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Critical Factors of Motorcycle Accidents in Greece

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Abstract

Motorcyclists constitute a vulnerable type of road users. Although much research has been conducted in this topic, still much effort is needed to understand the accident mechanisms of motorcycle accidents. Therefore, the present paper aims to investigate the critical factors of motorcycle accidents in Greece, by utilizing data for the period 1985-2011. For that reason, loglinear regression models were developed in order to investigate the influence of several parameters such as area type, driver age, lighting conditions and accident type on fatalities, severe and slight injuries of motorcyclists. Comparisons with accidents involving passenger car drivers are also carried out. The findings of the study indicate that the number of vehicles involved in the accident is the most significant factor in the fatalities model. On the other hand, the accident type seems to have a greater effect on the number of severe and slight injuries. This effect was found to be greater for motorcyclists than for passenger cars drivers. The findings of the study could be used to shed light on the factors affecting motorcyclists' fatalities and injuries and thus enhance their safety by considering appropriate policy measures.

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*Keywords:*Motorcycles, cars, accidents, severity, fatalities, injuries, log-linear regression

1. Introduction

For several years, road safety is a priority to researchers and governments, as the growing demand for daily travel leads to road accidents, and to related social and economic costs. Road accidents are estimated globally as the third cause of death after heart disease and cancer, and constitute one of the main causes of permanent disability worldwide, mostly in young people. Although important steps have been taken towards the reduction of road accidents, IRTAD estimated that in 2010, accidents killed 1.3 million people worldwide and injured 50 million.

Greece has a particularly high rate of traffic accidents. According to the police, in 2013 in Greece 12.072 accidents were recorded, with 15.691 victims, of which 879 were killed and 1.303 seriously injured. In the same year, according to the European Road Safety Observatory, in Europe 25.904 people died in road accidents.

Nowadays, the study of road safety regarding motorcycles and mopeds (Power-two-wheelers or PTWs as reported in the literature) is of increased importance due to the increase in their use over the last five years by 41% in Europe, according to ERSO. ERSO data also show that motorcyclists' deaths constitute 15% of all deaths on roads, while rising in contrast to the downward trend in accidents.

Motorcycle riders are more vulnerable in road accidents, because of the smaller size of the vehicle often poorly perceived by drivers of passenger cars, trucks, buses and taxis. At the same time, the lack of physical protection increases the likelihood of serious injury in case of accident involvement.

Many studies (Vlahogianni et al., 2012, Van Elslande et al, 2013, Yannis et al., 2013 and Saleh P., 2010), suggest that the main factors causing accidents involving motorcyclists are riders' behaviour factors (features of riders and riding behaviour, errors, unanticipated movement and manoeuvres of motorcycles, age, gender and experience, education and training, fatigue and alcohol, safety equipment), road environment characteristics (type of road, geometrical characteristics of the road, lighting and visibility, type of accident, type of intersection, road conditions), vehicle characteristics and weather conditions.

According to Yannis et al. 2012, the preference to use motorcycle increases as the space available for cars in cities decreases. This is influenced by economic and environmental factors, as it is a cheap and environmentally friendly mode of transport, convenient in both driving and parking. The ownership and use of motorcycles is being increased in southern European countries such as Greece, Italy and Portugal where the greatest numbers of motorcyclists' fatalities are displayed. While Portugal shows the largest decrease of dead cyclists from 2001 to 2010, the same period Italy and Greece remain above the EU average in 2001. Generally at the European level, accidents involving motorcycles are different from those involving other types of vehicles. Therefore, a study period from 2001 to 2010 in Europe found that the first seven years the number of killed motorcyclists killed has risen, followed by a large decrease of 17%.

The purpose of this study is to explore the critical factors affecting accidents of motorcycles in Greece, compared with the accidents of passenger cars using log-linear regression.

To this end, three mathematical models were developed, one for each category of severity, a model for drivers killed, one for the seriously injured and one for the slightly injured, based on existing statistical data.

The structure of the paper is as follows: First the data collection and the method of analysis are illustrated. Then the statistical models are developed and results are presented and discussed. Finally the overall conclusions and questions for further discussion are presented.

2. Data collection

The data were collected through the SANTRA (System of the Analysis of Traffic Accidents) which has been developed by the Department of Transportation Planning and Engineering of the National Technical University of Athens. The SANTRA database contains road accident data which occurred in the entire road network of Greece for the period 1985-2011, all of which come from the Hellenic Statistical

Authority. Hellenic Statistical Authority organizes and records overall data collected by the traffic police. Retrieval of data from the database is made through querying and the results are organized into tables. The data used in the research concern accidents between 2007 and 2011.

The raw data from the querying of SANTRA were introduced in Microsoft Excel. By processing the data, observations with incomplete data and those receiving the value "Other" were removed, while aggregation of data was implemented to the desirable level for statistical analysis. Also, in the processing of data accidents with non-injured drivers were not included. Thus, three separate data tables were created: one for killed drivers, one for severely injured and one for slightly injured drivers. Afterwards, data were coded in discrete integer values as shown in Table 1.

Table 1: Variables information

Variable	*Description*	*Type*
Severity of the accident	Killed	Dummy
	Seriously injured	
	Slightly injured	
Type of area	Urban	Binary
	Rural	
Lighting conditions	Daylight	Binary
	Night	
Type of accident	Single-vehicle accident (ran-off road, pedestrian collision, obstacle collision)	Binary
	Conflict (head-on collision, offset frontal collision, sideswipe collision, side collision)	
Driver's age	0-34	Dummy
	35-54	
	55+	
Number of vehicles involved	1	Binary
	≥2	
Type of vehicle	Motorcycle	Binary
	Passenger car	

Then, motorcyclists' accidents are compared with the passenger car drivers'. The next tables (Table 2, 3, 4 and 5) outline the variables description and information, as well as descriptive statistics of accident severity by area type, lighting condition, driver age, accident type.

Table 2: Severity of accidents by type of area.

Type of area	*Killed*				*Seriously injured*				*Slightly injured*			
	Motorcycle		*Car*		*Motorcycle*		*Car*		*Motorcycle*		*Car*	
Urban	1212	64%	602	32%	2439	73%	703	39%	16282	86%	8199	61%
Rural	679	36%	1293	68%	884	27%	1094	61%	2581	14%	5282	39%
Total	1891		1895		3323		1797		18863		13481	

Table 3: Severity of accidents for different lighting conditions.

Lighting conditions	*Killed*				*Seriously injured*				*Slightly injured*			
	Motorcycle		*Car*		*Motorcycle*		*Car*		*Motorcycle*		*Car*	
Daylight	961	51%	995	53%	1703	51%	897	50%	11310	60%	7509	56%
Night	930	49%	900	47%	1620	49%	900	50%	7553	40%	5972	44%
Total	1891		1895		3323		1797		18863		13481	

Table 4: Severity of accidents per driver age.

Driver age	*Killed*				*Seriously injured*				*Slightly injured*			
	Motorcycle		*Car*		*Motorcycle*		*Car*		*Motorcycle*		*Car*	
0-34	1188	63%	1129	60%	2229	68%	872	49%	10367	55%	5544	41%
35-54	496	26%	488	26%	869	26%	577	32%	6411	34%	4744	36%
55+	162	11%	278	14%	225	6%	325	19%	1614	11%	2852	23%
Total	1891		1895		3323		1797		18863		13481	

Table 5: Severity of accidents by accident type.

Type of accident	*Killed*				*Seriously injured*				*Slightly injured*			
	Motorcycle		*Car*		*Motorcycle*		*Car*		*Motorcycle*		*Car*	
Ran-off road	335	18%	463	24%	479	14%	411	23%	1384	7%	1494	11%
Pedestrian collision	23	1%	2	0%	63	2%	7	0%	746	4%	137	1%
Obstacle collision	337	18%	465	25%	442	13%	399	22%	1218	6%	1822	14%
Offset frontal collision	533	28%	402	21%	1244	37%	454	25%	7704	41%	5125	38%
Head-on collision	216	11%	323	17%	283	9%	315	18%	1020	5%	1724	13%
Side collision	146	8%	42	2%	231	7%	43	2%	3070	16%	944	7%
Sideswipe collision	162	9%	79	4%	283	9%	87	5%	2284	12%	1825	14%
Other	139	7%	119	7%	298	9%	81	5%	1437	9%	410	2%
Total	1891		1895		3323		1797		18863		13481	

Considering the type of area where the accident occurred, Table 2 shows that the most severe accidents with motorcycles occur in urban areas which could be attribute to increased traffic of motorcycles and more traffic conflicts in urban areas. On the other hand, the majority of fatalities and severe injuries of car drivers mainly occur on rural areas. This may happen due to the development of higher speeds, while slightly injured drivers are more commonly observed on urban areas where driving speeds are expected to be much lower.

As to the effect of lighting conditions on accidents severity (Table 3) conclusions cannot be directly drawn, as most killed and injured drivers are observed in daytime, where there is naturally higher use of motorcycles and other vehicles. The percentage of fatally injured motorcyclists in the day is 51% against 44% at night, the severely injured percentage is 51% versus 43% and the slightly injured percentage is 60% versus 33%. The respective percentages concerning drivers of cars are similar.

According to Table 4, it is observed that in the majority of accidents with motorcycles the driver belongs to the age group of 0-34, (63%) while the respective percentage of accidents involving car drivers is 60%. Regarding the severely injured persons, the majority of motorcyclists identified in the same age category is 68% (compared to 49% for the car-drivers). The results regarding accidents where the driver was slightly injured are somewhat similar: for motorcyclists, the share at ages 0-34 is 55%, while the respective percentage for drivers of cars is 41%. This phenomenon is observed maybe due to the inexperience of young drivers, which may leads to serious errors.

Table 5 illustrates the severity levels by the type of accident. The largest percentages of fatalities (both for car and motorcycle drivers) is observed to exist in offset frontal collisions. Other types of severe accidents involve a diversion from the road (run-off road), the side collision (two vehicles) and hitting a parked vehicle (involving one vehicle). Passenger vehicles face a similar issue, where the offset of conflict is also the most common type of accident, followed by hitting a parked vehicle, diversion from the road and head-on collision.

3. Method of analysis

For the statistical processing of data and the development of models in regards to the number of killed, seriously and slightly injured, after a series of tests to find the most appropriate models, the log-linear regression method was chosen. It is noted that there are other methods of analysis for this type of data which are attempted to be analysed, but ultimately in the present work the standard log-linear (Poisson generalised linear model) was chosen, because it best describes the dependent. The statistical analysis showed the final mathematical models that capture the correlation between the examined variables and factors affecting them.

The log-linear model has an additional condition (offset) following Poisson distribution. The numerator of the ratio is set as dependent and may take positive integer values and the denominator is set as an additional term. In this study as dependent variable it is the severity of the accident, defined as the number of killed, seriously or slightly injured. As an additional condition it is set the logarithm of the respective number of registered vehicles in the fleet.

The Poisson distribution is appropriate for the development of models on phenomena occurring rarely and are independent of each other. The number of casualties is a variable, which has similar properties to the variable of the number of accidents and generally supported that road accidents usually follow Poisson distribution.

The log-linear regression is a transformation of the simple linear regression and it is used in various applications. Specifically on road safety, in surveys where the influence of various parameters examined on an index or severity of accidents is a fairly common practice. The dependent variable takes positive values. The relationship between the dependent and independent variables is not linear, but exponential.

Finally, it was decided to examine a smaller number of variables than originally chosen because the analysis does not lead to reliable conclusions due to the type of collected data, as it is shown in mathematical models developed intermediately. The process of log-linear regression is followed by a series of tests so that the parameter estimation is valid for at least the 95% confidence level: p-value <= 0.05.

4. Results

4.1 Loglinear models

Statistical analysis of the data was performed by the method of log-linear regression as described above. It is aimed to explore the parameters that influence the number of persons killed, the number of severely injured and also the slightly injured in motorcycle and in car accidents. Then a comparison with passenger car accidents is carried out. In the developed mathematical models, the dependent variable was the severity, expressed as the number of killed, severely injured and slightly injured as shown in Table 6. The mathematical relationships of the models obtained for all three types of casualties are:

Model for persons killed:

$$\begin{aligned}\ln(killed) = {} & \ln(number\ of\ vehicles) - 13.800 - 0.422 \times (urban\ area) + 0.515 \times (daylight) \\ & + 1.772 \times (one\ involved\ vehicle) + 0.661 \times (age\ 0-34) + 0.261 \\ & \times (age\ 35-54) + 0.533 \times (motorcycle) + 0.698 \times (urban\ area) \\ & \times (motorcycle) - 1.531 \times (\text{Single}-\text{vehicle accident}) \times (motorcycle) - 1.379 \\ & \times (\text{Single}-\text{vehicle accident}) \times (\ car) \end{aligned} \qquad \text{(Eq.1)}$$

Model for the severely injured:

$$\begin{aligned}\ln(seriously\ injured) & \\ = {} & \ln(number\ of\ vehicles) - 14.154 + 0.246 \times (urban\ area) + 0.530 \\ & \times (daylight) - 1.576 \times (\text{Single}-\text{vehicle accident}) + 1.076 \times (age\ 0-34) \\ & + 0.568 \times (age\ 35-54) + 0.734 \times (motorcycle) + 0.582 \times (urban\ area) \\ & \times (motorcycle) + 1.366 \times (one\ involved\ vehicle) \times (motorcycle) + 1.548 \\ & \times (one\ involved\ vehicle) \times (\ car) \end{aligned} \qquad \text{(Eq.2)}$$

Model forthe slightly injured:

$$\begin{aligned}\ln(slightly\ injured) & \\ = {} & \ln(number\ of\ vehicles) - 12.666 + 1.085 \times (urban\ area) + 1.118 \\ & \times (daylight) - 1.920 \times (\text{Single}-\text{vehicle accident}) + 0.994 \times (age\ 0-34) \\ & + 0.821 \times (age\ 35-54) + 0.808 \times (urban\ area) \times (motorcycle) + 0.592 \\ & \times (age\ 0-34) \times (motorcycle) \end{aligned} \qquad \text{(Eq.3)}$$

Table 6: Statistically significant parameter estimates of independent variables in the three models.

Independent variables	*Killed*		*Severe Injuries*		*Slight injuries*	
	Beta coefficient	*p-value*	*Beta coefficient*	*p-value*	*Beta coefficient*	*p-value*
Constant term	-13.800		-14.154		-12.666	
Urban area	-0.422	0.000	0.246	0.034	1.085	0.000
Single-vehicle accident	-	-	-1.576	0.00	-1.92	0.000
Daylight	0.515	0.000	0.53	0.00	1.118	0.000
Age 0-34	0.661	0.000	1.076	0.00	0.994	0.000
Age 35-54	0.261	0.022	0.568	0.00	0.821	0.000
One involved vehicle	1.772	0.000	-	-	-	-
Motorcycle	0.533	0.000	0.734	0.00	-	-
Urban area ×Motorcycle	0.698	0.000	0.582	0.002	0.808	0.001
Single-vehicle accident ×Motorcycle	-1.531	0.000	-	-	-	-
Single-vehicle accident × Car	-1.379	0.000	-	-	-	-
One involved vehicle×Motorcycle	-	-	1.366	0.00	-	-
One involved vehicle×Car	-	-	1.548	0.00	-	-
Age(0-34)×Motorcycle	-	-	-	-	0.552	0.040

The conclusions drawn from Table 6, by comparing the three models (through direct comparison of the parameter estimates) are discussed below.

The type of area of the accident is a factor that affects the number of slightly injured 2.6 times more than the number of killed and 4.4 times more than the number of severely injured.

The lighting conditions affect the number of slightly injured 2.2 times more than the number of killed and 2.1 times more than the number of serious casualties.

The driver's age is a critical factor for all three models. As evidenced by the values of the parameter estimates, young age has an increased number of casualties on all three models and further affect the severely injured (1.6 times more than the killed and 1.1 times more than slightly injured). Regarding the age category of 35-54 years, this factor is most influential at slightly injured (3.2 times more than killed and 1.4 times more than the severely injured).

The number of vehicles involved in the accident is the most important critical factor in the model for the killed persons, but it does not appear to be a high significant factor in the other two models (of severely and slightly injured persons).

The type of accident is the most critical factor influencing the models of severely and slightly injured, while it is non-significant in the model of the killed persons. This factor affects 1.2 times the slightly injured than the severely injured.

The type of vehicle is a critical factor in killed and severely injured models. On the contrary it was found as non-significant in the slightly injured model. In the model of severe injuries its effect is 1.4 times higher than in the model of the killed.

4.2 Sensitivity analysis

Statistical analysis of the data was performed by the method of log-linear regression as described above. It is aimed to explore the parameters that influence the number of persons killed, theIn order to gain a better understanding of the influence of the various independent variables to the dependent variables a sensitivity analysis was chosen to be conducted (Figures 1-6) for the three models. In these figures, the change in the ratio of the number of injuries (killed, severe or slight) to the total number of vehicles, in relation to age categories is illustrated for urban and rural areas (separately for motorcycles and cars). These estimates are calculated on the basis of the exp(b) (i.e. exponentials of the model parameter estimate); it is known that in log-linear models these correspond to odds ratios, i.e. the ratio of odds of being killed, seriously or slightly injured in all vehicles for one category vs. the odds of the other category.

The number of fatalities divided by the total number of vehicles in each category is higher for motorcycles than for cars in all age categories (0-34, 35-54, 55+) and in all types of areas (urban and rural). More specifically, the risk of fatal injury for motorcyclists than drivers of cars is about 3 times higher in the urban area and about 1.5 times higher in rural area.

The ratio of the number of severe injuries to the total number of vehicles in each category is also higher for motorcycles than for cars in all age categories (0-34, 35-54, 55+) and in all types of area (urban and rural), on the basis of the interpretation of the coefficients of the model and the sensitivity analysis. The risk of a severe injury for motorcycle drivers than drivers of cars is about 3 times higher in the urban areas and about 1.5 times higher in rural areas.

The ratio of the number of slightly injured persons to the total number of vehicles in each category is also higher for motorcycles than for cars in all age categories (0-34, 35-54, 55+) and in all types of area (urban and rural), except for ages 35-54 and over 55 in the rural areas. Therefore, the risk of light injury is higher for motorcycle drivers than drivers of passenger cars among young people, 3.5 times in urban area and 1.5 times in rural area.

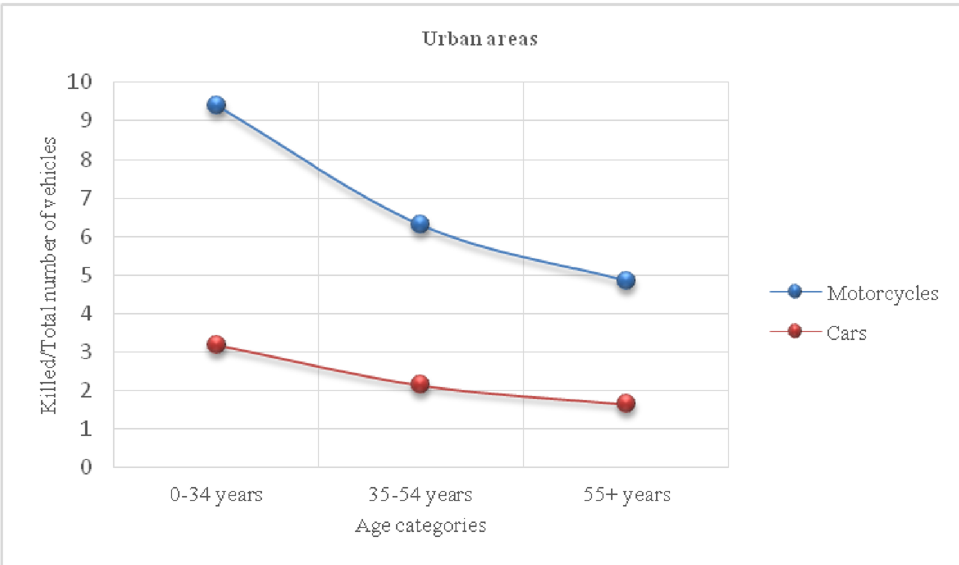

Figure 1: Sensitivity figure car vs. motorcycle in urban areas and driver age group: Killed/Total number of vehicles.

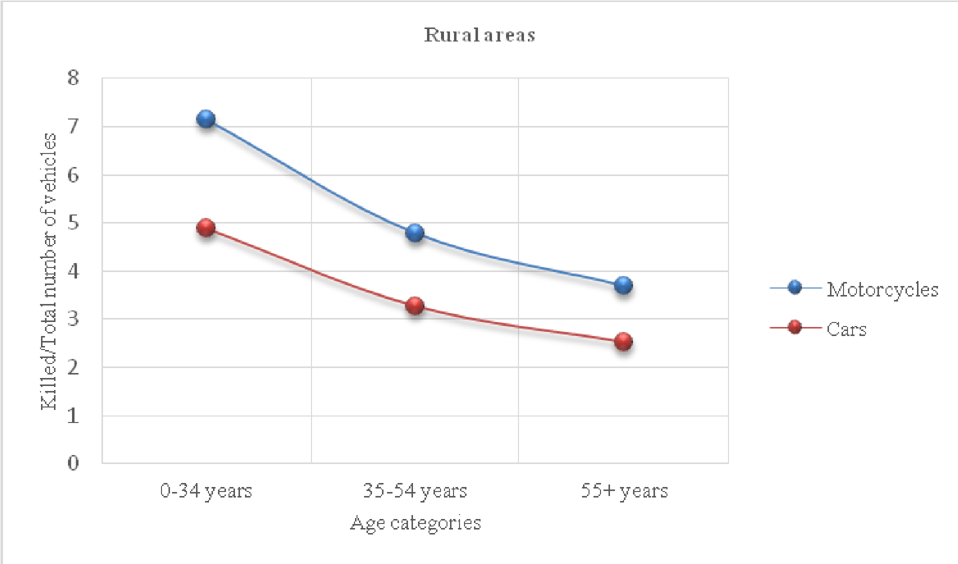

Figure 2: Sensitivity figure car vs. motorcycle in rural areas and driver age group: Killed/Total number of vehicles.

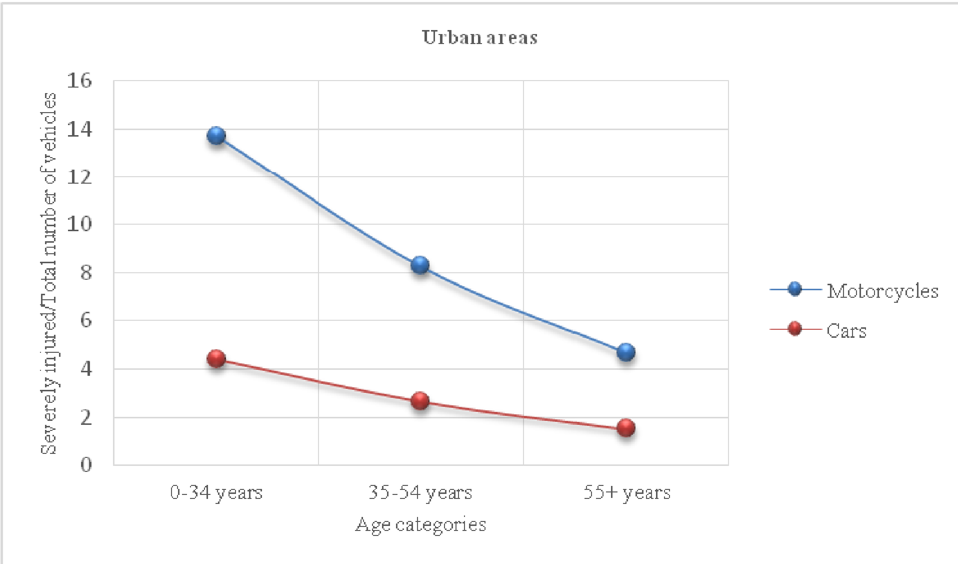

Figure 3: Sensitivity figure car vs. motorcycle in urban areas and driver age group: Severely injured/Total number of vehicles.

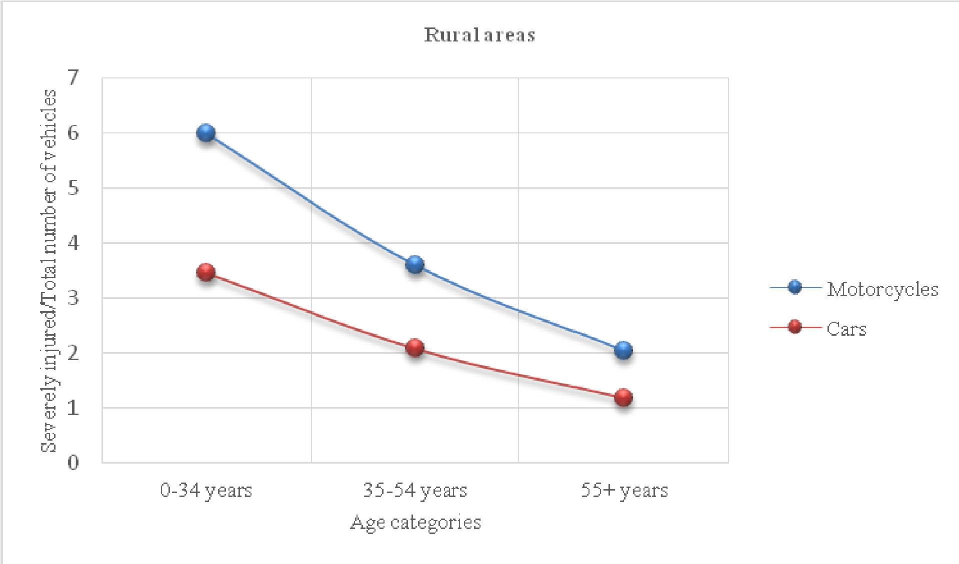

Figure 4: Sensitivity figure car vs. motorcycle in rural areas and driver age group: Severely injured/Total number of vehicles.

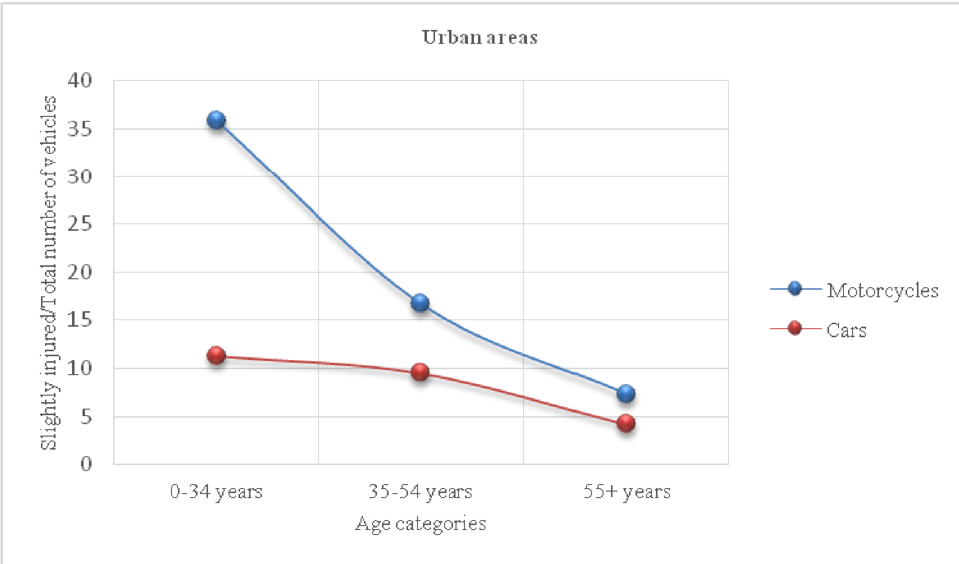

Figure 5: Sensitivity figure car vs. motorcycle in urban areas and driver age group: Slightly injured/Total number of vehicles.

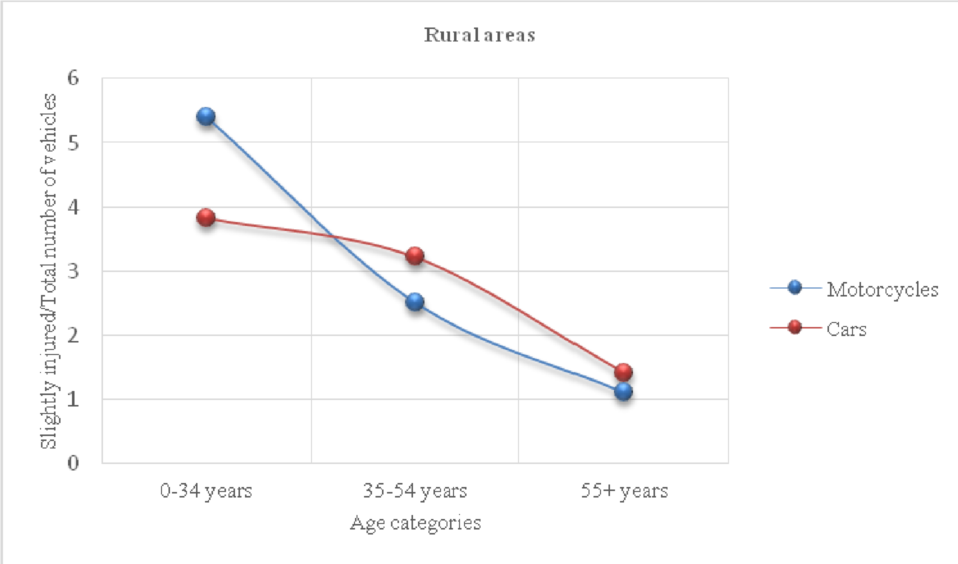

Figure 6: Sensitivity figure car vs. motorcycle in rural areas and driver age group: Slightly injured/Total number of vehicles.

5. Discussion and Conclusions

In the present study, the critical factors affecting accident severity of motorcyclists in Greece are investigated and compared with the corresponding factors affecting accidents of cars. Statistical analysis of the data in relation with the number of killed, severely and slightly injured persons was performed by log-linear regression.

Results of the fatalities model indicate that the most important influential factor is the number of vehicles involved, which is quite higher than the rest of statistically significant factors, such as the type of vehicle, lighting, age and type of area (which almost have the same effect). This magnitude of influence can be determined by the comparison of the parameter estimates of all the factors in the model. The number of vehicles involved can differentiate the severity of a collision or increase the number of persons involved in the accident, resulting in a change in the severity level of the accident.

Regarding the model of severe injuries, it was found that the most significant factor is the type of accident, which is 1.5 times more influential than the second most critical parameter (age), whilst the other parameters affect much less the number of serious casualties. The type of accident is associated with the number of vehicles involved, as in cases of run-off road collisions, pedestrian collisions or hitting a parked vehicle (or a fixed object) usually one vehicle is involved, while in cases of frontal and sideswipe collisions usually two or more vehicles are involved.

According to the slightly injured model, the type of accident is also the most important factor, followed in order of importance by lighting, the type of area and age. Similar to the model of severe injuries, the type of accident affects the severity of the accident and the number of drivers involved, and therefore the number of slightly injured.

The number of vehicles involved in the accident is more important for the severely injured rather than the killed, while it is not significant for the slightly injured.

Regarding the number of killed persons, it is influenced mainly by the type of the accident. This result could be considered as expected, considering the forces developed by the collision of one or more vehicles. With regard to the severely injured number, it is affected by the vehicle type (motorcycle or passenger car). For example, large forces can be deployed during the conflict but the driver passive systems provide enhance safety (e.g. airbags). A rider involved in a slight accident might get more severely injured than car drivers, because of the small size of the motorcycle and also the lack of protection. However, for the slightly injured, the type of vehicle has no significant effect.

The type of area is a factor that affects the number of slightly injured 2.6 times more than the number of killed and 4.4 times more than the number of severe injuries. Indeed, in urban areas vehicles moving at slower speeds due to congestion and traffic control, so the injury severity is lower.

The lighting conditions affect the number of slightly injured 2.2 times more than the number of killed and 2.1 times more than the number of serious casualties. Accidents occurring at night may be due to poor visibility at junctions.

The driver's age is a critical factor for all three models. Young persons have an increased number of injuries in all three models. The greatest effect can be observed in the severely injured model (1.6 times more than the killed and 1.1 times more than slightly injured). Regarding the age category of 35-54, it was found to be the most influential factor for the number of slight injuries, namely 3.2 times more than the killed and 1.4 times more than the severely injured. This finding is considered expected, as young people tend to drive more risky, by developing higher speeds or without using protective helmets, since they often underestimate the probability of an accident. At the same time, lack of experience in their behaviour in everyday driving during dangerous situations is observed.

Further research on this topic should be carried out. For example, investigations of all the raised issues of this study could be conducted, in order to compare the data and the results of studies in Greece and Europe. Future research could be extended by considering other potential risk factors of motorcyclists, such as the geometric characteristics of the road, the existence of intersection, manoeuvring vehicles, alcohol consumption, the purpose of the travel, helmet use and lastly the impact of speed and traffic conditions. Similarly, the attitudes of motorcycle and moped riders could be examined so as to have explore the entire sample of Powered-Two-Wheelers (PTWs) in Greece. Comparisons among Mediterranean countries with the greatest share of motorcycles in Europe (Italy, Spain) would also add to current knowledge. Lastly, it would be worth to investigate the effect of other potential risk factors such as the interaction of motorcyclists and other motorized users, the use of smart systems and riding style on the severity of accidents.

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