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ANALYSIS OF THE RELATIONSHIP BETWEEN SPEED CONSISTENCY AND TRAFFIC ACCIDENT PROBABILITY (ON THE MOJOKERTO-SURABAYA TOLL ROAD)

RIKI RISFIANDI
University of Indonesia, Depok, akurisfiandi85@gmail.com

Martha Leni Siregar
University of Indonesia, Depok, martha.leni@ui.ac.id

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Cover Page Footnote

Despite these insights, the study has several limitations. The data on vehicle speeds and accident occurrences were collected over a relatively short period, which may not fully capture long-term trends or seasonal variations. Additionally, the study primarily focuses on quantitative data, potentially overlooking qualitative factors such as driver behavior, weather conditions, and road maintenance practices that could also significantly impact traffic safety. Furthermore, the analysis is limited to the Surabaya-Mojokerto toll road, and the findings may not be directly applicable to other regions with different traffic conditions and infrastructure. Potential future research could address these limitations by incorporating a longer data collection period to observe trends over time and during different seasons. Expanding the scope to include qualitative data could provide a more comprehensive understanding of the factors influencing traffic safety. Additionally, comparative studies with other toll roads in Indonesia or similar regions globally could help validate the findings and offer broader insights. Research could also explore the impact of technological advancements, such as automated traffic management systems and vehicle-to-infrastructure communication, on improving road safety.

ANALYSIS OF THE RELATIONSHIP BETWEEN SPEED CONSISTENCY AND TRAFFIC ACCIDENT PROBABILITY (ON THE MOJOKERTO-SURABAYA TOLL ROAD)

[1]Riki Risfiandi[*] and [1]Martha Leni Siregar

[1]*Civil Engineering Department, Faculty of Engineering, Universitas Indonesia, UI Depok, 16424, Indonesia*

**Correspondence:* *riki.risfiandi@ui.ac.id*

ABSTRACT

Vehicle speed consistency plays a crucial role in maintaining traffic safety, with speed limits set to reduce accident fatalities. While the direct impact of speed limits on vehicle speed is minimal, their implementation significantly influences driver behavior, with about 85% of drivers complying with speed limits. However, variables such as traffic volume, weather conditions, and travel urgency often cause drivers to be inconsistent in adhering to these limits, increasing accident risk. On the Mojokerto-Surabaya toll road, data from Traffic Corps and Jasa Marga recorded 193 accidents with 101 fatalities from 2018 to August 2023, mostly caused by driver behavior such as excessive speed. This study analyzes the relationship between speed consistency and accident probability on this road, highlighting accident issues due to speed violations and inconsistency at ramp off/on locations. Results show the importance of toll road infrastructure considering vehicle volume, identifying accident blackspots, and implementing urgent speed management as key factors in improving safety on the Surabaya-Mojokerto toll road. The findings emphasize the need for better traffic management and speed regulation to reduce fatal accident risks.

Keywords: *Speed Consistency; Accident Blackspots; Traffic Management*

INTRODUCTION

Vehicle speed consistency is vital for ensuring safe and efficient traffic flow. Speed limit signs, whether indicating minimum or maximum speeds, play a crucial role in establishing a safe operating speed range for drivers. Enforcing speed limits is aimed at enhancing road safety by reducing the likelihood and severity of accidents. Research has shown that speed variability is a significant factor affecting road safety, with higher variability being associated with increased accident rates (Aarts & van Schagen, 2006). Moreover, consistent speeds not only contribute to safety but also improve fuel efficiency and reduce environmental impact (Elvik, 2013). Studies indicate that drivers who maintain a consistent speed are less likely to be involved in accidents compared to those with high speed variability (Hauer, 2000).

Inconsistent adherence to speed limits can result from various factors such as traffic volume, weather conditions, and driver urgency. This inconsistency often leads to excessive speeding, thereby elevating the risk of accidents (McCartt et al., 2010). Driver behavior, particularly speeding and fatigue, has been identified as significant contributors to road accidents (Stutts et al., 2003). Research underscores the importance of automated speed enforcement systems in reducing speed variability and improving compliance with speed limits (Cameron et al., 2003). Effective strategies for managing driver fatigue and promoting adherence to speed limits are essential for mitigating accident risks. Moreover, implementing educational campaigns about the dangers of speeding and fatigue can significantly reduce accident rates (Fell & Black, 1997).

The Mojokerto-Surabaya toll road in Indonesia has witnessed a concerning trend of increasing traffic accidents. An analysis of accident data from Traffic Corps (Korlantas) and Jasa Marga reveals a substantial number of accidents resulting in fatalities. Most of these accidents are attributed to driver behavior, including speeding and drowsiness while driving. Given the severity and frequency of accidents on this route, conducting a comprehensive study to examine the relationship between speed consistency and accident probability is imperative. Such an investigation can provide valuable insights into developing targeted interventions aimed at improving traffic safety on the Mojokerto-Surabaya toll road. Data-driven approaches have proven effective in identifying accident-prone areas and devising specific measures to enhance road safety (Montella, 2010).

This study aims to address the pressing issue of traffic accidents on the Mojokerto-Surabaya toll road by analyzing speed consistency and its impact on accident probability. By identifying key factors contributing to accidents, such as speed limit violations and inconsistent vehicle speeds, this research seeks to provide actionable recommendations for enhancing traffic flow safety on the Mojokerto-Surabaya toll road. Implementing variable speed limits based on real-time traffic and weather conditions has been shown to improve speed consistency and reduce accidents (Papageorgiou et al., 2008). Furthermore, integrating advanced driver-assistance systems (ADAS) can help maintain consistent speeds and alert drivers to potential hazards (Regan et al., 2006).

METHODS

The research method employed in this study is meticulously crafted to delve into speed management within the framework of speed limit signs, aiming to optimize speed consistency in traffic flow on toll roads. The methodological process is delineated into several primary stages,

meticulously designed to ensure seamless data collection and analysis alignment (Johnson & Onwuegbuzie, 2004).

In the first stage, researchers meticulously identify and delineate the problems associated with speed consistency concerning prevailing speed limit signs and their correlation with the probability of traffic accidents on the Mojokerto-Surabaya toll road. This problem identification stage lays the groundwork for the study, providing crucial context and direction.

Moving to the second stage, an exhaustive literature review is conducted, offering researchers a comprehensive understanding of the targeted issues. Insights gleaned from existing studies and theories serve as foundational pillars, informing the design of a systematic and structured research framework (Creswell & Plano Clark, 2017). Additionally, guidance from supervisors adds significant value, ensuring the relevance and robustness of the research endeavor.

Subsequently, in the third stage, researchers embark on data collection endeavors, sourcing information from both primary and secondary sources. Data acquisition encompasses various facets relevant to the analysis of the relationship between speed consistency at extant speed limit signs and the likelihood of traffic accidents on the scrutinized toll road. Collected datasets encompass a spectrum of variables, including speed metrics, accident characteristics, and other pertinent factors.

As the fourth stage unfolds, collected data undergoes meticulous scrutiny and analysis. Paired t-tests are employed to compare speeds across fast and slow lanes, while further analysis is conducted to unravel accident characteristics at focal points along the road. The resultant analytical insights are subsequently leveraged to evaluate the intricate relationship between vehicle speed dynamics and traffic accident probabilities.

Finally, in the fifth stage, researchers synthesize the findings gleaned from the data analysis phase into actionable solutions or recommendations. These proposed interventions are envisaged to catalyze improvements in speed management practices and enhance overall traffic safety on the Mojokerto-Surabaya toll road, thereby contributing to a more secure and efficient traffic environment.

RESULTS AND DISCUSSION

The Surabaya-Mojokerto toll road is a vital artery connecting two major cities in East Java, Surabaya and Mojokerto, with modern facilities such as rest areas, toll plazas, and advanced traffic management systems. Toll gates on this road serve as entry and exit points equipped with electronic transaction facilities, rest areas, and additional services, playing a significant role as information and service centers for road users. Among key toll gates like Waru Toll Gate, Mojokerto Barat and Timur, and Surabaya Timur, speed limits are regulated to maintain traffic safety and smooth flow, especially in ramp off and ramp on areas.

To monitor speed and traffic volume, surveys are conducted using speed guns and traffic counting devices at each point after ramp off and ramp on. These surveys are carried out by trained survey teams at strategic positions along the toll road, producing data on average speed, maximum speed, and vehicle volume over specific periods. The analysis results from these surveys are used to evaluate driver compliance with speed limits, identify accident-prone areas, and design more

effective traffic management strategies and safety policies. Thus, these surveys contribute to raising driving safety awareness, optimizing traffic management, and supporting government efforts in creating safer and smoother traffic in East Java.

Based on speed surveys on the Surabaya-Mojokerto toll road, average speed calculations are performed for each ramp off/on location based on fast and slow lanes for observed vehicle types. Results show speed variations at each location, with some locations showing higher speeds in the fast lane, while others show competitive speeds in the slow lane. Factors such as traffic volume, weather conditions, and road conditions affect driving speed. It is essential for toll road users to carefully understand and heed these survey results while always prioritizing driving safety and comfort. Additionally, the survey also calculates vehicle volume by type and lane, showing dynamic and varied traffic patterns at each location. This data provides a comprehensive picture that can be used to plan more effective traffic management strategies. By considering vehicle volume and average speed, relevant parties can enhance the efficiency and performance of the Surabaya-Mojokerto toll road.

Table 1 Average Speed based on Vehicle Proportion

Location	Fast Lane	Slow Lane
712A	15.31	27.41
723A	-8.08	-1.29
729A	-4.90	-2.25
733A	-0.39	4.56
712B	0.10	0.86
723B	7.41	-2.05
729B	1.01	5.36
733B	-0.31	2.52

After obtaining average speed based on vehicle proportion for each ramp off/on location on the Surabaya-Mojokerto toll road, the next analysis step is to conduct a paired t-test. This test evaluates and identifies the speed differences before and after passing through the ramp off/on. By performing this test, we can assess whether ramp off/on significantly impacts the speed of vehicles passing on the toll road. If statistical test results indicate significant differences between speeds before and after ramp off/on, it may suggest that ramp off/on affects traffic flow and vehicle speed. These test results will provide a deeper understanding of the efficiency and effectiveness of ramp off/on in the Surabaya-Mojokerto toll road traffic system, serving as a reference for future toll road infrastructure planning and development.

Table 2 Paired Samples Statistics

Paired Samples Statistics				
Lane	Mean	N	Std. Deviation	Std. Error Mean
Fast	1.27	8.00	7.24	2.56
Slow	4.39	8.00	9.75	3.45

Table 3 Paired Samples Correlations

Paired Samples Correlations			
Lane	N	Correlation	Sig.
Fast and Slow	8	0.778	0.023

Table 4 Paired Samples Test

Paired Samples Test			
Jalur	t	df	Sig. (2-tailed)
Cepat - Lambat	-1.44	7.00	0.19

The t-test analysis yielded a t-value of 1.44. To interpret this result, we need to compare it with the relevant t-table value. Using data from 7 ramp off/on locations and a significance level (α) of 0.05, the corresponding t-table value is 2.45. Comparing the t-value with the t-table value, we find that the t-value (1.44) is smaller than the t-table value (2.45). In this context, the difference in speed before and after the ramp off/on on the Surabaya-Mojokerto toll road is not considered statistically significant. This means that, based on the observations made, there is no significant difference in the speed change characteristics between the fast lane and the slow lane at the surveyed ramp off/on locations.

Moreover, it is important to note that the correlation result between the two data sets shows a fairly high value of 0.778. A correlation value close to 1 indicates a strong relationship between the two data sets. In this context, it shows a significant relationship between vehicle volume and speed at ramp off/on locations, even though the speed difference is not significant between the fast and slow lanes.

Therefore, even though there is no significant difference in speed changes between the two lanes, the high correlation result indicates the importance of considering vehicle volume in speed analysis at ramp off/on locations on the Surabaya-Mojokerto toll road.

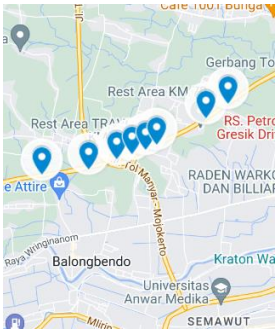
In the analysis of accident distribution, data was collected through the IRSMS (Integrated Road Safety Management System) web portal, which compiles accident data across Indonesia from traffic officers at the district police level. This analysis focused on filtering data to obtain specific

accident data for the Surabaya-Mojokerto toll road. Initially, 195 accidents were found from IRSMS data, but after filtering using the MyMaps platform to align with the studied toll road section, the number of relevant accidents became 165.

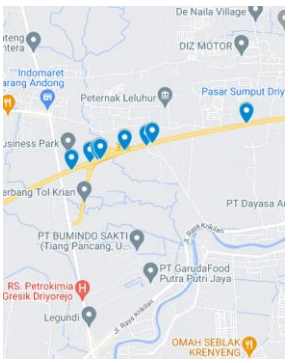
The subsequent analysis focused on the ramp on and ramp off areas within approximately 1 kilometer of each toll gate, covering the toll road segment from kilometre 712 to 733 and four toll gates: Penompo, Wringinanom, Krian, and Driyorejo. The results showed that over the past five years, there were 31 accidents in the studied area. This filtered data is expected to provide deep insights into the accident characteristics in the ramp on and ramp off areas and relevant toll gates, which are crucial for formulating prevention strategies and improving safety on the Surabaya-Mojokerto toll road.

GT Penompo

SS Wringinanom



GT Krian



GT Driyorejo

Figure 1 Accident Points at Each Toll Gate on The Surabaya-Mojokerto Route

After obtaining accident distribution data on the Surabaya-Mojokerto toll road, the next step was to score each accident occurrence. This scoring was done based on the method established by the Korlantas for determining blackspot locations or accident-prone points. This scoring method is designed to provide a weight or value reflecting the severity of each accident.

Once the scoring process for each accident occurrence was completed based on the method established by Korlantas, the next step was to analyze the number of casualties for each severity category and the total score generated for each accident location. This analysis aims to identify and determine locations that meet the criteria as blackspots or accident-prone points.

Based on the collected and analyzed data, it was found that the location at kilometre 729 in direction B on the Surabaya-Mojokerto toll road is one of the blackspot locations. The determination of this location is based on the total score obtained, where the score from accidents at this location has exceeded the value of 30. The standard value of 30 has been set as the threshold to determine a location as a blackspot based on the Korlantas scoring method.

Table 5 Total Casualties and Scores for Each Location

Location	Direction	Fatalities	Serious Injuries	Minor Injuries	Score
712	A	16	17	14	14
712	B	1	0	6	13
723	A	1	0	8	14
723	B	1	0	5	12
729	A	0	0	2	2
729	B	5	17	50	33
733	A	1	0	1	11
733	B	3	0	11	22

This indicates that the location at kilometre 729 in direction B has a high severity level of accidents and requires more attention in prevention and safety improvement efforts. By identifying blackspot locations like this, relevant parties can immediately formulate appropriate strategies or actions to reduce accident risks at that location, as well as evaluate infrastructure conditions, traffic regulations, or other factors that may contribute to the high accident rate at that location.

Table 6 Correlation Test Results between Speed and Accidents

Correlations										
Variable		Parameter	Speed Before	Speed After	Difference Speed	Score	Victims	Fatalities	Serious Injuries	Minor Injuries
Speed	Before	Pearson Cor.	1	0.546	0.534	0.252	0.591	.722*	.715*	0.36
		Sig.		0.161	0.173	0.547	0.123	0.043	0.046	0.381
	After	Pearson Cor.	0.546	1	-0.416	0.169	0.079	-0.142	0.021	0.163
		Sig.	0.161		0.305	0.688	0.853	0.738	0.961	0.699
	Difference	Pearson Cor.	0.534	-0.416	1	0.102	0.563	.926**	.754*	0.226
		Sig.	0.173	0.305		0.809	0.146	0.001	0.031	0.59
Accident	Score	Pearson Cor.	0.252	0.169	0.102	1	.771*	0.243	0.571	.880**
		Sig.	0.547	0.688	0.809		0.025	0.562	0.139	0.004

Correlations										
Variable		Parameter	Speed Before	Speed After	Difference Speed	Score	Victims	Fatalities	Serious Injuries	Minor Injuries
	Victims	Pearson Cor.	0.591	0.079	0.563	.771*	1	0.654	.954**	.923**
		Sig.	0.123	0.853	0.146	0.025		0.078	0	0.001
	Fatalities	Pearson Cor.	.722*	-0.142	.926**	0.243	0.654	1	.816*	0.318
		Sig.	0.043	0.738	0.001	0.562	0.078		0.013	0.442
	Serious Injuries	Pearson Cor.	.715*	0.021	.754*	0.571	.954**	.816*	1	.771*
		Sig.	0.046	0.961	0.031	0.139	0	0.013		0.025
	Minor Injuries	Pearson Cor.	0.36	0.163	0.226	.880**	.923**	0.318	.771*	1
		Sig.	0.381	0.699	0.59	0.004	0.001	0.442	0.025	

This study focuses on analyzing the relationship between traffic accidents and vehicle speed on the Surabaya-Mojokerto toll road, particularly at the ramp on/off areas at each toll gate. The objective is to understand the extent to which vehicle speed contributes to the frequency and severity of accidents in these locations using linear regression, a statistical method for measuring linear relationships between variables. SPSS software was used for data processing and statistical analysis, beginning with the input of speed and accident data at each ramp on/off location. Correlation tests, specifically Pearson correlation, were used to assess the strength of the relationship between speed and accident variables. A positive value close to 1 indicates a strong positive linear relationship, while a value close to -1 indicates a strong negative linear relationship. Values close to 0 indicate no linear relationship. Through Pearson correlation, the speed variable most correlated with accident variables can be identified, providing insights into the factors influencing accidents at the studied locations.

The correlation test results between speed and accident variables show interesting and relevant findings in the data analysis. Although there are several correlations between different types of speed and accident variables, the primary focus on the relationship between speed differences and the number of fatalities stands out in the analysis. Based on the output table, the significance between speed differences and the number of fatalities shows a significance value of 0.001, which is much lower than the conventional significance level of 0.05. This indicates a strong and significant relationship between these two variables. Furthermore, the correlation coefficient (r) between speed differences and the number of fatalities is 0.926. This figure exceeds the standard table value of 0.707, reinforcing the confidence that the correlation between the two is real and strong.

With these findings, the next step in the analysis is to apply a linear regression approach using SPSS statistical software. This analysis will allow us to evaluate and measure the extent of the influence of speed differences on the number of fatalities, providing deeper insights into the factors affecting fatal accidents at the studied locations.

In analyzing the relationship between speed differences and the number of fatalities on the Surabaya-Mojokerto toll road, linear regression tests were used considering additional variables as control factors. These control variables, such as the presence of speed limit signs, the number of road lanes, lane width, and shoulder width, were selected based on the characteristics of the studied toll road infrastructure. The aim is to understand the impact of infrastructure on the relationship between speed and accidents. The presence of speed limit signs can affect driver behaviour and average speed on the toll road, while the number and width of lanes can influence traffic flow and the potential for accidents. Shoulder width affects road safety by providing additional space for manoeuvring.

Linear regression analysis using SPSS assesses the relationship between speed differences (independent variable) and the number of fatalities (dependent variable). The results present regression coefficients to indicate the magnitude of change in fatalities based on changes in speed differences, and significance values to determine the statistical significance of the relationship between the two variables. This analysis provides a deeper understanding of how speed differences affect traffic safety on the studied toll road, taking into account relevant infrastructure factors.

Table 7 Linear Regression Test Results

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.947	0.896	0.819	2.25394

Table 8 ANOVA Results

ANOVAa						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	175.679	3	58.56	11.527	.019b
	Residual	20.321	4	5.08		
	Total	196	7			

In the simple linear regression analysis conducted, the dependent variable studied is the number of fatalities resulting from accidents, while the independent variables include six factors potentially influencing the occurrence of accidents: actual speed differential, shoulder width, speed, speed limit, presence of signs, number of lanes, and lane width. The regression test results indicate that only three independent variables significantly affect the number of fatalities: shoulder width, speed, and speed limit. Other variables, such as the presence of signs, number of lanes, and lane width, do not significantly contribute and therefore are not included in the regression model.

The coefficient of determination (R Square) of the regression model is 0.896, meaning approximately 89.6% of the variability in the number of fatalities can be explained by the three independent variables retained in this model. The standard error of the model is 2.25, indicating

how closely the estimates from the regression model approach the actual values from the observational data. Furthermore, the ANOVA results show an F value of 11.527 with a significance value (p-value) of 0.019. The significant F value indicates that the regression model as a whole is significant and has predictive power concerning the number of fatalities. These results provide valuable information about the factors most influencing road safety in the studied location, which can be used for road infrastructure improvements and future traffic safety policies.

Table 9 Linear Regression Results

Coefficientsa					
Model	Unstand. Coef.		Stand. Coef.	t	Sig.
	B	Std. Error	Beta		
(Constant)	7.537	9.935		0.759	0.49
Speed	0.671	0.139	0.986	4.833	0.008
Limit	-0.006	0.119	-0.011	-0.051	0.961
Width	-2.29	1.959	-0.2	-1.169	0.307

Based on the regression analysis results, of the three independent variables studied (speed, speed limit, and shoulder width), only actual speed shows statistical significance below 5%. This indicates that actual speed has a significant impact on the number of fatalities due to accidents on the Surabaya-Mojokerto toll road. Furthermore, the positive beta coefficient for speed indicates that higher average vehicle speeds in a given road segment will increase the number of fatalities.

This finding is a serious concern for traffic management improvement, particularly in speed regulation on the Surabaya-Mojokerto toll road. Recommended improvements include revising and optimizing speed limits, implementing vehicle speed monitoring technology, and increasing awareness and education for road users on the importance of adhering to set speed limits. Additionally, an evaluation of road infrastructure, such as shoulder width and road conditions, is needed to ensure the safety and comfort of road users.

Developing traffic management strategies focusing on speed control can be an effective step in reducing the risk of accidents and fatalities on the Surabaya-Mojokerto toll road. Supportive technology, such as speed monitoring systems and early warnings via navigation apps, can help inform drivers about applicable speed limits and provide warnings if they exceed safe speed limits. Furthermore, educational approaches and safety campaigns are essential to enhance driver awareness and behaviour in adhering to set speed limits, creating a safer and more sustainable traffic environment in the future.

CONCLUSION

Based on the previous discussion, this study reveals several key findings related to traffic and safety on the Surabaya-Mojokerto toll road. Firstly, although there is no significant difference in speed between lanes at ramp off/on locations, vehicle volume shows a strong correlation with speed, highlighting the importance of toll road infrastructure planning that takes future vehicle

volume into account. Secondly, accident blackspot analysis using the Korlantas method identifies kilometre 729 in the B direction as a high-accident area, necessitating more in-depth preventive strategies and infrastructure evaluations. Thirdly, the relationship between speed differential and the number of fatalities shows a strong and significant connection, with actual speed, shoulder width, and speed limits being significant factors. Approximately 89.6% of the variability in the number of fatalities can be explained by these factors. These findings underscore the urgency of speed management and road infrastructure improvements as crucial steps to enhance traffic safety on the Surabaya-Mojokerto toll road.

CLOSING STATEMENT

Despite these insights, the study has several limitations. The data on vehicle speeds and accident occurrences were collected over a relatively short period, which may not fully capture long-term trends or seasonal variations. Additionally, the study primarily focuses on quantitative data, potentially overlooking qualitative factors such as driver behavior, weather conditions, and road maintenance practices that could also significantly impact traffic safety. Furthermore, the analysis is limited to the Surabaya-Mojokerto toll road, and the findings may not be directly applicable to other regions with different traffic conditions and infrastructure. Potential future research could address these limitations by incorporating a longer data collection period to observe trends over time and during different seasons. Expanding the scope to include qualitative data could provide a more comprehensive understanding of the factors influencing traffic safety. Additionally, comparative studies with other toll roads in Indonesia or similar regions globally could help validate the findings and offer broader insights. Research could also explore the impact of technological advancements, such as automated traffic management systems and vehicle-to-infrastructure communication, on improving road safety.

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