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Original Article

# Factors Influencing Traffic Accidents on the Cipularang Toll Road: An Analysis Using Multiple Linear Regression

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## Abstract

Traffic accidents remain a critical issue in road safety, particularly on toll roads with high traffic intensity such as the Cipularang Toll Road. This study aims to analyze the factors influencing traffic accidents by applying a multiple linear regression approach, with a focus on human-related factors represented by driver physical condition. Data spanning 2023–2025 from the Cipularang Toll Road corridor were collected through structured interview surveys and supported by secondary data from official accident records. The variables examined include driver characteristics, vehicle conditions, traffic and environmental factors, and behavioral aspects. The results show that estimated speed and driving license type have a statistically significant effect on the dependent variable at the 5% significance level. Estimated speed is identified as the most influential factor, indicating that higher speeds are associated with a decline in driver physical condition, which may increase accident risk. The selection of physical condition as the dependent variable is supported by police reports indicating that a substantial number of accidents are caused by driver fatigue, drowsiness, and reduced alertness, especially on long-distance toll roads. Other variables, although not statistically significant, demonstrate relationships consistent with theoretical expectations. These findings highlight the importance of addressing both speed management and driver fatigue in reducing accident risk. The study contributes to evidence-based road safety strategies by providing a comprehensive analysis of accident-related factors, helping policymakers and toll road operators design more effective safety interventions, especially on high-risk segments like the Cipularang Toll Road.

**Keywords**: Cipularang Toll Road, Multiple Linear Regression, Risk Factors, Road Safety, Traffic Accidents.

## 1. Introduction

One of the most prominent manifestations of this problem is the high number of traffic accidents that not only result in fatalities and material losses, but also impose significant economic and social burdens. Although toll roads generally have better physical characteristics than arterial roads, toll roads still contribute a considerable proportion of traffic accidents. This can be observed in the visual presentation of accident data on the Cipularang Toll Road (Figure 1), which depicts a comparison of accident frequency trends and their severity levels during the 2023–2025 period through graphical representation.

Based on Figure 1, it is apparent that there is a pattern that is not entirely unidirectional between the number of accidents and the severity level. Visually, the total number of accidents remained relatively stable in 2023 and 2024 at 55 cases, then declined to 24 cases in 2025. However, the severity level indicators showed a different tendency. The number of fatalities increased from 16 cases in 2023 to 21 cases in 2025. Serious injuries also experienced a significant increase from 2 to 3 cases in the early years to 27 cases in 2025. Meanwhile, minor injuries showed a sharp surge from 55 cases in 2024 to 175 cases in 2025. The pattern visible in the figure indicates a discrepancy (anomaly) between the frequency of accident occurrences and their impacts.

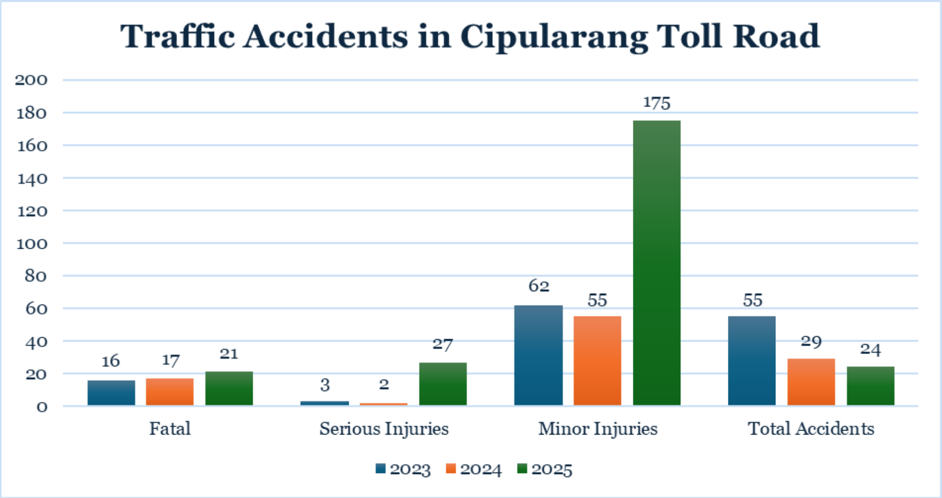


**Figure 1. Traffic Accidents in Cipularang Toll Road**
Source: Indonesia National Traffic Corps, 2026

The visual findings in Figure 1 indicate the existence of a hidden risk that cannot be explained solely through the number of accident occurrences. In other words, although the number of accidents tends to decline, the impact generated by each occurrence is actually growing larger. This indicates a non-linear risk pattern, in which a decrease in frequency is not always followed by a decrease in severity level. This condition indicates that factors such as high vehicle speeds, traffic density, and complex road geometric characteristics can amplify the impact when accidents occur.

The implications of this pattern are quite serious for road safety effectiveness, particularly on toll roads with high-speed characteristics such as the Cipularang Toll Road. Therefore, the focus of road safety management needs to be directed not only toward efforts to reduce the number of accidents, but also toward mitigating severity levels through speed control, improvement of road infrastructure design, and strengthening of driver behavior.

In the academic and transportation planning context, quantitative statistical approaches such as linear regression and spatial analysis are widely used to identify and measure the relationships between variables related to traffic accidents (Elvik, 2008; Tamin, 2000). However, studies that specifically apply multiple linear regression to the case of the Cipularang Toll Road remain very limited. Yet this approach is capable of providing a more comprehensive and measurable understanding of the simultaneous influence of various variables on accident rates.

Previous research, such as that conducted by Alsaleh et al. (2025), demonstrated that multivariate approaches are more effective in explaining the interactions between driver characteristics, vehicle types, and environmental conditions in determining accident severity levels. Local studies by Sihombing and Widyastuti (2021) and Yunistra et al. (2022) emphasized the importance of accident-prone location (blackspot) analysis by considering variables such as time of occurrence, weather conditions, and vehicle conditions in the Cipularang area. Furthermore, Oktopianto et al. (2023) found that curve radius and curve length had a significant influence on accident occurrences, particularly in areas with hilly terrain characteristics such as the Cipularang Toll Road.

Although accident figures are considerably high and various analytical approaches have been available, there remains a deficiency in integrated analysis between technical, human, and environmental factors within a unified statistical model. Therefore, this research becomes important to address that gap. The primary objective of this research is to identify factors that simultaneously and significantly influence traffic accidents on the Cipularang Toll Road using a multiple linear regression approach.

This research also addresses several research gaps identified from previous literature (Andarini et al., 2021; Joni & Jasim, 2022; Tuasikal et al., 2020). First, previous studies tended to use descriptive analysis or bivariate correlation, with limitations in the use of multivariate approaches such as multiple linear regression, particularly in Indonesia. Second, there remains a lack of integration between road geometric data, weather conditions, driver behavior, and temporal factors within a single analytical framework. Third, spatial analyses such as blackspot and trouble spot identification have not been widely integrated with statistical predictive models.

Based on these conditions, this research aims to fill that gap by analyzing factors that simultaneously influence traffic accident frequency on the Cipularang Toll Road. This research uses a multiple linear regression approach with independent variables including average vehicle speed, traffic volume, weather conditions, road geometric design, and time factors. This approach is expected to provide a more objective and measurable understanding of the relationships between these variables and traffic accidents, thereby supporting evidence-based policy making in road safety, including infrastructure planning, traffic management, and road user education.

By integrating findings from various previous studies and combining various methodological approaches, this research not only aims to explain the accident phenomenon on the Cipularang Toll Road, but also to develop a predictive analytical framework that can be replicated on other toll roads in Indonesia with similar characteristics.

## 2. Literature Review

### 2.1. Traffic Accident Factors

Traffic accidents are fundamentally events that occur due to non-ideal interactions among the three main components of the transportation system, namely humans, vehicles, and roads (Dewi et al., 2025). According to the World Health Organization (WHO, 2018), accidents cannot be attributed to a single factor, but rather result from a combination of multiple risk factors that occur simultaneously. Warpani (2002) also emphasizes that traffic accidents are a multifactorial phenomenon, where disruption in one element of the transportation system increases the likelihood of an accident, while simultaneous disruptions in two or more elements significantly amplify the risk.

Figure 2 below illustrates the relationship among the three primary factors causing traffic accidents, namely human, vehicle, and road factors. These elements are interconnected and form an integrated system that determines the level of accident risk in a particular location, including the Cipularang Toll Road. In the context of this study, the triangular relationship explains that accidents never occur due to a single factor, but rather as a result of the interaction of multiple factors that influence each other simultaneously.

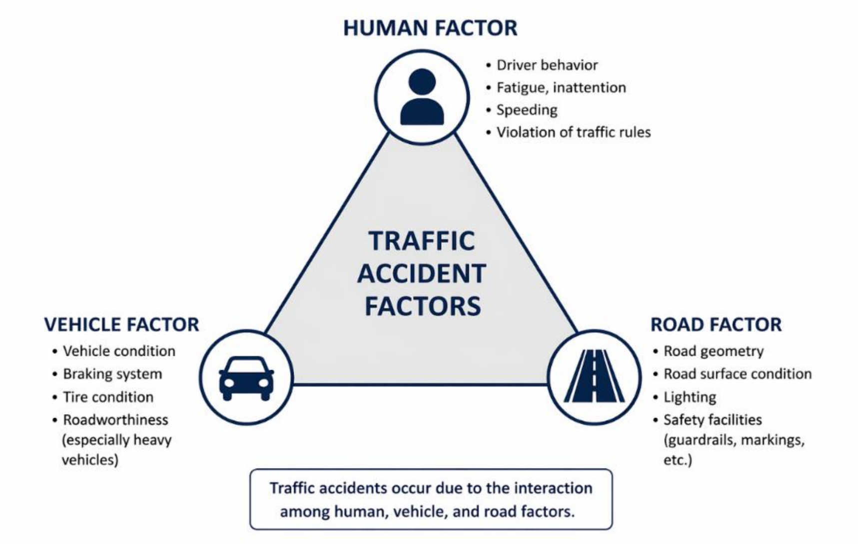


**Figure 2. Traffic Accident Factors**

The human factor includes driver behavior such as fatigue, negligence, speeding, and non-compliance with traffic regulations. This factor is often the primary trigger of accidents, as more than 70 percent of cases originate from driver error. However, human behavior cannot be separated from other factors. For instance, a drowsy driver may not result in a fatal accident if road conditions are supportive, such as adequate lighting and a non-slippery surface.

The vehicle factor relates to the technical condition of the transportation mode, including braking systems, tire conditions, and the roadworthiness of heavy vehicles. Poor vehicle maintenance can increase accident risk, particularly on challenging road segments such as the Cipularang Toll Road, which features steep gradients and sharp curves. In this study, the proportion of heavy vehicles relative to light vehicles is also an important indicator for understanding traffic load and the potential hazards arising from differences in speed and vehicle size.

Meanwhile, the road factor encompasses geometric design, physical conditions, and the surrounding environment. Elements such as gradient, curve radius, shoulder width, and the availability of safety facilities such as guardrails, road markings, and street lighting are critical in the analysis. On the Cipularang Toll Road, the undulating topography and hilly terrain create many segments with high levels of driving difficulty. When human and vehicle factors are not in optimal condition, challenging road characteristics can significantly increase the likelihood of accidents.

This triangular framework also demonstrates that these three factors cannot be separated, as changes in one factor will influence the others. For example, poor road conditions such as slippery surfaces or faded markings may lead drivers to reduce speed to adapt, while well-maintained vehicles may increase driver confidence and encourage higher speeds without fully considering the associated risks.

## 2.2. Multiple Linear Regression

Multiple linear regression is a statistical method used to analyze the relationship between one dependent variable (Y) and more than one independent variable ($X_1$, $X_2$, ..., $X_n$). In the context of road safety studies, this method is highly relevant because traffic accidents are influenced by a combination of interacting factors, including human, vehicle, road, and environmental conditions.

According to Montgomery et al. (2012), multiple linear regression is used to model the linear relationship between a dependent variable Y and several independent variables $X_i$ by estimating regression coefficients that represent the direction and magnitude of the effect of each variable. The general form of the multiple linear regression model is expressed as follows:

$$Y = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \cdots + \beta nXn + \varepsilon \quad (1)$$

where:

Y = dependent variable (e.g., accident rate or crash density),

$X_1$ - $X_n$ = independent variables such as average speed, traffic volume, curve radius, weather conditions, and vehicle type

$\beta_0$ = intercept (constant)

$\beta_1$ - $\beta_n$ = regression coefficients representing the influence of each independent variable on Y

ε = error term or residual not explained by the model

This model is widely applied in traffic accident studies because it provides important indicators such as the coefficient of determination ($R^2$), which explains how much variation in accident occurrence can be accounted for by the model. In addition, multiple linear regression enables the identification of dominant variables through significance testing (p-value), allowing accident contributing factors to be determined based on strong empirical evidence (Gujarati & Porter, 2009).

International studies have demonstrated the reliability of this method. Al-Bayati et al. (2021) applied multiple regression to model accident density on multilane roads and found that traffic volume and speed have significant effects. Gorzelanczyk and Tylicki (2023) also showed that regression can be used to optimize accident-related variables for predicting accident hotspots. In Indonesia, studies by Oktopianto et al. (2023) and Yunistra et al. (2022) confirm that multiple linear regression is effective in identifying the influence of road geometry and human factors on accident frequency, particularly on contoured road segments and toll roads.

Therefore, multiple linear regression not only provides statistical insight into the factors influencing traffic accidents but also produces predictive models that can serve as a basis for developing evidence-based road safety policies.

## 2.3. Previous Research

In the academic and transportation planning context, quantitative statistical approaches such as linear regression and spatial analysis are widely used to identify and measure the relationships between accident-related variables (Elvik, 2008; Tamin, 2000). However, studies specifically applying multiple linear regression to the Cipularang Toll Road case remain limited. In fact, this approach can provide a more comprehensive and measurable understanding of the simultaneous effects of multiple variables on accident rates.

Previous studies, such as those by Alsaleh et al. (2025), demonstrate that multivariate approaches are more effective in explaining interactions among driver characteristics, vehicle types, and environmental conditions in determining accident severity. Local studies by Sihombing and Widyastuti (2021) along with Yunistra et al. (2022) emphasize the importance of analyzing blackspot locations along with variables such as time, weather, and vehicle conditions in the Cipularang context. Additionally, Oktopianto et al. (2023) found that curve radius and curve length significantly affect accident occurrence, particularly in mountainous or contoured areas like Cipularang.

Despite the high accident rates and the availability of various analytical approaches, there remains a lack of integrated analysis combining technical, human, and environmental factors within a unified statistical model. Therefore, this study is essential to address this gap. The main objective of this research is to identify factors that simultaneously and significantly influence traffic accidents on the Cipularang Toll Road using a multiple linear regression approach.

This study also addresses several research gaps identified from previous literature. First, earlier studies tend to focus on descriptive or bivariate correlation analyses, with limited application of multivariate approaches such as multiple linear regression, particularly in Indonesia. Second, there is a lack of integration between road geometric data, weather conditions, driver behavior, and temporal factors within a single analytical framework. Third, spatial analyses (such as blackspot and trouble spot identification) are often not integrated with predictive statistical models.

Based on these conditions, this research aims to fill these gaps by analyzing the factors that simultaneously influence traffic accident frequency on the Cipularang Toll Road. The study employs a multiple linear regression approach, with independent variables including average vehicle speed, traffic volume, weather conditions, road geometric design, and time-related data. This approach is expected to provide a more objective and measurable understanding of the relationships between these factors and traffic accidents, thereby supporting evidence-based policy-making in road safety, including infrastructure design, traffic management, and user education.

By integrating insights from previous studies and combining multiple methodological approaches, this research not only aims to explain the accident phenomena on the Cipularang Toll Road but also to develop a predictive analytical framework that can be replicated for other toll roads in Indonesia with similar characteristics.

## 3. Methods

The research methodology applied in this research follows a systematic workflow to ensure that each stage is conducted in a structured manner. The workflow is presented in Figure 3. Research Flowchart.

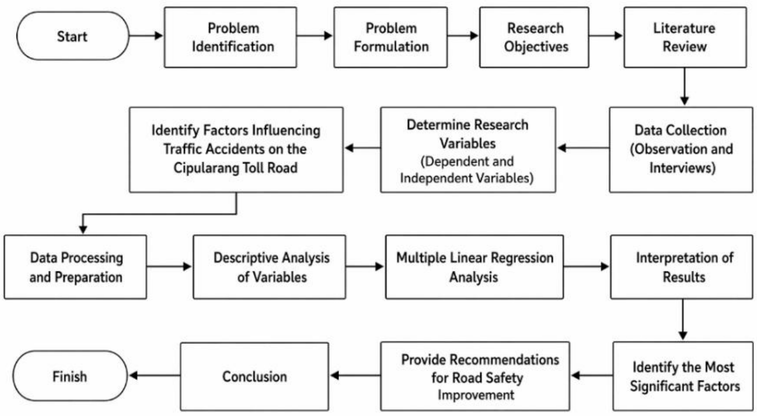


**Figure 3. Research Flowchart**

This study begins with problem identification, followed by problem formulation, the establishment of research objectives, and the development of a literature review. These initial stages aim to understand the context of traffic accidents on the Cipularang Toll Road and to build a solid theoretical and conceptual foundation for the study. Subsequently, the research focuses on formulating key analytical questions, including identifying the factors influencing traffic accidents, measuring the magnitude of their effects, and determining which factors have the most significant impact on accident risk.

To address these objectives, the study employs a combination of field observations, interviews, and literature review to identify the main contributing factors to traffic accidents. This is followed by data collection and processing, which are then analyzed using multiple linear regression. The analysis produces regression coefficients that indicate the magnitude and direction of the influence of each independent variable on the dependent variable, namely the level of traffic accidents. The interpretation of the statistical results is supported by relevant literature to ensure consistency and robustness of the findings.

Finally, the study identifies the most significant factors influencing accident risk and develops a mapping of these key variables. The results lead to two main contributions: the identification of the most influential factors in increasing or reducing accident levels, and the formulation of data-driven policy recommendations for toll road operators and traffic safety authorities. The research concludes with hypothesis testing, followed by the development of conclusions and recommendations. Through this systematic approach, the study is expected to provide both empirical and practical contributions to traffic accident mitigation efforts on toll roads in Indonesia, particularly on the Cipularang Toll Road.

## 3.1. Data Collection Method

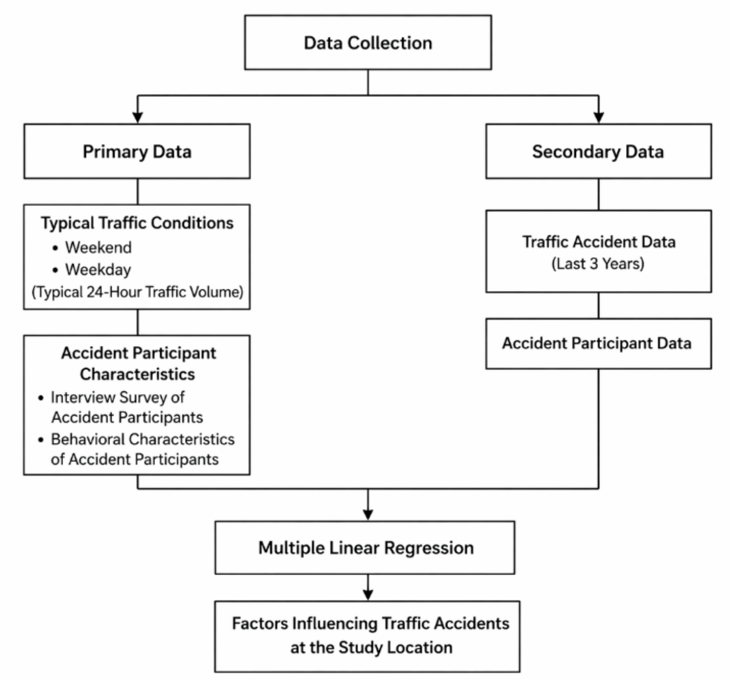


**Figure 4. Data Collection Flowchart**

The diagram depicted in figure 4 illustrates data collection framework that begins with data collection, which is divided into primary and secondary data. Primary data include typical traffic conditions such as weekend and weekday traffic volumes, as well as accident participant characteristics obtained through interviews and behavioral analysis. Secondary data consist of traffic accident records from the last three years and data related to accident participants. All collected data are then processed and analyzed using multiple linear regression to identify and quantify the influence of various factors on traffic accidents. The final output of this process is the identification of key factors that significantly affect traffic accidents at the study location.

The implementation of the interview survey in this study aims to obtain more in-depth information regarding the characteristics of traffic accident participants on the toll road study segment, particularly aspects that are not fully captured in administrative data. The interview survey is considered essential because human factors represent a key component in the road safety system, significantly influencing accident occurrence through driving behavior, physical condition, and decision-making processes while driving.

Respondents for the interview survey were selected based on accident participant data obtained from official records over the past three years on the study segment. This approach ensures that the respondents directly represent individuals involved in traffic accidents, thereby enhancing the empirical relevance of the information collected. The number of respondents was determined based on the minimum sample size requirements established earlier using historical accident data.

**Table 1. Interview Questionnaire**

| No | Question | Answer Options |
|---|---|---|
| 1. | Respondent Code | - |
| 2. | Gender | Male / Female |
| 3. | Age | ____ years |
| 4. | Highest Education Level | Elementary / Junior High / Senior High / Diploma / Bachelor |
| 5. | Main Occupation | - |
| 6. | Driving License Type | License A / License B / License C / None |
| 7. | Driving Experience | <1 year / 1-5 years / 6-10 years / >10 years |
| 8. | Daily Driving Duration | <2 hours / 2-4 hours / 5-8 hours / >8 hours |
| 9. | Frequency of Using Toll Roads | Rarely / Occasionally / Often / Very often |
| 10. | Vehicle Type | Car / Bus / Light Truck / Heavy Truck |
| 11. | Vehicle Condition Before the Incident | Good / Fair / Poor |
| 12. | Technical Issues Before the Accident | None / Brake / Tire / Engine |
| 13. | Time of Incident | Morning / Afternoon / Evening |
| 14. | Weather Condition | Clear / Light Rain / Heavy Rain / Fog |
| 15. | Traffic Condition | Smooth / Dense / Highly congested |
| 16. | Estimated Vehicle Speed | <40 km/h / 40-60 km/h / 61-80 km/h / >80 km/h |
| 17. | Physical Condition Before Driving | Fit / Fatigued / Drowsy / Mildly ill |
| 18. | Activity Before Driving | Resting / Long-distance travel / Driving for long hours |
| 19. | Mobile Phone Usage While Driving | Never / Occasionally / Often |
| 20. | Compliance with Speed Limits | Always comply / Sometimes violate / Often violate |
| 21. | Main Cause of Accident (Respondent's Perspective) | Human / Vehicle / Road / Weather |
| 22. | Influence of Road Condition on Accident | None / Small / Moderate / High |
| 23. | Suggestions for Safety Improvement | - |

The interviews were conducted in a structured manner using a set of predefined questions designed to explore various aspects of accident participant characteristics. The information collected includes basic driver identity, driving experience, physical and psychological condition at the time of the incident, compliance with traffic regulations, and perceptions of road and traffic conditions. The use of a structured interview format ensures consistency across respondents and facilitates subsequent data processing and statistical analysis.

The data obtained from the interview survey were then processed and classified into variables suitable for quantitative analysis, particularly as independent variables in the multiple linear regression model. By integrating accident participant characteristics with traffic-related data, this study aims to provide a more comprehensive understanding of how human factors interact with other variables in influencing accident occurrence on the toll road.

Thus, the interview survey serves not only as a complement to secondary data but also as a critical component in capturing behavioral and situational aspects of accident participants, contributing to the development of a data-driven road safety analysis model based on field conditions.

## 3.2. Statistical Method and Data Coding

This study employs a quantitative approach using multiple linear regression analysis to examine the influence of various independent variables on the dependent variable. Prior to analysis, all data collected from the interview survey were systematically processed and transformed into numerical form through a coding procedure. This coding process is essential to convert qualitative and categorical responses into measurable variables that can be analyzed statistically.

Each variable was assigned a numerical code based on its category. For nominal variables such as gender, vehicle type, and driving license type, dummy or categorical coding was applied. For ordinal variables such as education level, frequency of toll usage, compliance with speed limits, and traffic conditions, a ranking scale was used to reflect increasing levels or intensity. For example, responses such as “Rarely,” “Occasionally,” “Often,” and “Very often” were coded in ascending order (e.g., 1 to 4). Similarly, conditions such as “Good,” “Fair,” and “Poor” were coded to represent decreasing levels of vehicle condition. Continuous variables such as age and driving duration were maintained in their original numerical form.

Each variable used in this research was first identified based on its data characteristics, then a coding process was carried out to facilitate data processing and statistical analysis. The variable coding scheme covering the variable types and categorization of each indicator is presented in Table 2.

**Table 2. Variable Coding Scheme**

| No | Variable | Type | Coding |
|---|---|---|---|
| 1. | Age | Continuous | Actual value (years) |
| 2. | Gender | Nominal | 1 = Male, 2 = Female |
| 3. | Education Level | Ordinal | 1 = Elementary, 2 = Junior High, 3 = Senior High, 4 = Diploma, 5 = Bachelor |
| 4. | Driving License Type | Nominal | 1 = License A, 2 = License B, 3 = License C, 4 = None |
| 5. | Driving Experience | Ordinal | 1 = <1 year, 2 = 1-5 years, 3 = 6-10 years, 4 = >10 years |
| 6. | Driving Duration | Ordinal | 1 = <2 hours, 2 = 2-4 hours, 3 = 5-8 hours, 4 = >8 hours |
| 7. | Toll Usage Frequency | Ordinal | 1 = Rarely, 2 = Occasionally, 3 = Often, 4 = Very often |
| 8. | Vehicle Type | Nominal | 1 = Car, 2 = Bus, 3 = Light Truck, 4 = Heavy Truck |
| 9. | Vehicle Condition | Ordinal | 1 = Poor, 2 = Fair, 3 = Good |
| 10. | Technical Issues | Nominal | 0 = None, 1 = Brake, 2 = Tire, 3 = Engine |
| 11. | Time of Incident | Nominal | 1 = Morning, 2 = Afternoon, 3 = Evening |
| 12. | Weather Condition | Ordinal | 1 = Clear, 2 = Light Rain, 3 = Heavy Rain, 4 = Fog |
| 13. | Traffic Condition | Ordinal | 1 = Smooth, 2 = Dense, 3 = Highly congested |

| No | Variable | Type | Coding |
|---|---|---|---|
| 14. | Estimated Speed | Ordinal | 1 = <40 km/h, 2 = 40-60 km/h, 3 = 61-80 km/h, 4 = >80 km/h |
| 15. | Physical Condition | Ordinal | 1 = Fit, 2 = Fatigued, 3 = Drowsy, 4 = Mildly ill |
| 16. | Activity Before Driving | Nominal | 1 = Resting, 2 = Long-distance travel, 3 = Long driving |
| 17. | Mobile Phone Usage | Ordinal | 1 = Never, 2 = Occasionally, 3 = Often |
| 18. | Compliance with Speed Limit | Ordinal | 1 = Always comply, 2 = Sometimes violate, 3 = Often violate |
| 19. | Main Cause of Accident | Nominal | 1 = Human, 2 = Vehicle, 3 = Road, 4 = Weather |
| 20. | Effect of Road Condition | Ordinal | 1 = None, 2 = Small, 3 = Moderate, 4 = High |

After coding, the data were compiled and entered into statistical software for further analysis. Descriptive statistics were first conducted to understand the distribution and characteristics of each variable. Subsequently, multiple linear regression analysis was performed to estimate the relationship between independent variables and the dependent variable. The regression model produces coefficients that indicate the direction and magnitude of the influence of each variable. Statistical significance was evaluated using p-values, while multicollinearity among variables was assessed using tolerance and Variance Inflation Factor (VIF) values.

Through this approach, the study ensures that all variables are standardized and suitable for quantitative analysis, allowing for a robust and reliable interpretation of the factors influencing traffic accidents at the study location.

# 4. Results and Discussion

## 4.1. Result Analysis

### 4.1.1. Multiple Linear Regression Analysis

Multiple linear regression analysis was used to examine the simultaneous influence of independent variables on traffic accident rates. The analysis results are presented in Table 3 below.

**Table 3. Multiple Linear Regression Coefficients Results**

| No | Variable | B | Std. Error | Beta | t | Sig. | Tolerance | VIF |
|---|---|---|---|---|---|---|---|---|
| 1. | Constant | 1.257 | 1.797 | - | 0.700 | 0.488 | - | - |
| 2. | Age | 0.019 | 0.027 | 0.132 | 0.723 | 0.474 | 0.373 | 2.684 |
| 3. | Education | -0.337 | 0.171 | -0.323 | -1.965 | 0.056 | 0.457 | 2.187 |
| 4. | Driving License Type | 0.375 | 0.199 | 0.291 | 1.884 | 0,049 | 0.518 | 1.931 |
| 5. | Driving Experience | -0.338 | 0.288 | -0.224 | -1.173 | 0.248 | 0.339 | 2.950 |
| 6. | Driving Duration | 0.246 | 0.180 | 0.237 | 1.366 | 0.179 | 0.410 | 2.442 |
| 7. | Toll Usage Frequency | 0.132 | 0.148 | 0.117 | 0.890 | 0.378 | 0.711 | 1.406 |
| 8. | Vehicle Type | 0.113 | 0.148 | 0.129 | 0.759 | 0.452 | 0.431 | 2.322 |
| 9. | Vehicle Condition | -0.133 | 0.197 | -0.088 | -0.673 | 0.505 | 0.725 | 1.380 |
| 10. | Technical Issues | 0.267 | 0.166 | 0.253 | 1.610 | 0.115 | 0.500 | 2.001 |
| 11. | Time of Incident | -0.121 | 0.118 | -0.130 | -1.023 | 0.312 | 0.770 | 1.299 |
| 12. | Weather Condition | 0.005 | 0.145 | 0.004 | 0.031 | 0.975 | 0.707 | 1.415 |
| 13. | Traffic Condition | -0.046 | 0.185 | -0.033 | -0.249 | 0.805 | 0.693 | 1.442 |

| No | Variable | B | Std. Error | Beta | t | Sig. | Tolerance | VIF |
|---|---|---|---|---|---|---|---|---|
| 14. | Estimated Speed | 0.406 | 0.169 | 0.338 | 2.400 | 0.021 | 0.623 | 1.604 |
| 15. | Activity Before Driving | 0.123 | 0.179 | 0.099 | 0.683 | 0.498 | 0.593 | 1.685 |
| 16. | Mobile Phone Usage | 0.191 | 0.185 | 0.136 | 1.035 | 0.307 | 0.715 | 1.398 |
| 17. | Compliance with Speed Limit | -0.267 | 0.215 | -0.185 | -1.242 | 0.221 | 0.560 | 1.785 |
| 18. | Main Cause of Accident | 0.149 | 0.102 | 0.188 | 1.454 | 0.153 | 0.740 | 1.352 |
| 19. | Effect of Road Condition | -0.220 | 0.175 | -0.166 | -1.255 | 0.217 | 0.710 | 1.408 |

The results of the multiple linear regression analysis indicate that estimated speed and driver's license type are the only variables that have a statistically significant influence on the dependent variable at the 5% significance level. Estimated speed has a positive coefficient (B = 0.406; Beta = 0.338; p = 0.021), indicating that the higher the vehicle speed, the more the dependent variable increases, in this case the physical condition of the driver related to accident risk. Similarly, driver's license type (B = 0.375; Beta = 0.291; p = 0.049) also shows a significant positive relationship, indicating that differences in driver's license categories can reflect variations in driving exposure or behavioral patterns that influence accident conditions. Meanwhile, the education variable (p = 0.056) is not significant at the 5% level, but shows a negative relationship, indicating that higher education levels tend to be associated with safer or better conditions.

The dependent variable in this model is physical condition, which is specifically used because many traffic accidents on toll roads are strongly associated with driver fatigue and reduced physical readiness. Based on police reports, a significant proportion of accidents occur due to drivers experiencing fatigue, drowsiness, or decreased concentration while driving, especially on long-distance toll road segments such as Cipularang. This justifies the use of physical condition as a proxy for human-related risk factors in the regression model. Although other variables such as driving experience, technical issues, mobile phone usage, and compliance with speed limits are not statistically significant ($p > 0.05$), their coefficient directions remain consistent with theoretical expectations. For example, compliance and experience show negative relationships, indicating a protective effect, while technical issues and phone usage show positive relationships, indicating increased risk. Furthermore, all variables have tolerance values above 0.1 and VIF values below 10, confirming that there are no multicollinearity issues in the model. Overall, the findings highlight that speed and human-related factors, particularly physical condition linked to fatigue, play a critical role in traffic accidents, reinforcing the importance of fatigue management and speed control policies on toll roads.

## 4.2. Discussion

The results of the multiple linear regression analysis indicate that estimated speed and driving license type are the variables that have a statistically significant effect on the dependent variable, namely physical condition, at the 5% significance level. Estimated speed shows a positive and significant relationship (B = 0.406; Beta = 0.338; p = 0.021), indicating that higher driving speeds tend to be associated with a deterioration in the driver's physical condition, which may increase the risk of accidents. Similarly, driving license type (B = 0.375; Beta = 0.291; p = 0.049) also has a significant positive influence, suggesting that differences in license categories may reflect varying driving intensity, exposure, or behavior that affect driver condition during travel. This finding is consistent with the results of research by Elvik et al. (2019) which indicates that increases in speed consistently and significantly elevate accident risk, as higher speeds reduce reaction time and increase the cognitive load of drivers. Furthermore, the relationship between speed and accident risk is also explained in the power model, which demonstrates that small changes in speed can produce large increases in accident fatality rates (Cameron & Elvik, 2010).

The use of physical condition as the dependent variable is particularly relevant in this study, as many traffic accidents on toll roads are closely related to driver fatigue. Based on police reports, a substantial number of accidents occur due to drivers experiencing fatigue, drowsiness, or decreased alertness, especially on long-distance toll road segments such as the Cipularang Toll Road. This supports the assumption that physical condition is a critical representation of human factors in accident occurrence. Although other variables such as driving experience, technical issues, mobile phone usage, and compliance with speed limits are not statistically significant ($p > 0.05$), their coefficient directions remain consistent with theoretical expectations. For instance, variables such as driving experience and compliance show negative coefficients, indicating a potential protective effect, while technical issues and mobile phone usage show positive coefficients, indicating increased risk. Furthermore, the absence of multicollinearity issues, as indicated by tolerance values above 0.1 and VIF values below 10, confirms that the model is statistically reliable. Overall, the findings highlight that speed and driver-related conditions, particularly fatigue-related physical condition, are key factors influencing accident risk, emphasizing the importance of speed control and fatigue management strategies in improving road safety.

The use of physical condition as the dependent variable in this research is highly relevant because driver fatigue has been consistently identified in the literature as one of the primary causes of traffic accidents. Fatigue not only affects physical aspects, but also influences the cognitive functions of drivers, which ultimately reduces their ability to control vehicles optimally.

Empirically, various studies indicate that driver fatigue causes a significant decline in vehicle control, an increase in reaction time, and a reduction in alertness levels while driving (Aprianto et al., 2021; Febrianti & Rahayu, 2019). This condition is particularly dangerous especially in long-distance driving situations or at high speeds, where even the slightest delay in reaction can increase the risk of accidents occurring.

In line with these findings, other research also confirms that drowsiness and fatigue have a significant influence on the increase in traffic accident risk (Aprianto et al., 2021; Puspasari, 2023; Rahmawati & Azwar, 2025). Drivers who experience fatigue tend to have reduced concentration, difficulty maintaining vehicle lane position, and are slower in responding to changes in traffic conditions (Rahmawati & Azwar, 2025; Wangsa et al., 2021). This indicates that fatigue is not merely a subjective factor, but is a measurable risk variable that directly impacts driving safety.

Beyond the physical aspect, fatigue also has an equally important cognitive dimension. Research indicates that cognitive fatigue can influence driving behavior, including changes in speed patterns, inconsistency in vehicle control, and a decline in alertness levels toward the surrounding environment (Muhammad & Lutfi, 2019; Wibowo, 2025). This condition indicates that drivers not only experience a decline in physical capability, but also disruption in the decision-making process during driving.

Thus, these findings reinforce the argument that the physical condition of drivers is an important indicator in explaining traffic accident risk, particularly those related to the human factor. This affirms that fatigue management and improvement of driver alertness are crucial aspects in efforts to enhance road transportation safety.

The findings of this study provide important implications for the development of road safety mitigation strategies, particularly on toll roads with high traffic intensity such as the Cipularang Toll Road. The significant influence of estimated speed indicates that speed management should become a primary focus in reducing accident risk. This can be implemented through stricter enforcement of speed limits, installation of speed monitoring systems such as speed cameras, and the application of intelligent transportation systems (ITS) to monitor real-time traffic conditions. In addition, geometric improvements and road safety facilities, such as clearer signage and warning systems in high-risk segments, can help drivers better anticipate road conditions and adjust their speed accordingly.

Furthermore, the use of physical condition as a key variable highlights the importance of addressing driver fatigue as a major contributing factor to traffic accidents. Based on police reports indicating that many accidents are caused by fatigue and drowsiness, mitigation strategies should include the provision of adequate rest areas, public awareness campaigns on the dangers of fatigued driving, and recommendations for maximum driving duration limits. Toll road operators can also implement periodic reminders through variable message signs (VMS) to encourage drivers to take breaks. In the long term, integrating behavioral monitoring and driver assistance technologies may further enhance safety. Overall, a combination of speed control measures and fatigue management strategies is essential to effectively reduce accident risk and improve road safety performance.

## 5. Conclusion

This research aims to analyze the factors influencing traffic accidents on the Cipularang Toll Road using a multiple linear regression approach, with a specific focus on the human factor represented through the physical condition of drivers. The research results indicate that among the variables tested, estimated speed and driver's license type have a statistically significant influence on the dependent variable at the 5% significance level. Estimated speed shows the strongest influence, indicating that the higher the vehicle speed, the more the physical condition of drivers declines, thereby potentially increasing accident risk. In addition, the education variable shows an influence approaching significance, indicating that higher education levels tend to contribute to safer driving behavior.

The use of physical condition as the dependent variable is supported by empirical evidence from police reports indicating that the majority of traffic accidents are caused by driver fatigue, drowsiness, and reduced alertness, particularly on long-distance toll road segments. This reinforces that the human factor remains an important component in the occurrence of traffic accidents. Although other variables such as driving experience, vehicle condition, traffic conditions, and mobile phone use did not show statistical significance, the direction of relationships produced remains consistent with existing theory, thus still indicating a potential contribution to accident risk.

However, this research has several limitations that need to be considered. First, limitations in sample size may affect the stability of the regression model estimates used. Second, the data used relies on survey results or respondent reports, thus carrying the potential for recall bias that may affect the accuracy of information, particularly regarding driving behavior and physical condition while driving. Third, this research uses a cross-sectional design and therefore cannot describe the temporal causal relationship between independent and dependent variables. Fourth, the use of multiple linear regression (MLR) has limitations in capturing non-linear relationships or complex interactions between variables that may occur in traffic accident phenomena.

Overall, the findings of this research affirm that traffic accidents are influenced by a combination of various interacting factors, with speed and driver condition as the most important determinants in this research. Therefore, effective mitigation efforts need to prioritize speed control and driver fatigue prevention strategies. This research provides empirical and practical contributions through a data-based understanding of accident risk factors and serves as a foundation for the development of road safety policies, particularly on toll road segments with similar characteristics.

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