Contents lists available at GrowingScience

Decision Science Letters

homepage: www.GrowingScience.com/dsl

The effect of road types on severe road accidents in Peru

Rosita de los Ángeles Caisahuana Indigoyen[a*], Sheylla Leydi Cuyutupac Osores[a], Stefany Andrea Curichimba Macedo[a] and Ángel Narcizo Aquino Fernandez[a]

[a]*Universidad Continental, Peru*

C H R O N I C L E

Article history:
Received: July 9, 2022
Received in revised format: November 20 2022
Accepted: December 14, 2022
Available online: December 14, 2022

Keywords:
Road accidents
Multi-logit
Peruvian roads
Accident types
Road classification

A B S T R A C T

It is not a secret that road accidents cause significant suffering. Those accidents can last from wounded to dead people, negatively impacting a country. A bunch of recent investigations tried to tie road accidents with the quality of roads. Therefore, in a country with a significant infrastructure gap, it is necessary to analyze the relationship between the different kinds of roads and the severity of car accidents. The current research examined such a relationship by employing the Multi logit regression. It was found that the significance of different car accidents will vary among the road types. Moreover, with the help of probability analysis, it was discovered that speeding, emergency services availability, and road security seemed to have a crucial impact on road accidents.

1. Introduction

Death by road accidents is the eighth deadcause worldwide (World HealthOrganization, 2018). It is even deadlier than several types ofcancer or viruses (World Bank,2017). This trend is expected to grow in thefollowing years, becoming the fifth cause of death in the next decade (World HealthOrganization, 2018). Unlike many diseases, this death isalmost evitable. Villalobos andHernándes (2013) state that the leading cause of deadly caraccidents is speeding, alcoholism, pedestrian recklessness, driver imprudence,and mechanical failure. However, thereare external factors that influence car accidents. These factors areprincipally the road infrastructure and climate issues.

Developed countries have focused on drivers' education and correctly maintained their high-quality road systems. However, this scenario does not replicate in developing countries. Therefore, Shen et al. (2014) found that it is expected that road accidents have a significant increase in developed countries than in developing ones. Indeed, half of all deadly car accidents happen in middle and low-income countries (Peden & Di Pietro, 2017). Therefore, efforts have been taken to reduce car accident deaths by focusing on safe driving education. Also, sanctions became harder for drivers to discourage reckless driving (Goldenbeld, 2018). However, it does not seem to be enough in those countries (Lee, 2012).

For instance, in Peru, the number of road accidents has been increasing all the years except for 2020 (Superintendencia de Transporte Terrestre de Personas, 2021). It is widely known that due to covid 19 restrictions, the country locked down its population, which reduced the incidence of deaths by car accidents by almost 44%. Surprisingly, locking down the people and establishing restrictions on the free circulation of cars seemed to be the most effective measure to reduce car accidents in Peruvian history (Dirección de Seguridad Vial, 2021). However, this measure is not sustainable at the time.

* Corresponding author.
E-mail address: 71658190@continental.edu.pe (R. d. l. Á. Caisahuana Indigoyen)

doi: 10.5267/dsl.2022.12.003

After the restrictions by covid, the country continued its policy, compounded by driver's education, vial education, car supervision, and sanctions (Superintendencia de Transporte Terrestre de Personas, 2022). Nonetheless, these actions proved insufficient to prevent car accidents in a country that increases their cars by 10% annually (Posada, 2018). Moreover, this trend seems to double or even triple in the following decades (Dirección de Seguridad Vial, 2021). It means a significant demand for the national road infrastructure, which, as Bonifaz et al.(2020), has an offer gap of more than 72 billion dollars. It is expected then that over-employed roads become dangerous for both drivers and pedestrians.

In a country with only 1300 kilometers of highways, 20 000 kilometers of two-way roads, and more than 140 000 kilometers of non-asphalted roads is necessary to establish a possible impact of the deficient Peruvian road systems on car accidents (Bonifaz et al., 2020). Therefore, this research will analyze the effect of road types and car accidents in Peru.

2. Literature review

After an extensive literature review, the current research could only find two direct antecedents. Both of them studied in China. In the first one, Sun et al. (2021) analyzed the influence of road types on road traffic accidents in a northern Chinese province. By employing the road traffic accidents dataset from 2009 to 2018 of the Guizhou Province, the study could understand the relationship between the road types of this Chinese province and their road accidents. The road classification employed in this research was as follows: administrative road, functional road, public urban road, and urban expressway. The statistical method to analyze the characteristics of road collisions was the Chi-square. The study found that administrative roads were the most dangerous in the province. A reason for this finding was the geographical characteristics of this part of China.

The second study was performed by Tsubota et al. (2018). This research aimed to establish the relationship between road pavement and road accidents. This study points out the importance of good road maintenance, established as a risk factor in the analysis. The pavement condition was classified according to their age. Here, the period of construction or its total repair was counted. The Poisson regression model was employed to analyze the collected data. After the analysis, a positive relationship between pavement age and accident risk and the differences in risks according to road condition was found.

Other studies, like the one by Shiomi et al. (2017), studied the relationship between geometric road attributes and traffic accident risks. This study was focused on urban placements where the length of crosswalks and their setback distance impact car accidents. This research found a positive relationship between these characteristics and road accident risks. Similarly, Chin & Quddus (2003) studied the occurrence of traffic accidents at specific signalized intersections employing Poisson and the negative binomial model. The study found that approach volumes, the number of phases per cycle, left-turn lane, and cameras was significant when explaining the car accidents in these intersections.

In highways, Son et al. (2011) studied the incidence of road accidents on Virginia highways. They found that the characteristics of specific road sectors were more prone to car accidents than others. Additionally, the influence of traffic on car accidents was studied by Lee et al. (2003). During thirteen months, this research examined the positive impact of traffic jams and car accidents on the Gardiner Expressway.

In the previous studies, it was possible to establish the determinants of road accidents in both urban and interurban zones. The necessity to reduce the incidence of car accidents by using statistical methods proves the importance of this issue. Such worry is understandable since Yannis et al. (2014) study found that car accidents negatively affect a country's gross domestic product. Therefore, what is the relationship, if any, between car accidents and road types in Peru?

3. Methodology

The current study employed Sutran's dataset. It contained the record of car accidents and their death toll. Since the data belonged to Peruvian roads, their authorities classify them as national, departmental [regional], and local. However, they are classified according to the authority jurisdiction, not by their infrastructure. Hence, following the literature review, we ranked them into highways, asphalted double-way, and non-asphalted roads. For methodological purposes, we assigned the highways the number one, asphalted double way roads the number two, and non-asphalted roads the number three.

It is necessary to mention that the Peruvian authorities classify road accidents as follows: run-over, crash, run-off the road, and particular and roll-over accidents. All of those accidents can involve one vehicle or more than one. Special accidents mix more than one accident or are not included in the other ones, i.e., firing. For methodological purposes, we assigned from number one to five the road accidents starting with run-over and ending with roll-over as the list provided above. The evaluated dataset comprises 8 127 records from January 1st, 2020, to December 31st, 2021. Then, the collected data was daily.

For accident severity, it was necessary to classify them according to Peruvian law. The Peruvian law considers that if an accident causes wounded people, it is essential to punish the driver according to the severity of the wounds. Generally, it does not include the jail penalty. Therefore, the current research assigned number one to those accidents that caused injuries. Furthermore, the Peruvian law tends to punish with jail when the accident causes death. Then, accidents with wounded and dead people will be assigned with the number two. Of course, an accident that caused only dead people will be the worst.

Then, it will have the number three. It is known that an accident does not necessarily carry human damages; for those accidents with no human casualties, the number assigned was zero.

For analyzing the huge dataset provided by Sutran, it was necessary to employ the Multilogic model and its odds analysis. Then, it was required to utilize STATA for the statistical analysis.

3.1 Variables

The dependent variable will be the severity of the accidents recorded by the dataset. The independent variables were two: road type and accident type. Then, the first independent variable had three indicators, and the classification was written in the previous section. Meanwhile, the accident type variable was subdivided into 5, the accidents category given by SUTRAN and provided in the last paragraph.

3.2 Empirical Methods

Since the variables were categorical, it was necessary to go after logistic regression. However, since the current study wants to know the incidence of each variable's indicator, it was required to employ a multi-logit regression.

3.3 Multiple Logistic Regression

Multiple Logistic Regression is an extension of binary logistic regression. Indeed its main difference is allowing more than two categories for the dependent variable (Schafer, 2006). Like binary logistic regression, this regression evaluates the odds of categorical membership (Starkweather & Kay, 2002). Although this regression does not need the assumption of normal distribution, linearity, or homoscedasticity, it is still necessary to check for independence among their variableس (Schafer, 2006). In other words, it prohibits the relationship between a membership choice in one category and another. There are ways to evaluate this condition. One is by applying the Hausman, while it is possible to do so by an alternative test like the one of Small-Hsiao (Vijverberg, 2021). McFadden test. Moreover, El-Habil (2012)considers it essential to have a large sample for this kind of regression. Hence, it is necessary to have a critical sample size to get robust results.

The multiple logistic regression comes from the logistic regression (El-Habil, 2012). Hence, if we let K designate some predictors for a binary outcome, Y, by $x1, x2, \ldots, xk$, the model is $Logit[P(Y=1)] = \alpha + \beta_1 x_1 + \cdots + \beta_k x_k$. If we specify π (x), then: $\pi(x) = \frac{\exp(\alpha+\beta_1 x_1+\cdots+\beta_k x_k)}{1+\exp(\alpha+\beta_1 x_1+\cdots+\beta_k x_k)}$

Here, β_i represents the effect of x_i on the logs of *Y*=1 commanding other x_j. Likely, exp (β_i) becomes the multiplicative effect of a unit increase in x_i controlling other x_j. When the research has *n* observations with p-regressors and multiple categories in the qualitative response, it is necessary to put one logit into a base level, and the other be built around it (Schafer, 2006). Since any category can be taken as a base level, for explanatory purposes, the category called k will be the base level (El-Habil, 2012). Also, π_j is the probability of an observation in the *j^th^* category. If we would like to find a relationship between this odd and a set of explanatory vairbles $x_1, x_2 \ldots$, the multiple logistic regression will be: $\log\left[\frac{\pi_j(x_i)}{\pi_k(x_i)}\right] = \alpha_{0i} + \beta_{1j}x_{1i} + \cdots + \beta_{pj}x_{pi}$. When adding π to the unity, it reduces to: $\log\left(\pi_j(x_i)\right) = \frac{\exp(\alpha_{01}+\beta_{1j}x_{1i}+\cdots+\beta_{pj}x_{pi})}{1+\sum_{j=1}^{k-1}\exp(\alpha_{01}+\beta_{1j}x_{1i}+\cdots+\beta_{pj}x_{pi})}$

Therefore, for j =1, 2, …, (k-1), the multiple logistic regression calculates the model provided.

4. Results

In Table 1, it can be seen that the majority of accidents left people wounded, almost 50% of cases. Moreover, it can be seen that the majority of people who died in a road accident happened on an asphalt roadway. However, most casualties that were not wounded or dead occurred on asphalted roads. Although the non-asphalted roads had fewer accidents, they had a considerable number of people who were injured or departed from the accident.

Table 1
Descriptive statistic between accident severity and road type

	Highway	Asphalted	Non-asphalted	Total
No wounded nor dead	742	2132	84	2958
Wounded	1125	2945	151	4221
Wounded + dead	132	303	20	455
Dead	158	318	17	493
Total	2157	5698	272	8127

Table 2 shows the interaction between the severity of the accidents and the type of accident. It can be observed that most people who died suffered crashes on the road, while the least was from roll-over accidents. It is necessary to add that in Peru, many crashes happen because of head-on collisions when overtaking due to the design of the asphalted roads. Moreover, the accidents that left wounded and dead people also happened because of crashes in most cases.

Table 2
Descriptive statistics between accident severity and accident type

	Run over	Crash	Run off the road	Special	Rollover	Total
No wounded nor dead	39	1058	1664	129	68	2958
Wounded	167	2075	1883	42	54	4221
Wounded + deads	15	254	179	3	4	455
Dead	140	236	103	12	2	493
Total	361	3623	3829	186	128	8127

Table 3 portrays the impact of road type and accident type on accidents. It is necessary to remember, though, that the given classification explained in the Methodology part significantly impacts the relationship direction. Therefore, it is advisable to focus on finding a significant relationship among the studied variables. Thus, for accidents that cause injuries, it was found that all accident types had a relationship with highways. In the case of asphalted roads, only running over was not significant. On non-asphalted roads, crash and run-off road accidents had a meaningful relationship. For the next level of accident severity, it is observed that only running on the road had a significant effect on highways. Asphalted roads had similar relationships as in the previous analysis. For non-asphalted roads, only crashes were found to be substantial. In the deadly accidents, all road types but roll-over had significant relationships with the highway. For asphalted roads, only run-over did not have a meaningful relationship. Finally, for non-asphalted roads, it was encountered that crashing and running off-road had significant relationships.

Table 3
Relationship between road accidents and road types alongside with accident type

Road	Accident	Wounded	Wounded+deads	Deads
1	2	2.32** (-0.74)	-0.63 (-0.31)	-8.42*** (-2.79)
1	3	3.69*** (-1.17)	-3.1*** (-1.63)	-11.85*** (-4.61)
1	4	7.11*** (-3.27)	-0.02 (-17.04)	-6.38*** (-4.98)
1	5	3.54*** (-1.93)	-1.56 (-1.79)	-0.01 (-18.78)
2	1	0.04 (-0.02)	-0.57 (-0.37)	-1.2 (-0.46)
2	2	2.51** (-0.78)	-1.55 (-0.78)	-9.89*** (-3.14)
2	3	4.46*** (-1.39)	-2.95*** (-1.48)	-13.13*** (-4.29)
2	4	6.02*** (-2.30)	-3.13*** (-2.72)	-7.52*** (-3.43)
2	5	4.51*** (-1.68)	-2.72*** (-2.10)	-6.16*** (-4.82)
3	1	-0.58 (0.64)	0.52 (0.77)	0.06 (0.06)
3	2	2.03** (-0.77)	-2.04** (-1.59)	-5.97*** (3.22)
3	3	2.88*** (-1.04)	-0.68 (-0.39)	-6.84*** (-3.63)
3	4	0.05 (-0.06)	0.52 (0.77)	-0.01 (-17.54)
3	5	-0.81 (-0.75)	-0.01 (-15.96)	-0.01 (-18.19)
constant		4.68*** (1.44)	-1.57 (-0.77)	5.06*** (1.55)

Table 4 shows the odds per each scenario and combination. For the probability of accidents causing injuries, it can be observed that the lowest likelihood of suffering this kind of accident is on the highways. Moreover, it is shown that crashes and run-off road accidents had less probability of occurrence in asphalted roads while they were higher on the other two roads. For non-asphalted roads, it is more probable than other roads to suffer run-off accidents causing injuries.

Furthermore, for accidents with wounded and dead people, Table 4 portrays that it is a bit safer on highways than the other roads, especially for the probability of run-off-road accidents. Interestingly, it is less probable to suffer a notable accident that leaves wounded and dead people on asphalted roads. For the deadliest accidents, it was proven that highways had fewer probabilities than other roads to happen deadly run off-road and notable accidents. In the case of non-asphalted roads, it was seen that it is less probable to experience a deadly crash than on other roads. However, it was the most dangerous at the time of the probability of suffering a fatal run-off road accident.

It is necessary to add that the current regression fulfilled the assumption of independence between observations since the p>chi2 was .660.

Table 4
Odds of occurrence

Road	Accident	Wounded*	Wounded+deads*	Deads*
1	2	-52.11**	-27.23	-93.88***
1	3	-68.83***	-80.35***	-99.00***
1	4	-96.19***	-99.99	-99.31***
1	5	-85.45***	-83.33	-99.99
2	1	-1.67	-30.66	-36.92
2	2	-54.19**	-53.98	-95.70***
2	3	-74.98***	-77.27***	-98.63***
2	4	-89.97***	-93.43***	-96.77***
2	5	-81.27***	-87.74***	-99.20***
3	1	89.10	116.68	6.56
3	2	-53.46**	-79.69**	-96.00***
3	3	-64.54***	-32.29	-97.34***
3	4	-5.45	116.69	-99.99
3	5	-52.72	-99.99	-99.99

*percentages, ** significant at 5%,***significant at 1%

5. Discussion

The current research found significant relationships between road types and accidents. Their severity changed in every road type and combination. For instance, it was found that having a crash is more dangerous and deadlier on a highway than on a non-asphalted road. Highways are roads where speeding is expected due to the facilities they provide. Then, it is anticipated that crashes in combination with speeding have more possibilities to cause injury than having one on a non-asphalted road since drivers, due to the road condition, do not tend to overspend.

Nonetheless, it changed for a special accident since the probability of having wounded people due to this kind of accident was lower than having this one on an asphalted road. A possible reason is that Peruvian highways count on emergency systems that attend immediately in case of accidents. On the other hand, many asphalted roads are under the supervision of Provias, a state-owned firm- which is not as efficient as the private road managers.

For the next level of accident severity, the results were similar. It was seen that it was less probable to have wounded and dead people in run-off road accidents on highways than on asphalted roads. As in other accidents, the availability of emergency units seems to be vital here, too. For the deadliest accidents, it was found that it was riskier to have a running off-road on non-asphalted roads than on any other roads. Many Non-asphalted roads do not have security systems like road safety railings, proper illumination, and a total lack of emergency attendance. Then, if this kind of accident happened on a non-asphalted road, it would be more probable to find dead than in other scenarios.

Consequently, the relationship between car accidents and road type is far from having a unique answer. Each infrastructure has its own risk, which might make it more dangerous than others. Anyway, a partial relationship was found among the studied variables, as in the studies of Sun et al. (2021) and Tsubota et al. (2018). Nonetheless, the current study found an inverse relationship between road types, car accident types, and their severity. Although it might seem that it does not match entirely with the analysis of Tsubota et al. (2018), Shiomi et al. (2017), Son et al. (2011), and Lee et al. (2003), it is necessary to remember that we employed categorical variables which ranked from one to five in accident types and one to three in road types. Hence, it will vary according to the road and road accident types classification. In consequence, the odds analysis provides more helpful information than the information of coefficients.

6. Conclusion

The current analysis analyzed the relationship between road accident severity and road type. It was helpful to add the accident type to understand those relationships better. Therefore, the study found that road accident incidence and severity will differ among road types. Consequently, crashes were more severe on highways and asphalted roads than on non-asphalted streets. Furthermore, on those non-asphalted roads, the accidents like running off-road and rolling over had more chances to increase their severity than on highways. The probable reasons behind those results were the speed and the availability of emergency services.

Hence, it is necessary to make better roads, and on those roads where the quality of them is not a problem, it is compulsory to fight against speeding and other reckless behaviors.

References

Bonifaz, J. L., Urrunaga, R., Aguirre, J., & Quequezana, P. (2020). Brecha de infraestructura en el Perú: Estimación de la brecha de infraestructura de largo plazo 2019-2038. In *Brecha de infraestructura en el Perú: Estimación de la brecha de infraestructura de largo plazo 2019-2038* (First). Banco Interamericano de Desarrollo. https://doi.org/10.18235/0002641

Chin, H. C., & Quddus, M. A. (2003). Applying the random effect negative binomial model to examine traffic accident occurrence at signalized intersections. *Accident Analysis & Prevention*, *35*(2), 253–259. https://doi.org/https://doi.org/10.1016/S0001-4575(02)00003-9

Dirección de Seguridad Vial. (2021). *Boletín Estadístico de Siniestralidad Vial: I-Semestre, 2021*. https://www.onsv.gob.pe/boletin-estadistico-de-siniestralidad-vial-primer-semestre-2021/

El-Habil, A. M. (2012). An application on multinomial logistic regression model. *Pakistan Journal of Statistics and Operation Research*, *8*(2), 271–291. https://doi.org/10.18187/pjsor.v8i2.234

Goldenbeld, C. (2018). *Increasing traffic fines*. *January*.

Lee, C., Hellinga, B., & Saccomanno, F. (2003). Proactive freeway crash prevention using real-time traffic control. *Canadian Journal of Civil Engineering*, *30*(6), 1034–1041. https://doi.org/10.1139/l03-040

Lee, D. N. (2012). Do Traffic Tickets Reduce Motor Vehicle Accidents? Evidence from a Natural Experiment. *SSRN Electronic Journal*, *December 2011*. https://doi.org/10.2139/ssrn.1939586

Peden, M., & Di Pietro, G. (2017). Saving lives by improving road safety. *Public Health*, *144*(9521), S3–S4. https://doi.org/10.1016/j.puhe.2016.12.038

Posada, C. (2018). Aumento Continuo Del Parque Automotor, Un Problema Que Urge Solucionar. In *La Cámara* (Vol. 44). https://www.camaralima.org.pe/repositorioaps/0/0/par/r816_3/comercio exterior.pdf

Schafer, J. . (2006). Multinomial Logistic Regression Models. In *STAT 544-Lecture 19*. http://web.pdx.edu/~newsomj/cdaclass/ho_multinomial.pdf

Shen, Y., Hermans, E., Bao, Q., Brijs, T., & Wets, G. (2014). Serious Injuries: An Additional Indicator to Fatalities for Road Safety Benchmarking. *Traffic Injury Prevention*, *16*. https://doi.org/10.1080/15389588.2014.930831

Shiomi, Y., Watanabe, K., Nakamura, H., & Akahane, H. (2017). Assessing Safety of Signalized Intersections: Influence of Geometric Attributes and Regionality on Traffic Accident Risk. *Transportation Research Record*, *2659*(1), 71–79. https://doi.org/10.3141/2659-08

Son, H. "Daniel," Kweon, Y.-J., & Park, B. "Brian." (2011). Development of crash prediction models with individual vehicular data. *Transportation Research Part C: Emerging Technologies*, *19*(6), 1353–1363. https://doi.org/https://doi.org/10.1016/j.trc.2011.03.002

Starkweather, J., & Kay, A. (2002). Multinomial logistic regression. *Nursing Research*, *51*(6), 404–410. https://doi.org/10.1097/00006199-200211000-00009

Sun, T. J., Liu, S. J., Xie, F. K., Huang, X. F., Tao, J. X., Lu, Y. L., Zhang, T. X., & Yu, A. Y. (2021). Influence of road types on road traffic accidents in northern Guizhou Province, China. *Chinese Journal of Traumatology - English Edition*, *24*(1), 34–38. https://doi.org/10.1016/j.cjtee.2020.11.002

Superintendencia de Transporte Terrestre de Personas. (2021). *Reporte Estadístico: Accidentes de tránsito ocurridos en carreteras (a febrero del 2021)*.

Superintendencia de Transporte Terrestre de Personas. (2022). *Plan estratégico institucional 2020-2025 ampliado*. Superintendencia de Transporte Terrestre de Personas.

Tsubota, T., Fernando, C., Yoshii, T., & Shirayanagi, H. (2018). Effect of Road Pavement Types and Ages on Traffic Accident Risks. *Transportation Research Procedia*, *34*, 211–218. https://doi.org/https://doi.org/10.1016/j.trpro.2018.11.034

Vijverberg, W. (2021). Testing for IIA with the Hausman-Mcfadden Test. In *SSRN Electronic Journal* (Issue 5826). https://doi.org/10.2139/ssrn.1882845

Villalobos, L., & Hernándes, R. (2013). Accidentes De Tránsito Terrestre. *Medicina Legal de Costa Rica*, *30*(Septiembre), 6. http://www.scielo.sa.cr/pdf/mlcr/v30n2/art09v30n2.pdf

World Bank. (2017). *The high toll of traffic injuries: unacceptable and preventable*.

World Health Organization. (2018). Global Status Report on Road. In *World Health Organization*. http://apps.who.int/bookorders.