interval]*	
Engine capacity						
2 (1.00–1.80 cc)	2.371	1.830	1.12	0.263	.522	10.761
3 (2.00–2.80 cc)	1.270	1.052	0.29	0.773	.251	6.435
4 (3.00–3.70 cc)	6.300	4.696	2.47	0.014	1.462	27.153
5 (4.00–6.70 cc)	5.713	5.796	2.13	0.026	1.282	41.732
Vehicle age						
2 (11–20 years)	.910	.298	–0.29	0.773	.479	1.729
3 (21–30 years)	1.188	.376	0.54	0.586	.639	2.207
4 (31 years & above)	.904	.005	–0.02	0.985	.267	1.465
Drive type						
2 (4WD)	.566	.189	–1.71	0.088	.294	1.088
3 (RWD)	.320	.134	1.32	0.101	.226	1.011
4 (AWD)	.167	.00	0.99	0.741	.341	1.781
Vehicle type						
2 (saloon cars)	.361	4.69e+09	0.01	0.991	0	.
3 (minibus/bus)	1.85e+07	2.40e+10	0.01	0.990	0	.
4 (HGV)	3.76e+07	4.87e+10	0.01	0.989	0	.
5 (three-wheeler)	.603	2210.506	-0.00	1.000	0	.

4 Conclusions and policy implications

The frequent occurrence of road traffic crashes has had a huge negative impact on the socio-economic development of nations. Road accidents are largely dependent on vehicle-related factors and vehicle speed. Speed not only affects the severity of a crash, but is also related to the risk of being involved in a crash (Cameron and Elvik, 2010). This impact has made road traffic safety a topical issue. Therefore, it is very important to analyse factors influencing accident severity. This research investigated the impact of vehicle factors on the speed at which accidents occur and accident severity rates. The findings will help develop remedial measures aimed at improving road safety.

The predictors of speed and accident severity rates were vehicle engine capacity, vehicle age, vehicle type, and type of drive. The data was collected from the Ghana Police MTTD accident database, the drivers of vehicles or vehicle owners, and vehicle repair garages. The results suggest that there is a significant relationship between vehicle factors and the numbers of persons injured and the number of persons killed. Specifically, the result revealed that engine capacity, vehicle type, and type of drive had a significant impact on the rates of accident severity. Moreover, the effect of engine capacity, vehicle age, vehicle type and type of drive on the speed at which accidents occur was also highly significant.

The result on the impact of different categories of vehicle-related factors on accident severity rates and speed showed that there were interesting differences regarding the impact of various vehicle factors on speed selection, number of persons injured and killed. It was evident that vehicles with high-engine capacity were consistently more likely to increase speed and contribute to more severe injuries and deaths compared to vehicles with low-engine capacity. As the vehicle age increases the speed is likely to be reduced, but increases the probability of injuries with no effect on deaths. The 4WD and AWD vehicles were more likely to increase speed and injuries compared to FWD vehicles. However, the speed of RWDs reduced the probability of speed and injuries compared to FWD vehicles. The saloon cars had reduced speed and a smaller number of persons injured compared to pick-up. However, compared to pickups trucks, the HGV drivers recorded high-speed selection. In addition, the minibuses/buses increased the number of persons injured when compared to pickups.

It is evident that an increase in speed and the rates of accident severity is explained primarily by high-engine capacity, 4WDs, AWDs and size of the vehicles. The increase in vehicle age significantly reduced driver speed selection, but increased injuries. It is possible that over-aged vehicles were more likely to develop mechanical failures which could result in accidents. Furthermore, the drivers of4WDs and AWDs might unconsciously be breaking the driving rules and, consequently, ignore safe speed limits. Against this background, it is important to enforce the adherence to traffic rules to control driver speed aggression behaviour. This can be useful for enhancing road safety in Ghana. In addition, staying committed to the policy on banning of importation of over-aged cars is equally paramount for reducing accident severity.

Even though findings show that a negative binomial regression is a capable technique in providing significant interpretations of factors influencing speed and the rates of accident severity, further research could focus on other vehicle parameters such as; vehicle design, the weight of the vehicle, type of transmission and traffic flow, weather and so on. Furthermore, different countries in Africa could use the method adopted in this study and other statistical methods including multi-level models.

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