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Factors influencing accident severity: an analysis by road accident type

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Abstract

Nowadays, road safety is an issue particularly relevant because of the increasing occurrence of road accidents. For this reason, it is very important to analyze accident severity and the factors influencing it. This paper aims to investigate on the characteristics that can influence the severity of an accident by distinguishing between the various types of accident (e.g. front/side collision, rear-end collision). The included related factors were grouped in different categories referring to road, external environment, and driver. The proposed analysis has the specific objective to discover the possible differences between accidents severity expressed through information such as the number of dead or injured persons in terms of factors influencing the various crash types. The method proposed to this aim is the logistic regression, which is able to determine the weight of each factor involved in the analysis on accident severity. The emerging results suggest that there are interesting differences between accidents type. The findings show that logistic regression as used in this research is a capable tool in providing significant interpretations that can be used for future safety improvements in Italy.

Keywords: accident severity; binary logistic regression; type of road accident

1. Introduction

Road safety has always been a topic of fundamental importance for scientific research. One of the aspects more investigated is represented by road accidents, which cause direct impact on the social environment due to the death or the permanent disability of many people, and an economic problem owing to the expenses taken for compensating damages to property or people (Eboli and Mazzulla, 2008; de Oña et al., 2014).

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During the last year, road accidents produced in Italy about 20 billion EUR of damages, corresponding to 1.1% of the national Gross Domestic Product (GDP) (ACI, 2017). The great number of road accidents and their effects justify the importance of analyzing the factors that impact on accident severity (de Oña et al., 2011). Traditional considerations of road safety focus on physical environment, vehicle and road user (Cardamone et al., 2014), and factors affecting accident severity can be included in the following main groups: driver's characteristics, road's and vehicle's features, accident's characteristics, and weather factors (Kopelias et al., 2007; Chang and Wang, 2006).

Human factors have a relevant impact on accident severity. For this reason, many authors also focus on driving behavior, attitude and experience of car drivers, especially in the last few years where using mobile while driving and speeding driving behavior have become usual behavior among people, particularly among young people (Machado-León et al., 2016; Cardamone et al., 2016; Cardamone et al., 2017; Choudhary and Velaga, 2017).

Most of the works in the literature investigate on all the factors affecting road accidents in order to reduce the number of accidents and their severity (Al-Ghamdi, 2002). Generally, the severity of road accidents can be evaluated in terms of human fatalities and injuries. According to the literature review, we found various studies investigating on the factors affecting accident severity, which adopted different kinds of mathematical models for identifying the weights of the various factors on the severity of an accident. The use of logistic regression models is quite common since the outcomes of interests are usually the occurrence (or non-occurrence) of an event like a crash (Bangdiwala, 2018). As an example, logistic regression models were proposed by Al-Ghamdi (2002), Yau (2004), Chen et al. (2012), Theofilatos et al. (2012), Kadilar (2016), Potoglou et al. (2018), Zeng et al. (2019).

In order to give a useful contribution to the literature, we propose a study analyzing several characteristics concerning road, environment, driver, and accident characteristics, which can have an influence on the accident severity in terms of dead or injured persons. However, differently from the large part of the previous studies, we propose models where road accidents type is taken into account. A binary logistic regression is proposed in order to evaluate the impact of each considered variable on the road accidents type. Therefore, the models were specified by considering also accident severity. The specific objective of the work is to provide a more detailed analysis aiming to discover the different effect that could have a certain factor characterizing the accident on its severity by taking into account the different road accidents (front/side collision versus rear-end collision and impact with an obstacle).

The paper is organized as follows. Firstly, data used in this paper were described and statistically analyzed. Therefore, results emerging from the statistical issues of the proposed models were introduced and, finally, a discussion about the main findings was reported in a concluding section.

2. Data analysis

The proposed binary logistic regressions are implemented on the data of road accidents occurred in Italy during 2016 (Istat, 2018). The Italian National Institute of Statistics (Istat) collected these data by means of a survey carried out with the collaboration of law enforcement with local expertise (traffic police, local or municipal police, and other law enforcement) that have the possibility to collect elements characterizing road accidents. Claims from which injured persons that did not occur in areas open to public traffic, and claims in which no vehicles are involved are excluded from the survey.

In the present work we selected only accidents occurred between two vehicles and the final dataset consists of 40,172 records. The aspects related to the accidents were grouped defining four items: road characteristics, external environment, driver's characteristics, and accident features. The results of the statistical descriptive data analysis show an almost homogenous framework. As reported in table 1, the majority of the road accidents occurred within the built-up area, on a two-way roadway, at a road intersection with dry road surface, and both vertical and horizontal signposting. About external environment characteristics, more accidents were recorded during working days rather than in the weekend (although Friday recorded a little bit of increasing road accidents), during daylight hours and with sunny weather conditions. The drivers involved in road accidents are mainly males, aged between 18 and 44 years, having license for car driving acquired from 2007. The most frequent accident type is front/side collision, followed by rear-end collision. The involved vehicles are mainly cars. The number of fatal accidents is low if compared to the number of road accidents in which injuries are recorded.

In order to highlight multi-collinearity problems, correlations among the variables were calculated (Cramer's V statistic of correlation). As expected, there is a quite strong direct correlation between road surface and weather conditions (0.66), a moderate direct correlation between vehicle involved and license (0.34), road stretch and accident type (0.28), and a week direct correlation among other variables like driver's age and license issue year (0.24) (Clark and Hosking, 1986).

Table 1. Descriptive statistics.

Item	Related factors	Frequency [%]
Road	Location	Within the built-up area (78.4%); in extra-urban areas (19.2%); highway (2.4%)
	Street	A one-way roadway (16.1%); a two-way roadway (69.5%); two roadways (11.6%); more than two roadways (2.7%)
	Paving	Paved road (99.3%); paved road bumpy (0.5%); unpaved road (0.2%)
	Stretch	Roundabout (4.8%); intersection controlled by regulatory sign (35.3%); intersection controlled by traffic light (8.2%); intersection not controlled by a regulatory sign or a traffic signal (1.9%); rail crossing (0.1%); straight stretch (41.6%); curve (6.4%); speed bump, bottleneck (0.4%); slope (1.0%); lit and unlit gallery (0.3%)
	Surface	Dry (85.1%); wet (14.3%); slippery (0.4%); icy (0.1%); snowy (0.1%)
	Signposting	Absent (7.2%); vertical (8.7%); horizontal (8.0%); vertical and horizontal (75.7%); provisional, construction site (0.4%)
External environment	Day of the week	Monday (14.9%); Tuesday (15.3%); Wednesday (15.8%); Thursday (15.2%); Friday (16.2%); Saturday (13.5%); Sunday (9.0%)
	Weather conditions	Sunny (84.8%); fog (1.0%); rain (8.6%); hailstorm (0.1%); snow (0.1%); strong wind (0.1%); other (5.3%)
	Hour	Morning [6:00-14:00] (40.6%); afternoon [14:00-19:00] (42.6%); evening [19:00-23:00] (12.4%); night [23:00-6:00] (5.0%)
	Season	Winter (21.4%), Spring (27.2%); Summer (26.4%), Autumn (25.0%)
Driver	Age	<18 (0.9%); 18-44 (52.6%); 45-65 (32.9%); >65 (13.5%)
	Gender	Male (71.4%); female (28.6%)
	License	License for driving two-wheeled vehicle (4.9%); license for car driving (87.2%); license for HGV driving (7.4%); license for disabled person (0.3%); driver's permit (0.1%); not provided (0.1%)
	License issue	Before 1976 (2.3%); 1977-1986 (6.5%); 1987-1996 (9.9%); 1997-2006 (14.4%); 2007-2016 (67.0%)
Accident	Crash type	Front/side collision (67.9%); Rear-end collision (27.8%); impact with another stationary vehicle or obstacle (4.3%)
	Vehicle	Car (80.8%); HGV (7.6%); two-wheeled vehicle (10.5%); other vehicles (1.0%)
	Dead within 24 hours	0 (99.0%); 1 (0.8%); 2 (0.1%); >3 (0.1%)
	Dead within 30 days	0 (99.7%); 1 (0.2%); 2 (0.1%)

Firstly, a binary logistic regression model was developed for investigating the influence of road-related factors, environment-related factors, driver-related factors, and accident-related factors on the road accidents type. Therefore, logistic regression was used to test the relationship between the response variable (road accident type) and the related potential factors and to rank the relative importance of the independent variables. This kind of regression method can be applied when the dependent variable Y is dichotomous. The explanatory variables can be dichotomous, nominal, ordinal or quantitative (Hosmer and Lemeshow, 2013).

We considered road accidents type as a binary dependent variable in the model, recoded in two levels: 0 for accidents where a rear-end collision between two vehicles or an impact with another stationary vehicle or obstacle were occurred; 1 where a front/side collision between two vehicles was occurred. In the proposed model, the logit was the natural logarithm of the odds that the response variable Y was a front/side collision accident (Y=1) versus a rear-end collision or an impact with another obstacle (Y=0).

The variable characterising road accidents are mainly nominal variables and result adapted to be coded as dichotomous. Definitively, all the explanatory variables were defined as dichotomous where the values 0 and 1 were established as reported in table 2 by considering the results obtained from the statistical descriptive analysis. The value 1 was assigned to the level that occurs more frequently, and the value 0 to the cases that have the lowest frequencies. The variable related to road paving was excluded by the analysis because of their invariability inside the sample (paved roads are over 99% of the cases). On the contrary, we decided to not exclude from the analysis the variable weather conditions, despite a certain correlation with road surface variable.

Table 2. Classification and description of independent variables.

Item	Variable	Definition and assignment
Road	Location	0 = in extra-urban area
		1 = within the built-up area
	Street	0 = one-way road
		1 = two-way road
	Stretch	0 = no intersection
		1 = intersection
	Surface	0 = other conditions
		1 = dry
	Signposting	0 = other cases
		1 = vertical and horizontal
External environment	Day of the week	0 = festive
		1 = weekday
	Weather conditions	0 = other cases
		1 = sunny
	Hour	0 = evening or night
		1 = morning or afternoon
	Season	0 = autumn or winter
		1 = spring or summer
Driver	Age	0 = > 45 years
		1 = < 45 years
	Gender	0 = female
		1 = male
	License	0 = other licenses
		1 = car license
	License issue	0 = before 2006
		1 = after 2006
Accident	Crash type	0 = other accidents
		1 = front/side collision
	Vehicle	0 = other vehicles
		1 = car
	Severity	0 = only an injured person
		1 = more injured persons and dead

When a first model was developed, we performed a binary logistic regression by considering road accident type. The variable describing accident severity was defined by considering the number of dead persons within 24 hours, the number of dead persons within 30 days, and the number of injured persons. More specifically, we recoded the variable in two levels: 0 for accidents where one injured person is recorded, 1 for accidents where there are more injured or dead persons. In other words, the first level refers to not much serious accidents, whereas the second level includes serious and fatal accidents. Two binary logistic regression were performed: one for not much serious accidents (only one injured person), and one for serious and fatal accidents (more injured or dead persons).

3. Results

Three models were proposed, namely Model 1, Model 2 and Model 3. The Goodness-of-fit and model results are reported in tables 3, 4 and 5. Model 1 refers to a binary logistic regression where the relationship between road accident type and road, environment and driver-related factors were investigated. Model 2 and Model 3 refer to binary logistic regressions including the same variables of Model 1, where in Model 2 only not much serious accidents were considered, and in Model 3 only serious and fatal accidents.

Table 3. Goodness-of-fit.

Goodness of fit	Model 1	Model 2	Model 3
-2 Log likelihood	46,186.662	29,357.420	16,583.640
Cox & Snell R Square	0.211	0.219	0.210
Nagelkerke R Square	0.281	0.291	0.280
No. of observations	40,172	25,761	14,411

Goodness-of-fit showed in Table 3 highlighted Nagelkerke R Square having similar values (about 0.28). As in previous studies adopting logistic regression, the obtained values are not very high when compared to R Square values typically encountered with good linear regression models. However, as argued by certain authors, low R Square values in logistic regression are the norm and thus this indicator is not recommended as a measure of model goodness (Hosmer and Lemeshow, 2013).

Table 4. Classification table.

	Model 1			Model 2 (severity = 0)			Model 3 (severity = 1)		
	Predicted			Predicted			Predicted		
Observed	Other accidents	Front/side collisions	% correct	Other accidents	Front/side collisions	% correct	Other accidents	Front/side collisions	% correct
Other accidents	3,358	9,526	26.1	1,629	6,346	20.4	1,710	3,199	34.8
Front/side collisions	2,553	24,738	90.6	1,284	1,6502	92.8	1,058	8,444	88.9
Overall Percentage			69.9			70.4			70.5

The classification table shows that the model is mostly effective in predicting the crash type. Although the correct percentage of front/side collision prediction is almost lower, the overall percentage remains satisfactorily high (about 70.0%) which is a generally accepted percentage (Yannis et al., 2011).

All coefficients of the model were tested by using the Wald statistic. We can observe that most of all the variables were significant at 1% level of significance. Only few variables were not significant or significant at 10% level. More specifically, gender appears as a not significant variable in our analysis, although several authors founded different issues as discussed in the concluding section. All the other variables were statistical significant for the Model 1, highlighting the relative importance of each road, environment and driver-related factors included in the analysis in any case where an accident occurred (with or without dead persons or more than one injured).

By considering the values of B coefficients, we can notice that stretch type (accident occurred at a road intersection or not) is the road-related factor mainly affecting the nature of the crash accidents, followed by street type (one-way or two-way roads), location (within the built-up area or not), signposting (vertical and horizontal signposting or not) and hour of the day (daylight or not).

Table 5. Model results.

	Model 1				Model 2 (severity = 0)				Model 3 (severity = 1)			
Variable	B	Wald	Sig.	Exp(B)	B	Wald	Sig.	Exp(B)	B	Wald	Sig.	Exp(B)
Location	0.331	162.203	***	1.392	0.492	199.124	***	1.635	0.060	2.189	*	1.062
Street	0.501	448.832	***	1.651	0.380	166.241	***	1.462	0.739	332.732	***	2.094
Stretch	1.290	2967.983	***	3.632	1.217	1711.825	***	3.378	1.447	1280.473	***	4.252
Surface	-0.179	17.898	***	0.836	-0.062	1.352	n.s.	0.939	-0.369	28.559	***	0.691
Signposting	-0.305	139.262	***	0.737	-0.332	100.897	***	0.717	-0.287	46.665	***	0.750
Weather conditions	0.093	4.976	**	1.097	0.109	4.297	**	1.116	0.047	0.482	n.s.	1.049
Day of the week	-0.172	41.414	***	0.842	-0.175	24.958	***	0.839	-0.211	25.587	***	0.810
Hour	-0.284	94.275	***	0.753	-0.203	28.331	***	0.816	-0.449	95.625	***	0.638
Season	0.123	28.891	***	1.131	0.107	13.665	***	1.113	0.142	13.839	***	1.153
Age	-0.158	45.911	***	0.854	-0.206	50.008	***	0.814	-0.062	2.469	*	0.940
Gender	-0.004	0.034	n.s.	0.996	-0.018	0.339	n.s.	0.982	0.008	0.036	n.s.	1.008
License	0.151	20.045	***	1.163	0.100	5.811	**	1.105	0.219	13.583	***	1.244
License issue	0.076	9.644	**	1.078	0.007	0.054	n.s.	1.007	0.184	20.245	***	1.202
Vehicle	0.118	16.469	***	1.125	0.126	12.893	***	1.134	0.126	5.476	**	1.134

*** Significance at 1% level, ** Significance at 5% level, *Significance at 10% level.

By comparing Models 2 and 3 results we can observe that surface conditions affect crash type in a different way: when a not much serious road accident occurs surface conditions are not significant in predicting crash type, whereas a such road-related factor significantly affects crash type when a very serious accident occurs. More specifically, a front/side collision is less probable when road surface is dry (0.691 times less probable respect to other not dry conditions).

Similarly, when a not much serious road accident occurs licence issue is not significant in predicting crash type, whereas a such driver-related factor significantly affects crash type when a very serious accident occurs (1.202 times more probable). More in detail, having a car license seems to favour front/side collisions, especially in the case of serious accidents where a front/side collision results 1.244 more probable when the driver has a car license.

Conversely, weather conditions affect only the model considering not much serious road accidents, whereas a not significant value is obtained when serious road accident occurs. In particular, we can notice that when is sunny we have a higher probability to incur in a front/side collision (1.116 times more probable respect to other weather conditions).

At the conclusion, when the accident severity is not considered (Model 1), road-related factors mainly affect the nature of crash accidents. Taking into account accident severity, factors that more influence the probability that a front/side collision to be occurred are again road-related factors. In the case of not much serious accidents (Model 2), a relevant role is played also by environment-related factors. On the contrary, when serious accidents are considered (Model 3), driver-related factors seem to be an important effect on the probability to have a front/side collision.

4. Discussion of the results and conclusion

The findings obtained from the present work seem consistent to the results of the previous studies reported in the literature where the variables related to the main items that impact on the accident severity were included. Even if in the studies the treated variables are different, the majority of them proposed logistic regression analysis.

As an example, Al-Ghamdi (2002) found that accident location is significantly associated with a fatal accident. Also in our work, location impacts on accident severity.

Yau (2004) examined factors causing accident severity of three vehicle types via logistic regression models; the research found that each vehicle type significantly exhibited different accident severity factors. In addition, day of week and time of the accident showed a significant relationship with accident severity levels of motorcycle type. In our work, vehicles affect the crash type, but differences among the levels of accident severity are not relevant. Concordant results were found with respect to the other factors.

A logistic regression method was applied to a set of traffic collision data also for analyzing the factors that impact crashes severity at intersection (Chen et al., 2012). Factors as driver's age and gender, time of day, and crash type, were found to be statistically significant. The study indicated that male drivers were more likely to be involved in an intersection crash leading to a fatal outcome than their female counterparts. In relation to age, drivers aged 65 and above have higher odds of involvement in fatal intersection crashes than other age groups. In our study, gender appears as not significant, and drivers aged below 45 years have lower probability to be involved in a front/side collision, and this probability decreases considering not much serious accidents.

The research proposed by Theofilatos et al. (2012) aims to identify and analyze the factors affecting accident severity differentiating between inside and outside urban areas. From the two binary logistic regression models developed, it appears that inside urban areas types of collisions, as well as involvement of motorcycles, bicycles, buses, age groups, time of accident, and location of the accident, seem to affect accident severity. Outside urban areas, types of collisions, weather conditions, time of accident, one age group, and involvement of motorcycles and buses were found to be significant. In the same way, in our work inside urban areas the probability of a not much serious accident increases.

Kadilar (2016) developed a conditional logistic regression model to identify the factors, among drivers, roadway/environment, collision, and vehicle characteristics that could be associated with driver crash severity in Turkey. The results demonstrated that age, roadway condition, roadway type, time of day, collision location, and collision type were important determinants of accident severity. However, gender, roadway surface, and weather condition were found to have statistically insignificant effects on accident severity. Also in our study, gender is not significant on crash type, even when accident severity is taken into account.

Potoglou et al. (2018) examined the associations between the severity of non-fatal accidents in the City of Palermo, and driver and accident characteristics, road conditions, and seasonality of accident severity. Findings from a mixed-effects logistic regression model highlighted that the severity of non-fatal accident injuries was significantly associated with driver's age and seasonality. A similar result was obtained in our study, where the weight of age on crash type is higher considering the not much serious accidents.

Another study (Zeng et al., 2019) proposes a Bayesian spatial generalized ordered logit model using a one-year crash dataset collected from the Kaiyang Freeway in China. The results suggest that severe crashes are more likely to occur when professional drivers, trucks or other heavy vehicles are involved, in summer and sunny days, before dawn, for angle crashes, under light traffic conditions. Even in our work, the license and vehicle type, weather conditions, hour, and intersection impact on crash type with a different relevance related to the accident severity.

Compared to the studies already present, the proposed work aims to provide a useful contribution to the literature. The different effects of road-related factors, environment-related factors, driver-related factors, and accident-related factors on severity are investigated. Specifically, the results show that road-related factors mainly affect the nature of crash accidents, being the stretch type (road intersection or not) the variable having the highest impact. In addition to stretch, also street (one-way or two-way roads), location (within the built-up area or not) and signposting (vertical and horizontal signposting or not) significantly affect the occurrence of an accident type. Other important factors are environment-related factors (as hour of the day), driver-related factors (as license type), and accident-related factors (as vehicle type). Gender is not significant.

By considering not much serious accidents only, the factors mainly impacting on the accident type are stretch, location and street (road-related factors), age (driver-related factors), hour and day of the week (environment-related factors), and vehicle (accident-related factors). In addition to gender, also surface and license issue are not significant. On the other hand, in serious accidents the factors that play a relevant role are stretch, street and surface (road-related factors), hour of the day (environment-related factors), license and license issue (driver-related factors). In this case, gender and weather are not significant.

Regardless of accident severity, interventions on road-related factors seem to be essential to improve rod safety. Accordingly, road safety could be increased by improving road intersections and urban roads design, and promoting one-way roads use. For limiting not much serious accidents, traffic conditions need to be improved for increasing the road safety, especially during the night. Finally, for reducing the occurrence of serious accidents, also driver-related factors could be better controlled with the collaboration of law enforcement, because front/side collisions are more probable when a car driver is less expert.

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