THE IMPACT OF CRASH BARRIERS ON DRIVER BEHAVIOR IN CURVED ROADS, SRI LANKA

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ABSTRACT: Traffic accidents represent a significant public health concern, incurring substantial costs. While crash barriers can mitigate accidents and reduce their severity, research on their impact on driver behaviour, especially on gentle curves of single-carriageway, and two-lane roads, is lacking. This study addresses this gap in road safety knowledge by investigating how crash barriers influence speed and vehicle lateral displacement. A flat Class "AB" road with two consecutive mild curves, one featuring a barrier and the other without, was selected for comparison, ensuring similar visual cues for drivers. Data collection involved drones to measure speed and lateral displacement at the beginning, middle, and end of the curves. Statistical t-tests compared speeds and lateral displacements between curves with and without barriers, revealing significant differences ($p < 0.05$). Subsequent multivariate linear regression explored crash barrier effects on driver behaviour across various vehicle categories, considering different entering speeds, road conditions (wet and dry), and opposite-lane traffic conditions. The regression model indicated that road and opposite lane conditions did not significantly affect speeds and vehicle lateral positions. Instead, middle and exit speeds depended on entering speed and the presence of crash barriers. Vehicle speed at the middle and entry of curves decreased with crash barriers, suggesting an increased perception of safety. The analysis showed that vehicles tended to approach the centerline more in curves with crash barriers, especially heavier vehicles, increasing the risk of head-to-head accidents. Recommendations include widening lanes near crash barrier areas, with modelling providing insights into the necessary additional width.

Keywords: Crash Barrier, Driver Behaviour, Road Safety, Speed, Lateral Displacement, Regression Model

1. INTRODUCTION

Road traffic injuries remain a global public health crisis, claiming an estimated 1.35 million lives in 2020 (World Health Organization, 2020). Crash barriers, a vital component of roadside safety infrastructure, play a crucial role in mitigating the severity of these accidents. While their effectiveness in preventing vehicles from leaving the road is well-established, recent research suggests a more nuanced relationship between crash barriers and driver behaviour. Studies by Antonson et al., highlight the complex interplay between speed and crash barriers [1]. Their findings suggest that barriers may lead to increased speeds on curves, emphasizing the need for a holistic approach to road safety that considers not just physical barriers but also psychological factors influencing driver behaviour. Beyond speed, driver distractions and fatigue present additional challenges. Ben-Bassata and Shinar highlight that crash barriers could contribute to reduced driver attention and increased risk-taking behavior [2]. This emphasizes the necessity of addressing not only the physical aspects of barriers but also psychological factors to optimize road safety measures. Jin et al., found that crash barriers might inadvertently lead to increased driver distraction [5]. This discovery highlights the need for an integrated approach to road safety.

Comparative studies consistently demonstrate the positive impact of crash barriers on reducing speed variation, improving lateral positioning, and decreasing crash rates in horizontal curves [4].Wickremasinghe and Rajapaksa's analysis revealed a substantial reduction in speed in curves with crash barriers, highlighting their role in promoting cautious and controlled driving behavior [7]. Bertman et al., found that the drivers tend to acquire higher vehicle speeds on rural suburban roads with having guardrail barriers by comparing the vehicle speed with a similar road section without having any guardrails barriers [3]. Methodologies employed in these studies, including field research, driving simulations, and naturalistic observations , provide valuable insights into the interaction between crash barriers and driver behavior [6].

Despite these valuable insights, research gaps persist. The lack of comprehensive studies addressing speed and lateral displacement simultaneously and limitations such as small sample sizes emphasise the need for larger-scale, real-world studies. These would enhance our understanding of the influence of crash barriers on driver behaviour in horizontal curves.In conclusion, crash barriers are instrumental in mitigating the severity of accidents and protecting road users. However, a nuanced understanding of their interaction with driver behaviour, speed, and other factors is crucial for optimizing their effectiveness.

2. RESULTS AND DISCUSSION

Figure 1:Selected site location

Figure 1 shows the location on Gampola Nawalapitiya road at coordinates 7.0917 latitude and 80.5555 longitude. This location features two bends in the same direction, one with crash barriers and one without, each with a 36 m radius. The road shows minimal curvature variation, consistent super elevations, and uniform external factors, allowing for a comprehensive comparison of vehicle behavior in bends with and without crash barriers. A drone survey was conducted between 11:00 am and 1:00 pm on two weekdays.Vehicle trajectories were mapped. Hypothesis tests were conducted on vehicle speed data at the entry, middle, and exit points of curves, as well as on vehicle centerline cutting areas, using SPSS software to determine significant differences between two scenarios.The paired two-tailed P-value was found to be lower than 0.001 (<0.05), indicating that the significant value of the t-test is within the acceptable range. This result implies a significant difference in vehicle speeds at the entry, middle, and exit points of the curve, as well as a difference in the vehicle's lateral position between the two locations.

To understand their impact on driver behaviour, three multiple linear regression models were developed using SPSS. These models predict vehicle speed at the middle and exit of the curve, as well as the vehicle centerline cutting area. The analysis utilized a sample dataset of 194, 194 and 167 observations.

Model 1: Vehicle speed at the middle of the curve (S_M),	$S_M = 1.122 - 0.210x_1 + 0.846x_2$	x_1 - Presence of crash barrier (When Presence =1,Absent =0)
Model 2 : Vehicle speed at the exit of the curve (S_E),	$S_E = 1.929 - 0.362x_1 + 0.827x_2$	x_2 -Vehicle speed at entry of the curve(m/s)
Model 3: Vehicle centerline cutting area (C_U),	$C_U = 38.456 - 21.802x_1 -9.561x_3$	x_3-Vehicle category (1-Car,2-Large Goods Vehicle,3-Heavy Goods Vehicle,4-Bus)

Positive C_U values indicate that the vehicle travelled in the right lane and did not cross the centerline into the opposite lane. Negative C_U values indicate that the vehicle entered the opposite lane by cutting across the centerline of the road. Notably, the negative coefficient value of x_1 suggests that when there is a crash barrier, vehicles tend to slow down compared to scenarios without a crash barrier. Additionally, the negative coefficient for the vehicle category implies that heavy vehicles are more prone to cut the road centerline compared to light vehicles.Three linear regression models were evaluated, with all correlation checks confirming no multicollinearity. Significant model estimates were indicated by absolute t-values exceeding 1.96 and p-values below 0.001 The R squared values for all models exceeded 0.5, demonstrating good model fit. Durbin-Watson statistics were 2.014, 2.106, and 1.999, indicating no significant autocorrelation in the residuals. These results indicate robust models with significant predictors and reliable estimates.

Table 1: Summary of three models.

	Multiple R	R Square	Adjusted R Square	Standard Error	Observations
Model 1	0.933	0.87	0.869	0.525	194
Model 2	0.913	0.833	0.832	0.603	194
Model 3	0.758	0.575	0.569	13.775	167

3. CONCLUSION

This study examined the effect of crash barriers on driver behavior, focusing on vehicle speed and lateral position, while keeping other road parameters constant between two locations. It was assumed that the driver's behavior was influenced solely by the presence of the crash barrier. Regression models were developed to predict vehicle speed and lateral position based on the presence of the crash barrier. Two regression models assessed the relationship between vehicle speeds and crash barrier status, incorporating vehicle speed at the curve entry as an independent variable. The findings revealed a significant impact of both variables on vehicle speed, indicating that crash barriers do influence driving speed. Similarly, a regression model examined the association between vehicle lateral position and crash barriers, using vehicle type and crash barrier status as independent variables. The results showed that both factors significantly affect vehicle lateral position, suggesting drivers adjust their position based on the presence of crash barriers. The models were significant, highlighting that crash barriers are predictors of driver behavior.

The study found that crash barriers significantly affect vehicle speed and lateral position. Specifically, vehicle speeds were lower with crash barriers present, while light vehicles were closer to the center of the carriageway. In contrast, heavy vehicles were more likely to veer into the opposite lane when crash barriers were present. Recommendations include widening lanes near crash barriers, with modeling insights providing guidance on the necessary additional width. The study has several limitations. Data collection was manual and limited to two weekdays from 11:00 am to 1:00 pm, which may not be representative of all days and times. This study, conducted on a road with a 36 m curve radius, may not apply to other road types. Despite these limitations, the study suggests that while crash barriers can reduce vehicle speed and encourage central positioning, they may also cause drivers to veer into the opposite lane.

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