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Investigation of road accident severity per vehicle type

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Abstract

The aim of the present study is the investigation of road accident severity per vehicle type. For that reason, a dataset consisting of 59,316 recorded accidents in Greece was analyzed and mathematical models were developed by applying lognormal regression. Three expressions of accident severity were examined: i) the number of fatalities divided by the total number of involved vehicles, ii) the number of severe injuries divided by the total number of involved vehicles and iii) the number of slight injuries divided by the total number of involved vehicles. Furthermore, separate accident severity models were developed for each type of vehicle. The effect of various parameters, such as crash type and weather conditions on accident severity was identified for each type of vehicle (car, moped, motorcycle, bus and truck). Cars involve both private vehicles as well as vehicles used for commercial purposes (like taxis). In general, good weather conditions and night accidents increase severity. Moreover, crash types are consistently affecting accident severity.

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Keywords: Accident severity; vehicle type; lognormal regression

1. Introduction

The effective treatment of road accidents and thus the enhancement of road safety is a major concern to societies due to the losses in human lives and the economic and social costs. Tremendous efforts have been dedicated by transportation researchers and practitioners to improve road safety. In European Union there has been a consistent reduction in fatalities. In 1991, 76,230 fatalities were recorded in EU, whilst in 2013 the total number of fatalities was 25,938 (CARE, 2015). Greece faces the same significant reduction in fatalities as well. When the type of vehicle

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is examined, recent reports in Greece (ERSO, 2012), show that in 2009, 786 car occupant fatalities and 426 motorcyclist fatalities occurred.

Accident severity is therefore an issue which has gained the attention of many researchers so far (Chimba and Sando, 2009; Sze and Wong 2007; Yamamoto and Shankar 2004; Yau, 2004; Chang and Wang 2006; Milton et al. 2008; Quddus et al. 2002; Savolainen and Mannering 2007; Theofilatos et al., 2012).

Al-Ghamdi (2002), used logistic regression and found that crash location (intersection, non-intersection) and cause of accident (speed, running a red light, wrong way violation, etc.) significantly influence road accident severity. Ulfarsson and Mannering (2004), explored the differences in injury severity levels between male and female occupants in sport utility vehicles, minivans, pickups and passenger cars. The authors state that significant differences between male and female drivers were found to exist.

Valent et al. (2002) applied logistic regression to evaluate the association of driver characteristics and accident severity in Italy. The results indicated that males are more likely to be engaged in fatal accidents and that car drivers are less likely to be fatally injured than killed than motorcyclists. Chang and Wang (2006) carried out a study in Taipei, Taiwan and argue that the most important factor that affected crash severity was the type of vehicle. De Lapparent (2007) found that females and riders of motorcycles with high engine size were more likely to be severely injured. Pai (2009), utilized UK national crash data from 1991 to 2004 and analyzed the severity of two or more vehicle-crashes which have occurred at T-junctions involving at least one motorcycle. The author applied binary logistic regression and found that some factors which seem to increase severity are rider age (over 60 years old), high engine size, fine weather, right-of-way violation and involvement of heavy goods vehicle.

Although various research studies examining road accident severity have been found in international literature, only a few were carried out in Greece (Yannis et al., 2005; Theofilatos et al., 2012). Moreover, previous studies have shown the difference in severities between different types of vehicles. Consequently, the present study aims to contribute to existing knowledge by investigating road accident severity in Greece with particular focus on vehicle type, in order to identify the critical risk factors.

2. Methodology

2.1. Data

Accident data were collected from the Hellenic Statistical Authority’s database, which includes disaggregate road accident data based on police accident records in Greece. More specifically, a 5-year period was considered for this study, namely from 2004 to 2008. Totally, 59,316 road accidents were recorded and 105,074 injured persons were involved. Table 1 illustrates the distribution of injuries per vehicle type for the aforementioned time period in Greece. It is observed, that the largest percentage of fatalities occur when trucks are involved (12.7%), while the lowest percentage (3.6%) when a bus is involved. On the other hand, when mopeds are involved, the percentage of fatalities is still relatively low (6.3%) but the share of severe injuries reach their maximum (12.3%). It is noted that cars refer to both private vehicles as well as vehicles used for commercial purposes (like taxis).

Table 1. Distribution of injuries per vehicle type.

Vehicle type	Car	Truck	Bus	Moped (<50cc)	Motorcycle (>50cc)
Fatalities	8.4%	12.7%	3.6%	6.3%	5.3%
Severe injuries	9.0%	9.9%	5.4%	12.3%	9.8%
Slight injuries	82.6%	77.4%	91.0%	81.4%	84.9%

Table 2 illustrates the independent variables considered in this study, namely Area type, time of the accident, weather, crash type and median barrier. It is observed that all variables considered are binary or dummy.

Table 2. List of independent variables.

Variable	Type	Description
Area type	binary	0 for built-up area, 1 for non-built-up area
Time	binary	0 for night, 1 for day
Rain	binary	0 if no, 1 if no
Other weather conditions	binary	0 if no, 1 if no
Crash type	dummy	head-on, rear-end, side, sideswipe, pedestrian, fixed object, run-off road, other
Median barrier	binary	0 if no, 1 if no

The dependent variable is accident severity. It is noted that three expressions of accident severity are used. More specifically:

- Number of fatalities divided by the total number of involved vehicles.
- Number of severe injuries divided by the total number of involved vehicles.
- Number of slight injuries divided by the total number of involved vehicles.

Therefore, three injury types are investigated (fatalities, severe injuries and slight injuries). Moreover, accident severity is explored for each type of vehicle separately. For example, when cars are examined, only accidents with at least 1 car involved are considered. The same approach applies to each vehicle type separately, leading thus to the development of 15 statistical models.

2.2. Method of analysis

The chosen method of analysis is the lognormal linear regression. As noted previously in section 2.1, 15 statistical models are developed, in order to explore accident severity for each vehicle type separately. The next equation describes the method upon which the models were based:

$$Logy_{i} = \beta_0 + \beta_1\chi_{1i} + \beta_2\chi_{2i} + ...\beta_v\chi_{vi} + \varepsilon_{i}\,, \tag{1}$$

where y is the dependent variable, β_0 is the beta coefficient of the constant term, β_1,..., β_v are the beta coefficients of the independent variables x_{1i},x_{2i},…,x_{vi} and ε_i is the error term. The subscript i corresponds to the individual or observation, where i=1,2,...k. It is noted that since a logarithmic transformation of the dependent variable y took place, the relationship of independent variables and y is not linear. More specifically:

$$y = 10^{\beta_0 + \beta_1\chi_{1i} + \beta_2\chi_{2i} + ...\beta_v\chi_{vi}} \tag{2}$$

All regression fundamentals apply in this methodology as well. A variable is statistically significant if its t-test value is approximately higher than the absolute value of 1.64. Similarly, the goodness-of fit of the model is evaluated via the R-squared. Lastly, all independent variables have to be checked for multi-collinearity before entered in the final model.

3. Results

Each model regarded a specific vehicle type, therefore, 15 models were developed, namely 5 fatality models, 5 severe injuries models and 5 slight injury models. When a variable is not significant in the models it is highlighted as “n.s.” and the t-test value is not reported. Table 3 and Table 4 illustrate the modeling results of accident severity in terms of fatalities by the total number of involved vehicles, for each vehicle type. It is observed that some crash types (rear-end, side) are consistently significant for all vehicle types. However, other crash types are frequently significant as well. Regarding cars, the absence of rain, collisions with pedestrians, collisions with fixed objects as well as run-off road crashes increase fatalities. When trucks are considered, good weather increases fatalities, but head-on, rear-end, side and sideswipe crashes decrease fatalities. Lastly, the results of the model for buses, indicated that head-on, rear-end and side crashes decrease fatalities. When severity of mopeds and motorcycles is examined, the models indicated similar findings, however night accidents were found to increase severity for mopeds.

Table 3. Fatality models for cars, trucks and buses.

	Fatalities					
Independent variables	Car		Truck		Bus	
	beta coefficient	t-value	beta coefficient	t-value	beta coefficient	t-value
Constant term	0.451	15.944	-1.372	-22.971	-1.160	-10.746
Area type	n.s	-	n.s	-	n.s	-
Time	n.s	-	n.s	-	n.s	-
Rain	0.044	6.516	0.030	2.039	n.s	-
Other weather conditions	n.s	-	n.s	-	n.s	-
Head-on crash	n.s	-	0.317	21.699	0.348	4.784
Rear-end crash	0.077	6.446	0.335	14.436	0.382	6.932
Collision with pedestrian	-0.335	-41.928	n.s	-	n.s	-
Side crash	n.s	-	0.340	26.396	0.558	8.304
Sideswipe crash	0.074	4.654	0.257	5.751	n.s	-
Collision with fixed object	-0.272	-39.713	0.084	6.159	n.s	-
Run-off road	-0.291	-42.337	n.s	-	n.s	-
Other crash type	n.s	-	n.s	-	n.s	-
Median barrier	n.s	-	n.s	-	n.s	-
R^2	0.506		0.651		0.734	

Table 4. Fatality models for mopeds and motorcycles.

	Fatalities			
Independent variables	Moped (<50cc)		Motorcycle (>50cc)	
	beta coefficient	t-value	beta coefficient	t-value
Constant term	-1.314	-	-1.276	-35.34
Area type	n.s	-	n.s	-
Time	-0.019	-1.83	n.s	-
Rain	n.s	-	0.063	3.69
Other weather conditions	n.s	-	n.s	-
Head-on crash	0.304	19.412	0.304	26.29
Rear-end crash	0.32	21.656	0.322	25.99
Collision with pedestrian	n.s	-	n.s	-
Side crash	0.302	35.745	0.270	30.41
Sideswipe crash	0.339	17.403	0.328	25.04
Collision with fixed object	n.s	-	0.018	1.78
Run-off road	n.s	-	n.s	-
Other crash type	0.039	2.401	n.s	-
Median barrier	n.s	-	n.s	-
R^2	0.822		0.509	

When severity in terms of severe injuries per total vehicles involved is examined, a number of interesting remarks can be observed. Good weather was found to increase severe injuries for cars and motorcycles. Crash types were significant almost for all vehicle types. Moreover, collisions with pedestrians and run-off road collisions increase severity, however, in some cases these variables were not found significant.

The only variable that increases the ratio of severe injuries per total vehicles involved for buses is the collision with pedestrian. It is interesting that night accidents and good weather conditions increase severe injuries per total vehicles when motorcycles are involved. Considering mopeds, head-on and side crashes reduce the number of severe injuries per total vehicles, while collisions with pedestrians, other crash type and run-off road crashes increase accident severity.

Table 5. Severe injury models for cars, trucks and buses.

	Severe injuries					
Independent variables	Car		Truck		Bus	
	beta coefficient	t-value	beta coefficient	t-value	beta coefficient	t-value
Constant term	0.477	16.838	-1.420	-30.311	-0.815	-11.012
Area type	n.s.	-	n.s.	-	n.s.	-
Time	n.s.	-	n.s.	-	n.s.	-
Rain	0.044	6.229	n.s.	-	n.s.	-
Other weather conditions	n.s.	-	n.s.	-	n.s.	-
Head-on crash	n.s.	-	0.334	23.927	0.238	7.315
Rear-end crash	0.087	7.285	0.323	13.411	0.250	6.981
Collision with pedestrian	-0.336	-39.620	n.s.	-	-0.050	-2.537
Side crash	0.034	4.502	0.322	31.535	0.281	7.822
Sideswipe crash	n.s.		0.344	13.414	n.s.	-
Collision with fixed object	-0.257	-32.219	0.092	6.879	n.s.	-
Run-off road	-0.287	-35.998	n.s.	-	n.s.	-
Other crash type	n.s.	-	n.s.	-	n.s.	-
Median barrier	n.s.	-	n.s.	-	n.s.	-
R^2	0.511		0.737		0.779	

Table 6. Severe injury models for mopeds and motorcycles.

	Severe injuries			
Independent variables	Moped (<50cc)		Motorcycle (>50cc)	
	beta coefficient	t-value	beta coefficient	t-value
Constant term	0.287	5.482	-1.250	-33.86
Area type	n.s.	-	n.s.	-
Time	n.s.	-	-0.017	-0.247
Rain	n.s.	-	0.093	5.603
Other weather conditions	n.s.	-	n.s.	-
Head-on crash	0.093	5.057	0.300	23.558
Rear-end crash	n.s.	-	0.320	23.469
Collision with pedestrian	-0.229	-10.221	n.s.	-
Side crash	0.079	6.236	0.200	22.809
Sideswipe crash	n.s.	-	0.329	25.419
Collision with fixed object	n.s.	-	0.077	7.004
Run-off road	-0.216	-13.559	n.s.	-
Other crash type	-0.206	-11.83	n.s.	-
Median barrier	n.s.		n.s.	-
R^2	0.580		0.317	

Table 7. Slight injury models for cars, trucks and buses.

	Slight injuries					
Independent variables	Car		Truck		Bus	
	beta coefficient	t-value	beta coefficient	t-value	beta coefficient	t-value
Constant term	-0.501	-22.577	-1.822	-49.966	-1.411	-27.029
Area type	n.s.	-	n.s.	-	n.s.	-
Time	n.s.	-	n.s.	-	n.s.	-
Rain	0.161	31.577	0.032	4.761	n.s.	-
Other weather conditions	0.179	19.403	n.s.	-	n.s.	-
Head-on crash	0.142	23.981	0.387	42.761	0.324	11.753
Rear-end crash	0.209	36.140	0.421	42.412	0.374	21.067
Collision with pedestrian	-0.354	-48.795	n.s.	-	n.s.	-
Side crash	n.s.	-	0.363	49.221	0.334	23.699
Sideswipe crash	0.201	24.958	0.392	28.000	0.354	18.155
Collision with fixed object	n.s.	-	0.207	20.198	0.112	5.142
Run-off road	-0.167	-25.988	0.093	9.610	-	-
Other crash type	n.s.	-	n.s.	-	n.s.	-
Median barrier	0.152	23.217	n.s.	-	n.s.	-
R^2	0.293		0.529		0.477	

Table 8. Slight injury models for mopeds and motorcycles.

	Slight injuries			
Independent variables	Moped (<50cc)		Motorcycle (>50cc)	
	beta coefficient	t-value	beta coefficient	t-value
Constant term	-1.281	-29.23	-0.156	-4.777
Area type	-0.065	-5.902	-0.151	-18.494
Time	n.s.	-	n.s.	-
Rain	0.102	5.428	0.248	20.384
Other weather conditions	n.s.	-	0.277	13.858
Head-on crash	0.292	18.051	n.s.	-
Rear-end crash	0.282	20.176	n.s.	-
Collision with pedestrian	n.s.	-	-0.305	-30.844
Side crash	0.142	14.39	-0.136	-17.703
Sideswipe crash	0.275	20.189	n.s.	-
Collision with fixed object	0.202	12.251	n.s.	-
Run-off road	n.s.	-	-0.183	-16.192
Other crash type	n.s.	-	n.s.	-
Median barrier	n.s.	-	0.193	18.001
R^2	0.277		0.200	

Tables 7 and 8 demonstrate the results when severity in terms of slight injuries per total vehicles involved is examined. In general, head-on and rear-end crashes increase the ratio of slight injuries per total vehicles involved. Good weather, other weather conditions, head-on crashes, rear-end crashes, sideswipe crashes and presence of median barrier decrease the ratio of slight injuries per total vehicles for cars. On the other hand, collisions with pedestrians and run-off road crashes are positively correlated with slight injuries per total vehicles involved.

On the other hand, all significant variables for trucks (head-on, rear-end, side, sideswipe and other crash type, run-off road collisions, collisions with pedestrians) decrease slight injuries per total vehicles, except for good weather conditions. The same applies for buses as well, however, weather conditions was not found statistically significant.

When considering mopeds, it is interesting that the slight injuries per total vehicles increase in good weather conditions and in built-up areas. A negative correlation was observed with significant crash types. However, side crashes, collisions with pedestrians and run-off road collisions increase slight injuries per total vehicles for motorcycles.

4. Conclusions

The aim of the present study is the investigation of road accident severity per vehicle type. For that reason, a dataset consisting of 59,316 recorded accidents in Greece was analyzed and mathematical models were developed by applying lognormal regression. In those accidents 107,679 injured persons were involved.

Three expressions of accident severity were examined: i) the number of fatalities divided by the total number of involved vehicles, ii) the number of severe injuries divided by the total number of involved vehicles and iii) the number of slight injuries divided by the total number of involved vehicles. Furthermore, separate accident severity models were developed for each type of vehicle. The effect of various parameters, such as crash type and weather conditions on accident severity was identified for each type of vehicle (car, moped, motorcycle, bus and truck).

In total, 15 statistical models were developed. More specifically one model for each vehicle type (cars, trucks, buses, mopeds and motorcycles) and for each accident severity definition (fatalities per total vehicles, severe injuries per total vehicles and slight injuries per total vehicles). It is noted that it is the first time that such macroscopic analysis of accident severity for different vehicle types is carried out in Greece.

In general, good weather conditions and crashes during the night were found to be associated with increased accident severity. Concerning crash types, they were found significant in most models. However, the influence is not always the same and depends on the vehicle type involved. Therefore, it can be concluded that crash type plays an important role when accident severity is examined. This is also shown in a previous study by Theofilatos et al. (2012). The presence of median barrier was found insignificant for most models except for the slight injury model for cars, where a negative correlation with accident severity was found, as median barriers seem to decrease the number of slight injured persons per total vehicle.

The results of the study can be proved useful for enhancing road safety in Greece. Further research could focus on examining additional parameters such as road geometrical characteristics, traffic parameters such as flows, speeds and so on. Furthermore, different areas and regions in Greece could be explored. In this case, other statistical methods could be explored as well, for example multilevel models.

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