Revista Angolana de Ciências

Vol. 8, Nº 1. e080112. Janeiro – Junho, 2026
(Publicação em Fluxo Contínuo)

Traffic accidents in Ecuador (2020–2024): an econometric analysis

Acidentes de trânsito no Equador (2020–2024): uma análise econométrica

Siniestros de tránsito en Ecuador (2020–2024): un análisis econométric

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ABSTRACT

In Ecuador, road accident rates have experienced sustained growth during the 2020–2024 period, reflecting a combination of risks associated both with driver behaviour and the mechanical conditions of the vehicle fleet. In this context, the objective of this research was to econometrically analyse the determinants of traffic accidents in Ecuador during the 2020–2024 period using a multiple linear regression model. To address this, the study implemented a quantitative-explanatory and non-experimental investigation using a multiple linear regression model based on official INEC data. The variables incorporated into the model included speeding violations, alcohol and drug consumption, driver recklessness, and mechanical failures. In addition, the assumptions of the model were tested using normality, heteroscedasticity, autocorrelation, multicollinearity, and functional specification tests. The results confirm a high explanatory power, as well as positive and significant coefficients for all variables, where mechanical damages stand out as the determinant with the largest marginal impact, followed by alcohol/drug use, speeding, and recklessness. Although the model meets most assumptions, the RESET test suggests the possible omission of variables related to infrastructure or spatial effects. Altogether, this confirms that accident rates indeed respond to both human and structural factors, reinforcing the need to strengthen mechanical inspections, road safety education, and preventive strategies.

Keywords: Road accident rates; econometric determinants; mechanical failures; driver behaviour.

RECEIVED: 01/12/2025
ACCEPTED: 25/03/2026
PUBLISHED: 21/06/2026

How to cite: Cabrera, K.J., Ruales, W.J. y Garzón, V.J. (2026). Traffic accidents in Ecuador (2020–2024): an econometric analysis. *RAC: Revista Angolana de Ciências*, 8(1), e0801012. https://doi.org/10.54580/R0801.12

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E-ISSN. 2664-259X

Resumo

No Equador, os acidentes de trânsito apresentaram crescimento contínuo no período de 2020 a 2024, refletindo uma combinação de riscos associados tanto ao comportamento dos condutores quanto às condições mecânicas da frota de veículos. Nesse contexto, o objetivo desta pesquisa foi analisar econometricamente os determinantes dos acidentes de trânsito no Equador durante o período de 2020 a 2024, utilizando um modelo de regressão linear múltipla. Para tanto, o estudo implementou uma investigação quantitativa-explicativa e não experimental, utilizando um modelo de regressão linear múltipla com dados oficiais do Instituto Nacional de Estatística e Censos (INEC). As variáveis incorporadas ao modelo foram infrações por excesso de velocidade, uso de álcool e drogas, negligência do condutor e falhas mecânicas. Além disso, as premissas do modelo foram verificadas por meio de testes de normalidade, heterocedasticidade, autocorrelação, multicolinearidade e especificação funcional. Os resultados confirmam um alto poder explicativo, bem como coeficientes positivos e significativos para todas as variáveis. Os danos mecânicos destacam-se como o determinante com maior impacto marginal, seguidos pelo consumo de álcool/drogas, velocidade e imprudência. Embora o modelo atenda à maioria das premissas, o teste RESET sugere a possível omissão de variáveis relacionadas à infraestrutura ou a efeitos espaciais. Tudo isso confirma que os acidentes de trânsito são de fato influenciados por fatores humanos e estruturais, reforçando a necessidade de aprimorar os controles mecânicos, a educação para a segurança viária e as estratégias de prevenção.

Palavras-chave: Acidentes de trânsito, determinantes econométricos, falhas mecânicas, comportamento do condutor.

Resumen

En el Ecuador, la siniestralidad de tránsito ha experimentado un crecimiento sostenido durante el periodo 2020–2024, lo que manifiesta una combinación de riesgos asociados tanto al comportamiento de los conductores como a las condiciones mecánicas del parque automotor. En este contexto, el objetivo de la investigación fue analizar econométricamente los determinantes de los siniestros de tránsito en Ecuador durante el período 2020–2024, empleando un modelo de regresión lineal múltiple. Para ello, el estudio implementó una investigación cuantitativa-explicativa y no experimental mediante un modelo de regresión lineal múltiple que usa información oficial del INEC. Las variables incorporadas al modelo fueron infracciones por exceso de velocidad, consumo de alcohol y drogas, imprudencia del conductor y fallas mecánicas, además de que se comprobaron los supuestos del modelo mediante las pruebas de normalidad, heterocedasticidad, autocorrelación, multicolinealidad y especificación funcional. Los resultados confirman un alto poder explicativo, así como coeficientes positivos y significativos en todas las variables, donde se destacan los daños mecánicos como el determinante con mayor impacto marginal, seguido del uso de alcohol/drogas, la velocidad, y la imprudencia. A pesar de que el modelo cumple con la mayoría de supuestos, la revisión mediante la prueba RESET sugiere la posible omisión de variables relacionadas con infraestructura o efectos espaciales. Todo ello, confirma que efectivamente la siniestralidad responde a factores humanos y estructurales, lo que refuerza la necesidad de fortalecer controles mecánicos, educación vial y estrategias preventivas.

Palabras clave: Siniestralidad de tránsito, determinantes econométricos, fallas mecánicas, comportamiento del conductor.

Introduction

Traffic accidents constitute one of the main public health and citizen security problems in Ecuador, given the sustained increase recorded during the 2020–2024 period. This fact has not only caused a high number of fatalities and injuries but has also revealed the vulnerability of the Ecuadorian road system to human, mechanical and contextual factors that are interrelated in a complex manner. The rise in accidents reported by INEC raises the need to understand their determinants precisely in order to guide the formulation of more effective public policies.

At the international level, road safety is considered a multi-causal phenomenon, since it involves a series of behavioural, technical and structural elements. Among the factors with the greatest incidence are speeding, the consumption of psychoactive substances, driver recklessness and vehicle mechanical failures, which directly affect the occurrence and severity of accidents. In this sense, econometric analysis becomes a key tool to accurately assess the relative weight of each determinant and obtain quantitative evidence to predict risk patterns from historical data series.

From this perspective, the aim of the study is to econometrically analyse the determinants of traffic accidents in Ecuador during the 2020–2024 period using a multiple linear regression model. To this end, public information is used and statistical techniques are applied to estimate the relationship between the selected explanatory variables and road accident rates. Likewise, it seeks to generate empirical evidence that contributes to the design of strategies aimed at prevention, control and the strengthening of road safety education in the country.

General overview of traffic accidents in Ecuador (2020–2024)

Ecuador has experienced a sustained and marked increase in road accident rates during the 2020–2024 period, making it one of the main causes of morbidity and mortality in the country. According to the National Institute of Statistics and Censuses (INEC, 2025), during the fourth quarter of 2024 there were 5,631 traffic accidents, showing a variation of 1.62% higher than the same quarter of the previous year. The most common causes were driver inexperience and recklessness (38.87%), speeding (23.67%), alcohol and drugs (6.23%) and, in a proportion of 1.10%, mechanical damage to the vehicles involved. These four causes account for the majority of accidents occurring in the country, with a total of 20,614 victims, of which 18,312 were injuries and 2,302 were fatal cases.

Regarding the territory, the provinces of Guayas and Pichincha accumulated approximately 43% of the deaths, which indicates the relationship between vehicle density and accidents. Likewise, the national mortality rate was 12.81 deaths per 100,000 inhabitants, exceeding the pre-established target in the National Development Plan (12.66 deaths), which shows the stagnation of progress in reducing mortality from road accidents (National Planning Secretariat, 2024).

These results coincide with those reported by Santillán (2024), who states that road accident rates in Ecuador are a structural problem resulting from the integration of human, mechanical and contextual dimensions. The author notes that between 1998 and 2023 there were 563,634 accidents, 385,176 injured persons and 47,060 deaths, amounts that seem to show a progressive increase over the last two decades. The provinces of Guayas and Pichincha have the highest number of cases; on the other hand, Chimborazo, Santo Domingo and Orellana have the highest death rates (more than 22 deaths per 100,000 inhabitants).

Main determinants of road accidents

Traffic accidents constitute a complex public health problem that generates deaths, injuries and material damage; they are the result of the interaction of individual components such as the driver, the vehicle and the road environment (Zeng et al., 2024). Empirical evidence indicates that accidents are not the consequence of a single cause but rather the convergence of variables such as sociodemographic characteristics, risk behaviours (including speeding, alcohol and drug consumption, and driver recklessness), vehicle mechanical conditions and environmental factors such as road type and weather conditions, all of which significantly influence the occurrence of accidents (Endalew et al., 2024).

- **Speeding**
  Empirical evidence holds that inappropriate speed is one of the factors with the greatest determining capacity in the occurrence and severity of traffic accidents. A longitudinal study carried out in New Zealand between 2015 and 2019 showed that drivers who received multiple speeding violations had a significantly higher probability of suffering a serious accident in the following three years compared to non-offenders. On average, exceeding the limit by more than 15 km/h increases the risk of suffering an accident by more than ten times relative to drivers who respect the speed limit (Walton & Hendy, 2024).
  From an analytical approach, Torrão (2022), based on a review of 64 empirical studies, identifies that variables such as speed limit, impact speed and speed variation (delta-V) are direct determinants of injury severity, showing that increased speed is associated with higher levels of occupant harm. In the Ecuadorian context, records from the National Transit Agency show that between 2014 and 2019, speeding was associated with 37,577 traffic accidents, confirming its significant weight within the causal structure of accidents in the country (Oviedo et al., 2025). This finding shows that inappropriate speed not only increases the energy of the crash but also reduces the driver's reaction capacity, thus creating a direct relationship between inappropriate speed and fatality.

- **Drunkenness or drug use**
  Psychoactive substances, notably alcohol, cannabis and sedative drugs, are a fundamental factor in the risk of traffic accidents. The systematic review carried out by Frumento et al. (2022) on drivers involved in work-related accidents (in which up to 50% of the drivers involved tested positive for some substance, mainly alcohol) concluded that drug or medication use impairs psychomotor functions, causes sedation and deteriorates decision-making processes, while the probability of an accident increases dramatically.
  From an empirical perspective, a study carried out at a tertiary care centre in Nepal found that 12.19% of patients involved in traffic accidents were driving under the influence of alcohol, also showing the presence of severe injuries such as head and facial trauma in these cases (Joshi et al., 2023). In the Ecuadorian context, the legal and social analysis developed by Pinos et al. (2024) indicates that a considerable percentage of traffic accidents in the country is associated with driving under the influence of alcohol, narcotic or psychotropic substances, reflecting the direct incidence of drunkenness on the occurrence of road accidents. These results show that substance use not only alters the driver's cognitive and motor abilities but also significantly increases the risk and severity of accidents.

- **Driver inexperience and recklessness**
  Lack of skill, non-observance of rules and reckless behaviour are frequent causes of traffic accidents. Möller et al. (2022), in a 12-year follow-up of more than 20,000 novice drivers, demonstrated that riskier behaviour (improper overtaking, reckless driving) is associated with a 2.25 to 3.28 times higher risk of having an accident,

even when controlling for age and experience. The study reaffirms that violations are a reliable measure of risk behaviour and that recklessness not only refers to a lack of technical skill but also to an attitude of disobedience towards traffic regulations.

At the empirical level, Zhang et al. (2023) show that risk behaviours and violation of traffic rules are significantly associated with the occurrence of accidents, reflecting that poor decision-making and low behavioural control increase the probability of accidents. In the Ecuadorian context, driver inexperience and recklessness are identified as the main cause of traffic accidents. Specifically, in a local study carried out in the province of Santo Domingo, reckless behaviours such as running red lights (569 vehicles) and amber lights (2,562 vehicles) were recorded, showing clear patterns of disrespect for traffic regulations and their direct relationship with the occurrence of accidents (Alarcón et al., 2023). These findings confirm that driver inexperience and recklessness constitute a key determinant of road accident rates, as they reflect behaviours that directly increase the risk of accidents.

- **Mechanical damage**

Mechanical defects, although less frequent than human errors, underlie the severity and generation of accidents. Adanu et al. (2024) investigated more than 15,000 fatal accidents in Alabama, where brake and tyre errors account for 65% of the contributions to accidents associated with vehicle mechanical defects. Furthermore, vehicles older than ten years are most deficient due to mechanical failures, putting their occupants' lives at risk as they are associated with collisions causing very severe injuries. In the same study, mechanical errors in the lighting system and steering system lead to a higher exposure to severe injuries.

In the Ecuadorian context, mechanical failures are part of the causal structure of traffic accidents. Data from the National Transit Agency show that between 2019 and 2023, these recorded annual values ranging from 102 to 184 accidents, confirming their presence among the causes identified at the national level (Pazos & Simaluisa, 2024). These results show that, although their frequency is lower compared to human factors, mechanical damage directly affects the severity of accidents, especially in contexts where the vehicle fleet has deficiencies in maintenance and technical control, thus consolidating itself as a relevant determinant of road accident rates.

Regression model approach

In the analysis of road accident rates, the choice of the most appropriate econometric model is one of the most relevant aspects since it depends on the nature of the dependent variable and the structure of the available data. In this case, the specialised literature has widely used count models, such as the Poisson model and the negative binomial model, because traffic accidents are usually considered discrete variables expressed as frequencies or counts of accidents (Hamdan et al., 2025). The Poisson model assumes that the mean equals the variance of the dependent variable, although this condition is rarely met in real accident data, where overdispersion is common (Sagamiko & Mbare, 2021).

Given this limitation, the negative binomial model has emerged as a more versatile alternative, allowing the relaxation of the equality assumption between mean and variance characteristic of the Poisson model while including an unobserved heterogeneity term that improves fit in the presence of overdispersion (Zhang et al., 2022). However, both approaches have certain limitations, such as the requirement to satisfy specific distributional assumptions or the difficulty of directly interpreting marginal effects. On the other hand, Champahom et al. (2023) have integrated more advanced models, including zero-inflated negative binomial models with spatial effects, which allow capturing spatial correlation between the units of analysis. The latter, however, require more disaggregated databases and more complex methodological structures.

In this context, and considering the characteristics of the information used in the present investigation, the application of a multiple linear regression model was chosen. The choice is justified because the analysis is carried out with aggregated data at the national level for the 2020-2024 period, which allows the dependent variable to be treated as a continuous variable and estimates the existence of linear relationships between the determinants of accidents. Likewise, this approach offers a direct interpretation of the estimated coefficients, making it possible to clearly identify the magnitude and direction of the effect of each explanatory variable on road accident rates (Mazón et al., 2020).

Thus, the study applies a multiple linear regression model to estimate the effect of speeding violations, positive cases of alcohol and drugs, driver recklessness or inexperience, and vehicle mechanical failures on the total number of traffic accidents in Ecuador during the 2020-2024 period. This methodological decision responds to the need to identify the relative weight of each determinant within an explanatory approach with direct interpretation of coefficients, allowing the marginal incidence of each factor to be quantified and its contribution to the behaviour of road accident rates in the country to be assessed. In line with this approach, Sipos et al. (2021) point out that econometric models are suitable for analysing the relationship between accident frequency and risk factors, provided that spatial effects and data quality are respected.

Assumption tests of the econometric model

Compliance with the classical assumptions governing the multiple linear regression model is mandatory to ensure the correct statistical validity of the estimates provided by the Ordinary Least Squares method. According to Davidson & MacKinnon (2021), the essential counterfactual nature of these assumptions also supports the fact that the estimators are unbiased, consistent and efficient, in line with the premises of the Gauss-Markov theorem. The empirical verification of the classical assumptions therefore makes it possible to discover whether there are violations that could hinder the interpretation of the coefficients or simply alter the inference about how traffic accidents are determined in Ecuador. In this sense, to guarantee the robustness of the estimated model, the main econometric assumptions are evaluated below: linearity, normality of residuals, homoscedasticity, absence of multicollinearity and independence of errors.

- **Linearity assumption**
  This assumption holds that the dependence of the dependent variable on the explanatory variable must conform to linearity in the parameters. This means that the marginal effect of each variable remains constant and that the model specification adequately reflects the behaviour of the data. In this regard, Li et al. (2024) point out that verification of the linearity assumption can be carried out by visual inspection of residuals, since systematic patterns (such as 'S' or 'U' shapes) show a relationship that is not correctly modelled. Furthermore, they highlight that specification tests such as Ramsey's RESET test make it possible to formally detect deviations in the chosen functional form and therefore possible breaches of linearity.

- **Normality of residuals**
  The normality of the error term is a condition that must be met for the t and F significance tests to be valid. According to Khatun (2021), if the errors are normally distributed with zero mean and constant variance, the OLS estimators follow an exact normal distribution, often even with small samples, allowing proper inference. In practice, normality can be checked using the Jarque-Bera test or the Shapiro-Wilk test, carried out together with histograms and Q-Q plots. The tests carried out help ensure that the explanatory factors (e.g., speed or alcohol consumption) related to accidents are free from biases specifically derived from an anomalous distribution of residuals.

- **Homocedasticidad**
  Homoscedasticity means that the variance of the error term is constant for all observations. When this assumption is violated, heteroscedasticity occurs, which leads to unbiased but inefficient estimators and incorrect standard errors. Hansen (2021) points out that the Breusch-Pagan test and the White test are the most widely used to detect this anomaly. In the analysis of traffic accidents, heteroscedasticity can occur if the variance of errors increases with the number of vehicles or population density. If detected, robust standard errors should be obtained or logarithmic transformations applied to stabilise the variance.

- **No multicollinearity**
  The assumption of no multicollinearity implies that the explanatory variables should not be correlated with each other, since strong collinearity prevents the specific effect of each variable from being distinguished, leads to high variance in the coefficients and reduces the level of significance. Hansen (2021) argues that this does not bias the coefficients but makes them inefficient and difficult to interpret. The tool for detecting collinearity is the Variance Inflation Factor, where values greater than 10 indicate severe collinearity. In this sense, variables such as vehicle fleet and vehicle density may be correlated with each other, so VIF is essential to verify whether the selected determinants are independent.

- **Independence of errors**
  Independence of errors or absence of autocorrelation is another essential assumption when dealing with time series or data grouped by years. Davidson & MacKinnon (2021) indicate that autocorrelation implies dependence between errors, which distorts the validity of hypothesis tests. The Durbin-Watson statistic is the main technique used to detect it, with values close to 2 indicating independence and distant values, in either direction, indicating the problem of autocorrelation, mainly positive.

Methodological approach

Research approach and design

The type of study adopted is quantitative, explanatory and non-experimental, since it seeks to determine the incidence of different factors on traffic accidents in Ecuador during the 2020-2024 period. In this sense, Vizcaíno et al. (2023) argue that the quantitative approach emphasises the measurement and numerical analysis of data, allowing causal relationships between variables to be established and generalisable results to be achieved through the application of statistical techniques. In this sense, quantitative designs are placed within the possibility of examining the relationship between variables without manipulating them, thus guaranteeing the objectivity of the analysis that identifies the conclusions.

Data sources and period

Official secondary sources were used, with data from the National Institute of Statistics and Censuses corresponding to the 2020-2024 period, in which information such as the number of accidents, speeding violations, breathalyser test results, vehicle fleet and weather conditions can be found; at the same time, these were filtered to ensure temporal homogeneity and comparability across the years analysed.

Definition of variables

In order to operationalise the variables used in the econometric model, Table 1 presents their definition, type and expected sign. These variables represent the most relevant factors according to the road safety literature, which consistently identifies speeding, alcohol and drug consumption, driver recklessness and mechanical failures as direct determinants of the occurrence and severity of traffic accidents (Zeng et al., 2024; Endalew et al., 2024; Frumento et al., 2022). According to Becker et al. (2021), the selection of explanatory variables should be based on theoretical and empirical criteria, avoiding omissions or inclusions that could bias the model.

Table 1.
Definition of variables

TYPE OF VARIABLE	NAME	OPERATIONAL DESCRIPTION	EXPECTED SIGN
Dependent	ACCIDENTS	Total number of traffic accidents registered monthly at the national level according to INEC.	—
Independent	SPEED	Monthly average of recorded speeding violations.	(+)
Independent	ALCOHOL_DRUGS	Monthly average of positive cases detected in alcohol and drug consumption controls.	(+)
Independent	RECKLESSNESS	Monthly number of reported violations due to inexperience or reckless driving.	(+)
Independent	MECH_DAMAGE	Monthly number of accidents attributed to mechanical failures or defects in the vehicle (brakes, tyres, lights, steering).	(+)

Note. This table presents the variables used in the multiple linear regression model to analyse traffic accidents in Ecuador.

Statistical approach and methodological foundation

Estimation was carried out using the Ordinary Least Squares method, guaranteeing the assumptions of linearity, unbiasedness and homoscedasticity. Davidson & MacKinnon (2021) highlight that under these conditions, the estimators are the best linear unbiased estimators. In addition, the model assumptions were verified by applying the following tests:

- Jarque-Bera for normality of residuals.
- Breusch-Pagan for heteroscedasticity.
- Durbin-Watson for autocorrelation.

A multiple linear regression model was applied to quantify the influence of the selected determinants on the frequency of traffic accidents. The general model is expressed as:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{4i} + \varepsilon_i$$

where Y_i represents the number of accidents ; X_{1i}, X_{2i}, X_{3i}, X_{4i} correspond to the independent variables; β_j are the estimated parameters; and ε_i is the error term.

Limitations

The study acknowledges certain limitations arising from the use of secondary data. These include possible biases derived from official accident recording practices, methodological differences between sources, and restrictions on disaggregating data by province, which could influence the correct interpretation of the results. However, these limitations do not question the overall validity of the analysis, since the sources are verifiable and official.

Results

Presentation of the estimated model

The multiple linear regression model was estimated considering as dependent variable the total number of traffic accidents registered in Ecuador during the 2020-2024 period and as explanatory variables speed, alcohol and drug consumption, driver recklessness or inexperience, and mechanical damage.

The estimated equation was as follows:

$$\textbf{SINIESTROS} = 203.10 + 1.27(\textbf{\textit{VELOCIDAD}}) + 2.94(\textbf{\textit{ALCOHOL\_DROGAS}}) \\ +0.91(\textbf{\textit{IMPRUDENCIA}}) + 6.69(\textbf{\textit{DAÑOS\_MEC}}) + \varepsilon$$

In general terms, the equation can be expressed as:

$$Y = 203.10 + 1.27X_1 + 2.94X_2 + 0.91X_3 + 6.69X_4 + \varepsilon$$

The overall model was highly significant and had high explanatory power ($R^2 = 0.8910$; R^2 adjusted = 0.8831), indicating that 88,3 % of the variability in accidents is explained by the factors included in the regression.

Coefficients and initial interpretation

In order to present in more detail the results obtained from the multiple linear regression model, Table 2 shows the estimated coefficients for each explanatory variable together with their corresponding standard error, t-statistic, p-value and the significance levels obtained.

Table 2.
Coeficientes e interpretación inicial

VARIABLE	COEFFICIENT	STANDARD ERROR	T	P-VALUE	SIGNIFICANCE
Speed	1.2708	0.1917	6.63	0.000	Significant
Alcohol_drugs	2.9436	0.5005	5.88	0.000	Significant
Recklessness	0.9105	0.1013	8.99	0.000	Significant
Mech_damage	6.6963	0.4816	13.91	0.000	Significant
Constant	203.1036	75.9500	2.67	0.010	Significant

Note. This table shows the estimated coefficients for the explanatory variables in the regression model.

The results in Table 2 show that the variables in the model have positive coefficients with statistical significance, thus confirming the prediction that traffic accidents in Ecuador will increase during the 2020-2024 period. The p-values, which are less than 1%, allow the null hypothesis to be rejected, validating the robustness of the estimators (Mansournia et al., 2022). Broadly speaking, this means that human and mechanical factors significantly contribute to road accident rates, also providing empirical evidence consistent with the multi-causal framework of road safety.

Specifically, the MECH_DAMAGE variable has the highest coefficient at 6.6963, thus remaining the determinant with the greatest marginal incidence on accidents. This result suggests that vehicle technical failures constitute a critical structural factor, showing that the state of the vehicle fleet and preventive maintenance play a determining role in the occurrence of accidents. On the other hand, the ALCOHOL_DRUGS variable, with a coefficient of 2.9436, is also a determinant of considerable importance, again corroborating that drug or alcohol consumption significantly increases the probability of accidents by affecting the driver's cognitive and motor abilities.

Finally, both the SPEED variable (1.2708) and the RECKLESSNESS variable (0.9105), although with smaller relative magnitude, retain very high statistical significance, ensuring their place in the model. There is a positive relationship between speeding, severity and accident probability; on the other hand, recklessness is nothing other than the manifestation of risk behaviours linked to non-compliance with traffic regulations. Consequently, the results reveal a multi-causal phenomenon, where mechanical factors clearly have a more prominent weight in the period analysed, which undoubtedly requires improving vehicle technical control, road education and regulation.

Assumption tests of the econometric model

To measure the statistical validity of the estimated model, Table 3 presents the most significant results of the diagnostic tests applied to the classical assumptions of the multiple linear regression model, analysing the normality of residuals, homoscedasticity, autocorrelation, multicollinearity and correct functional specification, to verify that the obtained estimators are consistent, efficient and unbiased.

The data obtained from Table 3 indicate that the model generally satisfies the classical assumptions of multiple linear regression. In this sense, the test implemented to check normality does not allow rejecting the null hypothesis, implying that the residuals are approximately normally distributed and therefore allow the use of t and F tests for statistical inference. Similarly, the result of the Breusch-Pagan test confirms the presence of homoscedasticity, which guarantees the efficiency of the estimators, and the VIF analysis shows that there is no severe multicollinearity among the explanatory variables. However, the Durbin-Watson statistic ($d = 1.089$) shows only a subtle positive autocorrelation that could be explained by the temporal nature of the data.

However, the main critical finding comes from the Ramsey RESET test, whose result allows the rejection of the null hypothesis of correct functional specification. This result indicates the possible omission of relevant variables or the presence of non-linear relationships not captured by the model. In this context, from a methodological perspective, an alternative would be the inclusion of additional variables related to structural factors, such as road infrastructure characteristics, vehicle density or weather conditions, which could improve the explanatory power of the model. Likewise, the inclusion of non-linear terms or functional transformations (such as logarithms or quadratic terms) would allow capturing possible non-linear effects in the relationship between determinants and accident rates, given that the RESET test is especially sensitive to the presence of non-linearity and functional specification errors in the model (Christodoulou & Tserkezos, 2023).

Additionally, in response to the problems detected, the use of more robust alternative models is suggested. For example, considering that the dependent variable corresponds to accident counts, Poisson or negative binomial models could represent a suitable alternative, especially in the presence of overdispersion. Similarly, the slight autocorrelation observed could be addressed using time series models or the incorporation of autoregressive terms. On the other hand, the evidence of possible omitted variables also opens the possibility of using spatial models, which allow capturing the geographical dependence of traffic accidents. Overall, although the estimated model offers consistent and statistically valid results, the consideration of these methodological alternatives would strengthen the analysis and improve the precision of estimates in future research.

Table 3.
Assumption tests of the econometric model

ASSUMPTION EVALUATED	TEST APPLIED	STATISTIC	P- VALUE	INTERPRETATION
Normality of residuals	Skewness/Kurtosis test	$\chi^2(2) = 1.36$	0.5070	Ho not rejected; therefore, errors follow a normal distribution.
Homoscedasticity	Breusch–Pagan test	$\chi^2(1) = 0.21$	0.6502	Ho not rejected; therefore, homoscedasticity exists.
Autocorrelation	Durbin–Watson test	d = 1.089	—	Slight positive autocorrelation; does not compromise overall validity.
Multicollinearity	VIF (Variance Inflation Factor)	Mean = 3.20	—	No severe multicollinearity (VIF < 10).
Functional specification	Ramsey RESET test	F(3,52) = 6.27	0.0010	Ho rejected → possible omission of variables or partial non-linearity.

Note. The results of the tests applied to the assumptions of the multiple linear regression model are presented.

The results indicate that road accident rates in Ecuador respond to a reordering in the relative importance of their determinants, with a profile in which mechanical determinants show a greater structural weight than expected. This behaviour could not only reflect problems in the proper maintenance of the vehicle fleet but also institutional weaknesses in the vehicle technical control system. In this line, not only is there a displacement of human factors, but also a more complex interaction is observed where risks cluster and reinforce each other, since in the occurrence of accidents several negative conditions are simultaneously present.

Nevertheless, the interpretation of these findings must consider additional limitations associated with the quality of the information. Possible under-recording of accidents (especially minor or unreported accidents) may lead to an underestimation of the phenomenon and bias results towards more severe events. Likewise, the quality of police data may present inconsistencies in the classification of causes, which affects the precision of the explanatory variables. Added to this are the time lags between the occurrence of the accident and its official registration, which can distort the contemporaneous relationship between the model variables and weaken the direct causal interpretation of the estimated coefficients.

Additionally, the period analysed includes the initial years of the pandemic (2020-2021), which introduces a key conjunctural factor in the dynamics of accident rates. Mobility restrictions, reduced traffic and changes in travel patterns may have significantly altered the frequency and characteristics of accidents, generating a possible break in the usual data trend. Subsequently, economic reactivation and increased mobility would have caused adjustment or rebound effects in the following years. Consequently, part of the results obtained could be capturing both structural relationships and transitory effects associated with this exceptional context, which suggests interpreting the findings with caution and considering the inclusion of time control variables in future research.

Discussion

The results obtained make it possible to affirm that traffic accidents in Ecuador during the 2020-2024 period are determined by a combination of human and mechanical factors with notable statistical significance. This behaviour corroborates that road safety is a multi-causal phenomenon determined by driver decisions and the structural conditions of the vehicle fleet and the road environment. The high explanatory power of the model demonstrates that the selected determinants adequately explain the recent vulnerability to accidents in the country.

A relevant aspect is that mechanical damage has the largest coefficient in the estimated model. This issue points to a substantive change in the causal structure of vehicle technical failures, which have come to play a more important role than in previous years, probably related to the ageing of the vehicle fleet and non-compliance with technical inspections; although the human factor is generally the norm in the scientific tradition on road safety, this points to a new nuance in Ecuador's recent reality.

In order to contrast the results obtained with recent scientific evidence, five empirical studies were selected and are presented in Table 4. The choice was made based on criteria of thematic relevance, timeliness and methodological complementarity, prioritising research that addresses the main determinants analysed in the model: human, mechanical and structural factors. In this sense, studies employing different approaches (econometric, multivariate and spatial) were included in order to achieve a comprehensive contrast of the findings. The selection of five studies is not based on an arbitrary quantitative criterion, but on the need to represent the different dimensions of the phenomenon in a balanced manner without incurring redundancies derived from the inclusion of multiple investigations with similar approaches.

Table 4.
Relationship of the study findings with recent evidence on road accident rates

STUDY	METHODOLOGICAL APPROACH	MAIN FACTORS IDENTIFIED	RELATIONSHIP WITH THE RESULTS OF THE PRESENT STUDY
Adanu et al. (2024)	Accident severity models	Mechanical failures, vehicle conditions	Coincides with the main finding of the study, where mechanical damage presents the largest marginal effect.
Castillo et al. (2020)	ARIMA + multinomial logit	Recklessness, lack of attention, vehicle characteristics, road type	Coincides on the importance of the human factor, but the present study reveals a greater current weight of the mechanical factor.
Domínguez et al. (2023)	Multiple correspondence analysis	Distraction, speed, alcohol, mobile phone use	Reaffirms the relevance of speed and alcohol, consistent with the positive coefficients found.
Möller et al. (2022)	Longitudinal (cohort) study	Risk behaviours, violations, recklessness	Reinforces the significance of the RECKLESSNESS variable, showing its impact on the occurrence of accidents.
Sipos et al. (2021)	Spatial models (SAR–SEM–SAC)	Influence of infrastructure, road design, spatial autocorrelation	Supports the interpretation of the RESET test: omitted variables related to road conditions and spatial distribution may exist.

Note. Relationship of the study findings with recent evidence on road accident rates.

The comparison confirms that the determinants found in the present work are not only consistent with previous evidence but also provide a relevant update. The work of Castillo et al. (2020) and Domínguez et al. (2023) allows us to affirm that human risk factors remain relevant, which coincides with the significance of the variables speed, alcohol/drugs and recklessness. However, the greater magnitude of the coefficient associated with mechanical damage reflects an emerging condition: the technical reliability of the vehicle has acquired a stronger weight than in previous periods, probably due to changes in the economic environment and regulatory control.

Similarly, the spatial approach developed by Sipos et al. (2021) would allow a deeper interpretation of two model results: the slight positive autocorrelation captured by Durbin-Watson and the rejection of the RESET test. This suggests that accident rates could be affected by geographical patterns or by road infrastructure qualities that have not been introduced into the econometric specification. Consequently, future research should include variables such as vehicle density, road class or structural conditions of urban environments to increase the robustness of the model.

The inclusion of the studies by Möller et al. (2022) and Adanu et al. (2024) extends the interpretative scope of the results by integrating recent empirical evidence on two key dimensions of the model: driver behaviour and vehicle mechanical conditions. In particular, Möller et al. (2022) reinforce the importance of risk behaviours and recklessness as determining factors in the occurrence of accidents, which is consistent with the statistical significance observed in the RECKLESSNESS variable. For their part, Adanu et al. (2024) provide evidence on the role of mechanical failures in accident severity, which is especially relevant when contrasting with the findings of the present study, where mechanical damage shows the largest marginal effect. Together, both studies not only validate the obtained results but also strengthen the interpretation that road accident rates in Ecuador respond to an interaction between behavioural and structural factors, highlighting the growing importance of the technical state of the vehicle fleet.

Conclusions

- The work demonstrates that traffic accidents in Ecuador during the 2020-2024 period respond to a combination of human and mechanical aspects whose influence is both statistical and substantive. The econometric model provides evidence that speeding, alcohol and drug intake, driver negligence, as well as mechanical failures, directly increase the frequency of accidents. Among these factors, vehicle technical failures contribute most marginally to increasing road accident rates, which denotes a significant change in the causal structure of recent accidents and highlights the need to strengthen mechanical control and preventive maintenance of the vehicle fleet.
- On the other hand, the agreement of the model with previous scientific evidence and the identification of potential omitted variables related to spatial and infrastructural aspects reinforce the need to incorporate more comprehensive approaches in future research, since the evidence also shows that road safety in Ecuador remains a structural problem that requires synergic actions of regulation, education, operational control and mobility. Therefore, the results allow us to understand the current determinants of accidents and provide a basis for guiding interventions aimed at reducing mortality and improving road safety in the country.

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