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***Research paper***

# Long-Run Drivers of Road Accidents: Governance and Business Implications of Alcohol, Law Enforcement, Infrastructure and Urbanization

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**Abstract**

This study investigates the long-run determinants of road accident mortality in the Philippines, focusing on alcohol consumption, rule of law, and infrastructure development from 2000 to 2022. Using the Autoregressive Distributed Lag (ARDL) approach, results confirm a significant long-run relationship, with alcohol consumption showing a strong positive effect. The error correction model indicates that deviations from equilibrium adjust at a rate of 81% annually. Although short-run effects and other variables such as the rule of law and paved roads were statistically insignificant, their inclusion offers insight into broader governance and infrastructural dynamics.
The findings underscore the need for sustained governance interventions and provide actionable implications for the business sector, particularly in transport, logistics, and insurance. Firms are encouraged to adopt safety-oriented strategies such as driver training, compliance monitoring, and telematics technologies. This interdisciplinary study contributes to public health and business research by integrating governance, behavioral, and infrastructural factors into a long-term road safety framework. It emphasizes the shared responsibility of government and private actors in reducing road fatalities through coordinated, data-driven interventions.

***Keywords***: *Behavioral Risk Management; Economic Planning; Government Regulation; Infrastructure Investment; Public Health Intervention*

## 1. Introduction

Transportation, road safety, and traffic management are serious areas of inquiry owing to their profound implications on public health, economic stability, and social equity. Road traffic injuries (RTIs) are considered a pressing issue, standing as the eighth leading cause of mortality globally and the top cause of death among young people aged 15-29. Road accidents are also projected by the World Health Organization (WHO) to cost the international economy roughly $518 billion a year, equal to 1–2% of many countries' gross national product [1]. Economically, in the Philippines, the RTI toll was valued at PHP26.519 billion during the year 2014[2], where every accident leading to deaths within Metro Manila carried an average cash loss of PHP3.5 million [3].
Beyond economic losses, the accurate collection and reporting of road accident data play a crucial role in shaping policies and programs aimed at improving road safety. Policymakers use hard facts to effect evidence-based actions that reduce dangers and strengthen traffic laws. More significantly, road crashes disproportionately affect vulnerable populations, particularly poorer communities that lack good access to health care and emergency services [4]. Literature further indicates that economic insecurity can result in higher road traffic mortality, highlighting the complex dynamics between socioeconomic conditions and road safety outcomes [1].
These figures underscore the pressing necessity of integrative road safety policies. Nevertheless, a significant amount of research on RTAs has previously centered on behavioral risk factors like alcohol use [5,6], infrastructure flaws [6], and the impact of legislation [7]. Though these risk factors are critical, they fail to completely encompass the overall social and governance determinants shaping road accident deaths, especially in the Philippine context.
Perhaps one of the better-researched behavioral risk factors is alcohol consumption. According to a Greek study, 40.7% of victims involved in fatal RTAs had a blood alcohol content, with an important number of cases involving young male drivers between 21–30 years old [7]. Likewise, studies in Brazil revealed that binge drinking doubled the risk of a road accident. In response, many nations have enacted legal reforms like reduced blood alcohol concentration (BAC) limits, enhanced penalties for driving while intoxicated, and breathalyzer tests being mandatory [7]. Although these measures have been linked to declines in road deaths, their success is only possible with rigorous enforcement, which is still uneven in most developing countries, including the Philippines. Compromised law enforcement, corruption, and poor monitoring systems often thwart the full potential of these legislative measures.
Apart from personal behavior, road infrastructure is also very important for road safety. Deteriorated and poorly designed roads, poor pedestrian facilities, and inefficient traffic management systems all add to the risk of RTAs [6]. But studies on infrastructure rarely give

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attention to the role of governance in guaranteeing the quality, upkeep, and accessibility of transport networks. Successful road safety measures do not only entail the physical upgrading of road conditions but also robust governance systems emphasizing safety and fairness in infrastructure development.

Socioeconomic inequalities continue to compound the risks involved with RTAs. Reports have shown that people of lower incomes are predisposed to increased risks of accidents on the roads owing to overdependence on inappropriate means of transportation like motorcycles and public utility vehicles [6].

Furthermore, they usually have limited access to emergency medical care, lowering their survival possibilities after a serious crash. Despite these well-known associations, little research exists that fully investigates how governance arrangements impact socioeconomic inequalities in road safety results.

While global studies have extensively documented the effects of alcohol, governance, and infrastructure on road safety, their applicability to the Philippine context requires deeper scrutiny. In contrast to many high-income countries where traffic laws are uniformly enforced and infrastructure is well-maintained, the Philippines faces persistent issues such as uneven law enforcement, localized corruption, and regional disparities in road quality. These governance challenges interact with behavioral risks—such as high alcohol consumption among young drivers—in ways that magnify their impact on road safety. Moreover, infrastructure investments in the country often prioritize coverage over safety-oriented design, lacking elements like sidewalks, speed bumps, or clear signage. This divergence from international best practices suggests that improvements in road safety require not just behavioral interventions or infrastructure upgrades alone, but integrated governance reforms tailored to the country's institutional realities. Therefore, synthesizing global findings with local dynamics highlights the importance of a multi-layered, context-sensitive approach to road accident prevention in the Philippines.

Considering these limitations, this investigation aimed to investigate the social-governance determinants of RTA mortality in the Philippines. It examined the interaction of the rule of law, road infrastructure quality, and urban populations in determining road safety outcomes. In taking a multidimensional perspective, this study presented evidence-based policy recommendations for policymakers, urban planners, and public health authorities to formulate more efficient strategies for reducing RTA-related deaths and dampening the economic and social costs of road crashes.

This study aimed to identify the social and governance factors influencing the road mortality rate in the Philippines and provide insights to the government and business sectors. Specifically, this paper described the status of road accident mortality rate, total alcohol consumption per capita, rule of law index, urban population, and length of paved road of the Philippines from 2000 to 2022. Additionally, this paper developed a model explaining the influence of social and governance indicators on the road accident mortality rate of the Philippines.

Traffic accidents in the Philippines are a constant problem affected by several factors, such as alcohol use, police efficiency, quality of road infrastructure, and urban population growth. Both the Land Transportation Office (LTO) and the Metropolitan Manila Development Authority (MMDA) have indicated that driving under the influence is a dominant cause of road crashes, indicating that alcohol use might have a considerable long-term impact on accident rates. Therefore, a hypothesis can be constructed that higher alcohol intake causes higher traffic accidents in the long term.

Then, law enforcement is also a very important factor that can prevent road accidents. Republic Act No. 10586 (Anti-Drunk and Drugged Driving Act) and other traffic laws should, in principle, slow down accidents. Nevertheless, complications of law enforcement like corruption, unequal application of law, and a lack of traffic personnel tend to make matters harder. There can be a hypothesis that more effective law enforcement has a negative long-run correlation with traffic accidents, provided its enforcement is uniform.

The quality of road infrastructure in the Philippines varies considerably by region. Poorly condition roads, inadequate signs, and poor pedestrian facilities cause accidents. Improved quality of roads like expressways and upgraded transport systems, however, may generate positive and negative long-run impacts on accident rates. A hypothesis can therefore be formulated that road infrastructure quality has a long-run effect, but one that is uncertain on traffic accidents.

Lastly, rapid urbanization, particularly in Metro Manila, Cebu, and Davao, has led to increased vehicle congestion and higher accident rates. While urban planning efforts and transportation reforms (e.g., EDSA busway system, MRT expansion) aim to improve road safety, the transition phase often results in more accidents. This suggests a need to hypothesize that urbanization has a significant long-run effect on traffic accidents, though the direction may be context-dependent.

By situating the hypotheses within the Philippine context, this study enables policymakers and researchers to better understand how key variables—such as alcohol consumption, adherence to traffic laws, and infrastructure—interact over time. These insights provide a foundation for crafting long-term, evidence-based policies aimed at reducing traffic accidents. While road safety is often framed primarily as a governance issue, addressing it effectively requires a multisectoral approach. Government interventions alone are insufficient unless complemented by collaborative efforts from other key stakeholders, particularly the business sector.

Industries such as transportation, logistics, insurance, and automotive manufacturing are directly impacted by trends in road safety—not only through increased operational risks and costs but also through their roles in corporate sustainability and social responsibility. Providing actionable insights to businesses allows them to proactively align with public safety goals by implementing internal risk-reduction policies, employee training programs, and behavior-focused innovations. Many private enterprises also have the agility and resources to pilot advanced technologies—such as telematics, real-time monitoring, and behavior-based insurance—that support safer roads. Thus, translating long-run empirical findings into private sector strategies enhances both their resilience and their contribution to nationwide road safety.

Moreover, business sector responses can serve as catalysts for broader systemic change. When firms understand the long-term implications of lax enforcement, high alcohol consumption, and underdeveloped infrastructure, they are more inclined to invest in preventive measures that not only protect their employees and assets but also influence public attitudes and behaviors. These efforts, when aligned with government strategies, foster a shared culture of accountability and safety. From a governance standpoint, fostering public-private collaboration based on empirical data ensures more coherent policy implementation and strengthens the overall effectiveness of road safety programs. This integrated approach creates a more resilient, data-informed ecosystem that benefits both society and the economy.

## 2. Methods

This research aimed to identify the social and governance determinants of road accident mortality in the Philippines. Having this objective, the researcher used ex-post facto research using the time series data from 2000 to 2022. The researcher tested the following modes to capture the objective of the study:

Eq. 1 $$lnAcc_t = \beta_0 + \beta_1 lnAlcohol_t + B_2 lnPR_t + B_3 lnUrban_t + B_4 lnROL_t + \varepsilon_t$$

where: lnAcct -Natural logarithm of Road Accidents Mortality Rate at time t
lnAlcoholt - Natural logarithm of Total alcohol consumption per capita (Litters projected; +15 years of age) at time t
lnPRt - Natural logarithm of Length of Paved Road (in KM) at time t
lnROLt – Natural logarithm of Rule of Law at time t
β0 – Intercept term
β1, β2, β3, β4 - Long-run coefficients representing the elasticity or impact of each independent variable on the road accident mortality rate
All data utilized in this study were sourced from the World Bank Data Bank, a reputable and comprehensive repository of global economic and social indicators. This ensures consistency and reliability of the macro-level variables. The operational definitions of these variables are as follows:

- Road Accidents Mortality Rate (Acc): This serves as the dependent variable, representing the number of road traffic fatalities per 100,000 population in the Philippines. This metric provides a standardized measure of the severity of road safety issues, allowing for cross-temporal comparisons. Higher values indicate poorer road safety outcomes.
- Total Alcohol Consumption per Capita (Alcohol): This independent variable measures the total alcohol consumption in liters of pure alcohol, projected for individuals aged 15 years and older. This variable is a proxy for the prevalence of alcohol use in the population, hypothesized to positively influence road accident mortality.
- Length of Paved Road (PR): Measured in kilometres, this variable represents the extent of developed road infrastructure within the Philippines. It serves as an indicator of road infrastructure quality and accessibility. Its long-run effect on road accidents is hypothesized to be uncertain, as improved infrastructure can both enhance safety (e.g., better design) and increase risk exposure (e.g., higher speeds, more traffic).
- Rule of Law Index (ROL): This variable, sourced from the World Bank's Worldwide Governance Indicators, reflects perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence. A higher index value indicates stronger law enforcement and governance. It is hypothesized to have a negative long-run correlation with road accident mortality, signifying that more effective and uniform law enforcement contributes to improved road safety.
- Urban Population (Urban): This variable represents the total urban population in the Philippines, reflecting the degree of urbanization. Rapid urbanization often leads to increased vehicle density, congestion, and changes in transportation patterns, potentially influencing accident rates. Its long-run effect is hypothesized to be significant, though the direction may be context-dependent, reflecting both the challenges and potential improvements associated with urban development and planning.

To prepare the variables for cointegration analysis and ensure the robustness of time-series modeling, all continuous variables were transformed using the natural logarithm. This approach is widely applied in empirical economics to stabilize variance, linearize exponential growth patterns, and allow for elasticity-based interpretation of coefficients. Specifically, the total alcohol consumption per capita, the rule of law index, the urban population, and the length of paved roads were all log-transformed. For the alcohol consumption variable, a small constant was added to account for a low outlier value, ensuring that all data points remained strictly positive before transformation. In cases where the rule of law index exhibited high variability, logarithmic transformation was applied cautiously to preserve the interpretability of institutional quality. These transformations facilitated a more reliable analysis of long-run equilibrium relationships among the variables influencing road accidents.

Given the use of time-series data, standard Ordinary Least Squares (OLS) regression might have led to spurious regressions if the variables were non-stationary (i.e., their mean, variance, or autocorrelation changed over time). To address this, a cointegration analysis was performed. Cointegration tests determined whether non-stationary time series variables had a stable long-run relationship, meaning they moved together over time despite short-term fluctuations.

Before proceeding with cointegration analysis, the stationarity properties of each variable were examined using the Augmented Dickey-Fuller (ADF) test with a constant term and automatic lag length selection based on the Schwarz Information Criterion (SIC). This test helped to identify the order of integration for each series. Following the unit root tests, the Johansen Cointegration Test was applied to determine the existence of long-run equilibrium relationships among the variables (ACC, ALCOHOL, PR, ROL, URBAN). The test was performed with a linear deterministic trend assumption and a lag interval of 1 to 1 in first differences. Both the Trace statistic and Maximum Eigenvalue statistic were used to determine the number of cointegrating equations at the 0.05 significance level. This analysis was crucial for confirming the presence of stable long-run relationships, which would then support the estimation of an Error Correction Model (ECM) to further analyze both the short-run dynamics and the adjustment process towards long-run equilibrium.

Beyond the core econometric tests for stationarity and cointegration, additional statistical treatments were employed to ensure the robustness and validity of the estimated model. Initial descriptive statistics were computed for all variables (Road Accidents Mortality Rate, Total Alcohol Consumption per Capita, Length of Paved Road, Rule of Law Index, and Urban Population). These statistics, including mean, median, standard deviation, minimum, and maximum values, provided a preliminary understanding of the data's central tendency, dispersion, and range over the observation period (2000-2022).

Upon the estimation of the Error Correction Model (ECM), several diagnostic tests were conducted to check the model's assumptions and ensure the reliability of the results. The presence of autocorrelation in the residuals was assessed using tests such as the Breusch-Godfrey Serial Correlation LM Test. This test helped to determine if the error terms were correlated over time, which would violate the assumption of independent errors and potentially lead to inefficient coefficient estimates. To check for heteroskedasticity (non-constant variance of the error terms), tests such as the White Test or the Breusch-Pagan-Godfrey Test were applied. The presence of heteroskedasticity would imply that the standard errors of the coefficients were biased, affecting the validity of hypothesis tests. The normality of the error terms was assessed using tests like the Jarque-Bera test. While OLS estimators are asymptotically normal regardless of residual distribution, severe non-normality could indicate misspecification or the presence of outliers. Finally, the stability of the estimated long-run coefficients was examined using the cumulative sum of recursive residuals (CUSUM) of squared recursive residuals (CUSUMSQ) tests. These tests helped to detect structural breaks or instability in the parameters over the sample period, which could affect the validity of the estimated long-run relationships. These diagnostic tests were crucial for ensuring that the estimated ECM was well-specified and that its results could be reliably interpreted for policy implications.

## 3. Results

This section presents the empirical findings of the study, focusing on both the short-run and long-run relationships between road accident rates and selected explanatory variables using the Autoregressive Distributed Lag (ARDL) modelling approach. The analysis begins with

the estimation of the ARDL model, followed by the Bounds Test for cointegration to determine the presence of a long-run equilibrium relationship. Diagnostic tests were also conducted to ensure the reliability of the model, including assessments for normality, heteroskedasticity, serial correlation, and model stability. The results are interpreted with emphasis not only on statistical outputs but also on their practical implications, particularly in shaping policies related to public safety, infrastructure, and regulatory enforcement.

**Table 1:** Descriptive Statistics of the Variables

| | Mean | SD | Minimum | Maximum |
|---|---|---|---|---|
| Road Accidents Mortality Rate | 10.23 | 2.164 | 1.000 | 12.5 |
| Total alcohol consumption per capita | 5.68 | 1.117 | 0.204 | 6.33 |
| Rule of Law | 25.31 | 6.335 | 4.557 | 33.49 |
| Urban Population | 1.77 | 0.420 | 0.276 | 2.38 |
| Length of Paved Road (in KM) | 26237.11 | 6162.003 | 4063.871 | 33997 |

Table 1 presents the descriptive statistics of the key variables used in the study. The mean mortality rate from road accidents stands at 10.23 deaths per 100,000 population, with a standard deviation of 2.16, indicating a moderate variation across the observed years. The minimum observed value is 1.00, while the maximum reaches 12.5, highlighting periods of both low and high fatality rates.

Total alcohol consumption per capita averages 5.68 liters, with values ranging from a low of 0.204 liters to a high of 6.33 liters, reflecting substantial variation over time. This variation could be attributed to changes in lifestyle, enforcement of alcohol-related laws, or public health campaigns.

The Rule of Law index has a mean value of 25.31, with a standard deviation of 6.34, suggesting moderate fluctuation in the country's governance and institutional strength over the period. Values ranged between 4.56 and 33.49, reflecting significant differences in regulatory environments that may influence road safety.

Urban population, expressed in log form, has a mean of 1.77, with a relatively narrow standard deviation of 0.42, suggesting less variability in urbanization trends over the study period. Lastly, the length of paved roads shows a high mean of 26,237 kilometres, with a large standard deviation of 6,162 km, indicating wide disparities in infrastructure development across time.

These descriptive insights offer initial evidence of the potential influence of alcohol consumption, governance quality, urbanization, and road infrastructure on road accident mortality, thereby justifying their inclusion in the empirical model.

**Table 2:** Summary of Augmented Dickey-Fuller (ADF) Unit Root Test Results

| Variable | ADF Test at Level (t-stat, p-value) | ADF Test at First Difference (t-stat, p-value) | Order of Integration | Remarks |
|---|---|---|---|---|
| lnAcc | -3.086 (0.0425) | — | I (0) | Stationary at level |
| lnAlcohol | -1.958 (0.3015) | -4.113 (0.0049) | I (1) | Stationary after 1st difference |
| lnPR | -0.472 (0.8792) | -13.351 (0.0000) | I (1) | Stationary after 1st difference |
| lnROL | -2.590 (0.1099) | -4.528 (0.0020) | I (1) | Stationary after 1st difference |
| lnUrban | -2.199 (0.2122) | -2.350 (0.1667)<br>-4.520 (0.0022, at 2nd diff.) | I (2) | Stationary only after the 2nd difference |

The Augmented Dickey-Fuller (ADF) unit root test was employed to determine the stationarity properties of each time series variable. Results, as shown in Table 2, indicate that road accident mortality (lnAcc) is stationary at the level, i.e., integrated of order zero (I(0)). The variables alcohol consumption per capita (lnAlcohol), length of paved road (lnPR), and rule of law (lnROL) are non-stationary at the level but become stationary after first differencing and are therefore integrated of order one (I(1)). In contrast, the urban population variable (lnUrban) was found to be non-stationary even after first differencing, and only achieved stationarity at the second difference, indicating that it is integrated of order two (I(2)).

Given that the ARDL bounds testing approach to cointegration is only applicable when none of the series are integrated at order two or higher, the urban population variable was excluded from subsequent model estimation. This adjustment ensured that the assumptions underlying the cointegration analysis were satisfied, thereby strengthening the validity of the empirical results.

**Table 3:** ARDL Short-Run Regression Results (Dependent Variable: lnAcc)

| Variable | Coefficient | Std. Error | t-Statistic | p-value |
|---|---|---|---|---|
| c | -1.1994 | 1.7356 | -0.6911 | 0.4989 |
| lnAcc (1) | 0.1861 | 0.2079 | 0.895 | 0.3833 |
| lnAlcohol | 1.2938 | 0.6089 | 2.1249 | 0.0486* |
| lnROL | 0.1288 | 0.1253 | 1.0285 | 0.3181 |
| lnPR | 0.0403 | 0.1511 | 0.2666 | 0.793 |
| *$R^2$ – 0.3650* | *Adjusted $R^2$ – 0.2156* | *F-stat – 2.443* | *p-value (F) – 0.0864* | *Durbin-Watson- 1.619* | *AIC - -1.8295* |

The Autoregressive Distributed Lag (ARDL) model was employed to estimate the relationship between road accident mortality (lnAcc) and its potential predictors: alcohol consumption (lnAlcohol), quality of rules/laws (lnROL), and extent of paved roads (lnPR). Although the overall F-statistic ($F = 2.44$, $p = 0.086$) did not meet the conventional threshold for statistical significance at the 5% level, some noteworthy observations can still be drawn from the model, particularly from a practical and policy standpoint.

Among the predictors, alcohol consumption exhibited a statistically significant and positive relationship with accident mortality ($\beta = 1.29$, $p = 0.049$). This finding aligns with existing literature that associates higher alcohol consumption with increased risk of traffic fatalities. Despite the overall model's insignificance, this result carries practical relevance: it implies that efforts aimed at reducing alcohol consumption or enforcing drinking-related regulations could contribute meaningfully to lowering road accident mortality, even if broader structural factors remain statistically inconclusive in this model.

Meanwhile, the coefficients for lnROL ($\beta = 0.129$, $p = 0.318$) and lnPR ($\beta = 0.040$, $p = 0.793$) were not statistically significant. This does not necessarily negate their possible influence but may suggest that their effects are either indirect, delayed, or subject to interaction with other unmeasured factors such as enforcement quality, driver behaviour, or vehicle condition.

It is important to interpret these findings with caution. The non-significant F-statistic indicates that the model, as a whole, does not explain a substantial portion of the variation in road accident mortality. This may be attributed to the relatively small sample size (22 observations),

potential omitted variables, or limited variability within the dataset. Nevertheless, the observed relationship between alcohol and accident mortality provides a practical signal worth considering, particularly for public health policy and road safety interventions.

While the statistical strength of the model is limited, the practical implication—especially the impact of alcohol consumption—should not be disregarded. These findings call for further, more robust studies and data expansion to validate the relationships and strengthen the predictive power of the model.

**Table 4:** ARDL Long-Run Form and Bounds Test Results

| Variable | Coefficient | Std. Error | t-Statistic | p-Value |
|---|---|---|---|---|
| C | -1.1994 | 1.7356 | -0.6911 | 0.4989 |
| lnAcc (1) | -0.8139 | 0.2079 | -3.915 | 0.0011* |
| lnAlcohol | 1.2938 | 0.6089 | 2.1249 | 0.0486* |
| lnROL | 0.1288 | 0.1253 | 1.0285 | 0.3181 |
| lnPR | 0.0403 | 0.1511 | 0.2666 | 0.793 |
| *Note: The coefficient of lnAcc(-1) represents the error correction term (ECT).* | | | | |
| *Bound Test F-stat = 7.812 > Upper Bound @ 1% → Cointegration exists* | | | | |

The results of the ARDL long-run form reveal important insights regarding the long-term relationship between the number of road accidents and its determinants. The F-statistic of 7.812 from the Bounds Test exceeds the critical value for the upper bound at the 1% level, indicating the presence of a statistically significant long-run relationship among the variables.

Among the regressors, alcohol consumption (lnAlcohol) shows a positive and statistically significant long-run effect on road accidents ($p = 0.0486$). This suggests that an increase in alcohol consumption is associated with a higher number of accidents, which carries practical implications for road safety policies, particularly those related to drunk driving.

Although lnPR and lnROL are not statistically significant in the long run ($p > 0.05$), their inclusion helps model completeness. Notably, the error correction term (ECT) is negative and statistically significant (coefficient = -0.8139, $p = 0.0011$), confirming that the system corrects itself towards equilibrium in the presence of short-run disturbances. This means that approximately 81.4% of deviations from the long-run path are corrected each year.

The Error Correction Model (ECM) results in Table 5 provide evidence of both short-run and long-run relationships between the variables. The error correction term, CointEq(-1), is negative and statistically significant (coefficient = –0.8139, $p < 0.01$), confirming the existence of a long-run equilibrium relationship among the variables. This coefficient implies that approximately 81% of the previous period's deviation from long-run equilibrium is corrected in the current period, indicating a relatively fast speed of adjustment toward equilibrium.

Among the explanatory variables, lnAlcohol (alcohol consumption) is significant at the 5% level ($p = 0.0398$), suggesting that in the short run, increases in alcohol consumption are positively associated with accident rates. In contrast, lnPR (paved roads) and lnROL (rule of law) do not show statistically significant short-run effects on lnAcc, although their directions are positive. These results suggest that while infrastructure and governance may play roles in accident trends, their immediate impact may be less pronounced than behavioral factors like alcohol consumption.

**Table 5:** Error Correction Model Results for Road Accident Mortality Rate (Dependent Variable)

| Variable | Coefficient | Std. Error | t-Statistic | p-value |
|---|---|---|---|---|
| lnAlcohol | 1.2938 | 0.5811 | 2.2267 | 0.0398* |
| lnROL | 0.1288 | 0.0948 | 1.3596 | 0.1917 |
| lnPR | 0.0403 | 0.0941 | 0.4281 | 0.6739 |
| CointEq(-1) | -0.8139 | 0.2001 | -4.0672 | 0.0008* |

**Table 6:** Summary of Diagnostic Test Results

| Diagnostic Test | Test Statistic / Result | p-value | Interpretation |
|---|---|---|---|
| Normality Test (Jarque-Bera) | JB = 4.85 | 0.088 | Residuals are approximately normally distributed. |
| Heteroskedasticity (BPG Test) | F = 2.22; Obs*$R^2$ = 7.56 | 0.1096 | No evidence of heteroskedasticity. |
| Serial Correlation (BG-LM Test) | F = 0.78; Obs*$R^2$ = 2.08 | 0.4743 | No evidence of autocorrelation. |
| CUSUM Test | Line stays within 5% significance bounds | — | The model is structurally stable over time. |

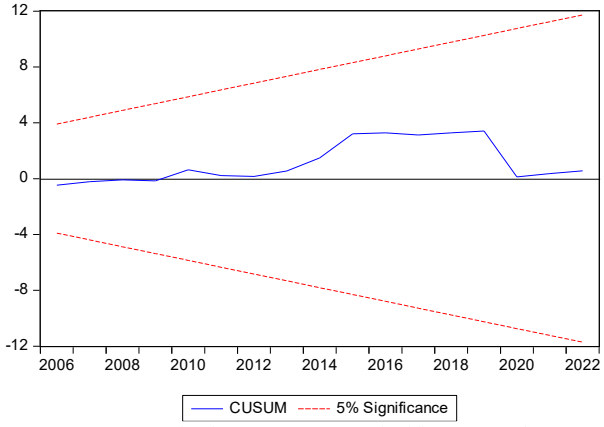


**Fig. 1:** Result of CUSM Test (5% Significance Level)

The diagnostic tests indicate that the ARDL model satisfies key statistical assumptions, ensuring the reliability of the estimates. The Jarque-Bera test produced a p-value of 0.088, suggesting that the residuals are approximately normally distributed and thus suitable for hypothesis testing and inference. Moreover, the Breusch-Pagan-Godfrey test for heteroskedasticity yielded a p-value of 0.1096, indicating that the variance of the residuals is constant over time, and there is no evidence of heteroskedasticity. In terms of serial correlation, the Breusch-Godfrey LM test showed a p-value of 0.4743, signifying that the residuals are not autocorrelated and supporting the appropriateness of the dynamic structure of the model. Finally, the stability of the model was confirmed through the CUSUM and CUSUMQ tests, where the

cumulative sum lines remained within the 5% critical bounds throughout the sample period. This implies that the model is structurally stable, with no significant parameter instability or variance shifts. Collectively, these results affirm that the ARDL model is well-specified and that the findings derived from both the short-run and long-run estimations can be interpreted with confidence.

## 4. Discussions

The results confirm that there is a long-run co-integrating relationship between road accident mortality and the study's key predictors: alcohol consumption, rule of law, and paved road infrastructure. While alcohol consumption was the only variable to show statistical significance in both short- and long-run models, the inclusion of governance and infrastructure factors remains theoretically essential. Their lack of significance may be attributed to known limitations in policy enforcement, lagged effects, or challenges in operationalizing institutional strength and infrastructure quality in empirical models. As Notrica et al. observed, even well-designed regulations or infrastructure improvements do not always yield immediate returns in countries with uneven enforcement or low public compliance [7]. Thus, the absence of short-term impacts for the rule of law and road infrastructure should not be read as evidence of irrelevance, but rather as a reflection of complex implementation dynamics. This highlights the need for sustained, system-level interventions that align behavioral regulation with institutional reform and infrastructure planning.

Recent experimental research by Starkey et al. supports this interpretation, demonstrating that Intelligent Speed Assistance (ISA) smartphone applications can significantly improve drivers' speed compliance, particularly in zones where physical cues fail to align with posted limits. The study found that ISA apps, even in passive or visual-only formats, did not impair driver performance or cause distraction, and were effective in prompting behavioral adjustments without the need for physical enforcement or infrastructure upgrades. These findings suggest that app-based behavioral interventions may serve as short-term, scalable solutions to complement long-run governance and infrastructure reforms. Especially in contexts like the Philippines, where vehicle fleets are older and institutional capacity is uneven, ISA technology offers a promising avenue for reducing accident risk by nudging driver behavior directly—bypassing some limitations associated with enforcement lags and resource constraints [12].

The statistically significant relationship between increased alcohol consumption and road accident mortality, when controlling for both short- and long-run effects, reinforces international evidence linking alcohol use to traffic-related injuries and fatalities, particularly in developing and middle-income countries, as noted in the study of Oliveira et al., Papalimperi et al.[5] These findings emphasize the urgency for sustained behavioral interventions, including strict enforcement of Republic Act No. 10586 (Anti-Drunk and Drugged Driving Act), wider deployment of breathalyzer checkpoints, and mass media road safety campaigns.

Although the rule of law was not statistically significant in this study, its positive coefficient aligns with theoretical expectations that stronger legal institutions reduce accident incidence by promoting compliance and reducing corruption [9]. This interpretation is supported by Kanavos and Vandoros, who emphasize that improvements in institutional quality—such as consistent enforcement and transparency—are strongly associated with improved road safety outcomes [1]. Weak governance often leads to selective law enforcement, public mistrust, and operational inefficiencies, undermining even well-crafted regulations. In the Philippine context, this reinforces ongoing calls to enhance traffic law enforcement through police training, digitized citation systems, and reduced discretionary authority. These institutional reforms are critical in creating a culture of compliance and public accountability that underpins long-term road safety improvements.

Complementing these governance-focused strategies are emerging technology-based interventions that offer scalable and proactive solutions. Telematics systems enable continuous monitoring of driver behavior—such as speeding and erratic maneuvers—and support real-time coaching and feedback loops. When integrated with alcohol testing or fatigue monitoring protocols in commercial fleets, these systems help prevent high-risk behaviors before they lead to accidents [13]. Intelligent Speed Assistance (ISA) applications further support these efforts. As demonstrated by Starkey, Charlton, Malhotra, and Lehtonen, ISA smartphone apps significantly improved speed compliance, even in areas where physical road cues were unclear or insufficient [14]. Their study found that even passive or visual-only ISA formats were effective in modifying driver behavior without causing distraction or impairing performance. These results suggest that ISA apps may serve as a low-cost, short-term intervention to complement long-term infrastructure and governance reforms. Additionally, AI-driven traffic cameras and automated e-ticketing systems can reduce dependence on manual enforcement and limit opportunities for corruption. These technologies generate actionable data that can inform evidence-based policies and strengthen institutional decision-making. Collectively, these innovations serve as both interim and structural solutions—especially vital in the Philippine setting, where institutional and enforcement capacities are still developing.

Paved road length did not have significant coefficients either, though reliance on infrastructure quantity (e.g., kilometers of paved roads) as a surrogate for quality could help to explain such observations. Ahmed et al. contend that road infrastructure modifications only work in combination with a safety-oriented design, periodic maintenance, and contextual additions like sidewalks and speed bumps [6]. Road widening has not necessarily been associated with such improvements in the Philippines, which may account for the weak explanatory power of the variable. From the perspective of public investment, this argues that in the future, infrastructure policies also need to focus not only on coverage but also on usability, accessibility, and safety features in densely inhabited or rapidly urbanizing regions. The exclusion of the urban population from the ARDL final model as a result of I(2) credibility is a limitation. However, the theoretical and real-world significance of the variable for accident trends is still limited. Rapid urbanization, as observed in Boquet and the Asian Development Bank, is associated with vehicle congestion, risky road behavior, and inconsistent enforcement—remaining features to embed in next-generation models through proxy measures such as vehicle density, public transport patronage, or satellite-based congestion readings [11,10]. The limitations of using paved road length as a proxy for infrastructure effectiveness underscore the need to measure how roads are used rather than just how many exist. Telematics platforms, as discussed by GoFleet, offer granular insights into traffic flow, congestion hotspots, and dangerous driving patterns—data that traditional infrastructure statistics cannot capture [13]. This supports the idea that smart technologies, including vehicle tracking and driver monitoring systems, could serve as proxy indicators for road usability, enforcement gaps, and congestion stress, especially in rapidly urbanizing regions. Such tools could enrich ARDL or panel models that seek to capture the nuanced effects of urbanization and mobility behavior on accident trends.

Governance literature suggests that road safety outcomes depend not only on formal legislation but also on institutional quality, coordination, and the distribution of responsibility among actors. In high-capacity states, responsibility for road safety has progressively shifted from the individual driver to system-level actors such as transport agencies, municipalities, and vehicle manufacturers. This approach, described by Hysing as "responsibilization," reflects a transition from reactive enforcement to proactive design of safer transport ecosystems. Sweden's Vision Zero model, for instance, exemplifies this shift by treating road fatalities as preventable through systemic design rather than solely through user compliance or enforcement [15].

In contrast, low- and middle-income countries such as the Philippines tend to retain a driver-centric approach, where the burden of safety is placed almost entirely on road users and traffic enforcers. This fragmented model often leads to uneven enforcement, policy inconsistency, and accountability gaps. According to the PwC (2024) "Destination 2030" report on road safety governance, countries with high road mortality typically lack clear lead agencies, reliable crash data, and multi-sectoral coordination frameworks [16]. These deficits apply directly to the Philippine context, where institutional overlap between MMDA, LTO, LGUs, and other enforcement bodies dilutes accountability and complicates strategic planning.

Empirical studies further confirm that governance quality significantly moderates how behavioral and cultural factors influence road outcomes. Arslan and Özkan demonstrated that in countries with lower governance scores, cultural dimensions like power distance and uncertainty avoidance are more likely to exacerbate risky driving behaviors, such as speeding or non-compliance with traffic rules [17]. In the Philippines, where informal practices and selective law enforcement persist, this interaction between weak institutions and cultural dynamics could explain why the rule of law variable in this study had no statistically significant effect despite its theoretical importance.

Moreover, global governance analyses emphasize the importance of coordination between national and subnational actors. Canoquena and King highlight that OECD countries with better safety records tend to exhibit strong vertical coordination—linking national targets with local implementation capacity—and maintain data-driven feedback loops to adjust policy [18]. In contrast, the Philippine road safety environment remains highly centralized but operationally fragmented. For example, while Republic Act No. 10586 mandates anti-drunk driving enforcement, its implementation is often undermined by local resource constraints, poor monitoring infrastructure, and limited integration with public health or urban planning agencies [9].

These comparative insights support the view that policy design in the Philippines must evolve beyond traditional enforcement and infrastructure expansion. The findings of this study—especially the significant role of alcohol consumption and the statistically insignificant governance and infrastructure variables—mirror a larger structural disconnect: laws exist, but institutional follow-through is inconsistent. As such, addressing road safety in the Philippines will require deeper governance reforms, including the establishment of a single road safety lead agency, improved inter-agency coordination, expanded use of crash data analytics, and integration of risk-reduction frameworks across sectors. Bridging these governance gaps is essential to translating behavioral policies into real-world safety outcomes.

The role of the private sector goes beyond being made compliant with laws and standards and can be a key driver in the realisation of public health goals, especially road safety. Sectors-transport, insurance, logistics, automotive, and public transport industries are not only at risk from operational factors arising from road crashes but are increasingly able to determine the health consequences through their policies and technologies. The emerging use of telematics systems—which track driver habits, vehicle speed, and route efficiency—has demonstrably lowered the number and severity of accidents. A decrease in the number of accidents correlates to a decrease in the frequency of injuries hospitalised, with lower pressure response at emergency departments related to head trauma and rehabilitation services. Such business-led road safety initiatives thus add callosity to the health systems as they prevent needless injuries, earnings loss due to road accidents, and healthcare costs from road crash victims. Internal corporation-wide policies such as testing for alcohol for drivers, safety training, and protocols for fatigue management have dual benefits (they protect the workers and, at the same time, contribute to the population-wide reduction of risks of accidents). They are consistent with public health objectives by focusing on behaviors (drunk/unsafe driving) at the level of the organization, and can help supplement enforcement pursuits by the government. When applied across sectors, these steps can contribute to cutting national accident rates, saving lives, and building healthier and more sustainable communities. In this context, strategic business operations should go beyond compliance or operational-focused strategies and be positioned as part of a multi-sectoral health framework for road safety.

## 5. Conclusion

This study examined the long-run determinants of traffic-related fatalities in the Philippines using the ARDL bounds testing approach. While the short-run model lacked overall statistical significance, the presence of cointegration and a highly significant error correction term confirmed a stable long-term relationship between crash mortality and key predictors—alcohol consumption, governance quality, and infrastructure development. Notably, alcohol consumption emerged as a significant long-run factor, reinforcing the importance of sustained behavioral and regulatory interventions. Although the rule of law and paved road variables were not statistically significant, their inclusion offers valuable directional insights, suggesting that outcomes are shaped by a broader system of institutional performance and public investment.

From a policy perspective, the findings emphasize the need for continuity, coordination, and long-term investment in reducing traffic-related harm. For the business sector—particularly transport operators, insurers, and logistics firms—this study highlights how internal safety protocols, compliance strategies, and innovation in monitoring technologies can yield both social and operational benefits. Ultimately, improving transport safety is a shared responsibility. Even in the absence of immediate statistical effects, ongoing efforts from both public and private sectors remain essential in achieving meaningful reductions in crash-related losses over time.

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