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EVALUATING THE EFFECTIVENESS OF SCHOOL SAFETY ZONES ON A NATIONAL ARTERIAL ROAD: EVIDENCE FROM MANADO CITY, INDONESIA

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Abstract. *This study embodies the implementation and effectiveness of the School Safety Zone (ZoSS) at Pertiwi Junior High School and Senior High School in Manado, located on Jalan A.A. Maramis, a national arterial corridor in Manado City. The research method used a field survey with facility compliance analysis based on the Decree of the Director General of Land Transportation No. SK.3582/AJ.403/DRJD/2018, traffic performance assessment according to the 2023 Indonesian Road Capacity Guidelines (PKJI), and a Two-Sample T-Test statistical test. The evaluation results showed that several ZoSS facilities did not fully meet technical standards due to faded road signs and damaged signs. Statistical analysis confirmed a significant decrease in vehicle speed after entering the ZoSS area. However, its effectiveness is still limited because the majority of drivers continue to drive above the speed limit of 30 km/h. Meanwhile, road performance remains stable at level of service (LOS) C with a degree of saturation value between 0.456 and 0.681. In conclusion, the current implementation of ZoSS is not optimal in controlling vehicle speed and improving pedestrian safety. Technical infrastructure improvement steps are needed.*

Abstrak. Studi ini mengevaluasi implementasi dan efektivitas Zona Selamat Sekolah (ZoSS) di SMP dan SMA Pertiwi Manado, yang terletak di Jalan A.A. Maramis, sebuah koridor arteri nasional di Kota Manado. Metode penelitian menggunakan survei lapangan dengan analisis kepatuhan fasilitas berdasarkan Keputusan Dirjen Perhubungan Darat No. SK.3582/AJ.403/DRJD/2018, penilaian kinerja lalu lintas menurut Pedoman Kapasitas Jalan Indonesia (PKJI) 2023, serta uji statistik Two-Sample T-Test. Hasil evaluasi menunjukkan beberapa fasilitas ZoSS belum sepenuhnya memenuhi standar teknis akibat marka jalan pudar dan rambu yang rusak. Analisis statistik mengonfirmasi adanya penurunan kecepatan kendaraan yang signifikan setelah memasuki area ZoSS. Meskipun demikian, efektivitasnya masih terbatas karena mayoritas pengendara tetap memacu kendaraan di atas batas kecepatan 30 km/jam. Sementara itu, kinerja jalan tetap stabil pada tingkat pelayanan (LOS) C dengan nilai derajat kejenuhan antara 0,456 hingga 0,681. Kesimpulannya, implementasi ZoSS saat ini belum optimal dalam mengendalikan kecepatan kendaraan dan meningkatkan keselamatan pejalan kaki. Diperlukan langkah perbaikan teknis infrastruktur.

INTRODUCTION

Road traffic injuries remain one of the leading causes of death among children and adolescents worldwide. According to the World Health Organization (WHO), road traffic crashes account for a significant proportion of fatalities among individuals aged 5–29 years, particularly in developing countries where rapid motorization is not always accompanied by adequate road safety infrastructure (Parajuli et al., 2024; Susanti, 2025) School environments represent critical locations where children are exposed to traffic risks during daily commuting activities. Consequently, improving road safety around educational facilities has become an important objective within sustainable transportation planning and urban traffic management.

One of the most widely implemented traffic safety measures near educational facilities is the establishment of School Safety Zones (SSZs), commonly referred to in Indonesia as Zona Selamat Sekolah (ZoSS) (Lefrandt & Rumayar, 2024; Novalira & Susilo, 2024; Utary et al., 2022). These zones are designed to provide priority protection for school children through a combination of traffic calming measures, speed restrictions, road markings, warning signs, pedestrian crossing facilities, and other supporting infrastructure. The fundamental objective of School Safety Zones is to reduce vehicle speeds, improve driver awareness, and create a safer environment for vulnerable road users.

Previous studies have demonstrated that speed reduction is one of the most effective approaches for minimizing pedestrian injury severity (Bahrami et al., 2025; Heydari et al., 2020; Lefrandt & Rumayar, 2024; Parajuli et al., 2024; Pichayapan et al., 2020; Talwar & Yuan, 2024). Research conducted in various countries has shown that even small reductions in vehicle speed significantly decrease the probability of fatal pedestrian crashes. Consequently, many jurisdictions enforce reduced speed limits within school zones, typically ranging between 20 km/h and 40 km/h depending on local regulations and traffic conditions (Quistberg et al., 2019).

In Indonesia, the implementation of School Safety Zones is regulated through the Directorate General of Land Transportation Decree No. SK.3582/AJ.403/DRJD/2018. The regulation specifies the technical requirements for road markings, traffic signs, warning devices, pedestrian facilities, and operational procedures intended to enhance safety around schools Farid et al., 2025; Fountas et al., 2022; Heydari et al., 2020; Novalira & Susilo, 2024; Pichayapan et al., 2020; Utary et al., 2022). Despite the existence of these guidelines, several studies have reported that the effectiveness of ZoSS implementation remains inconsistent across different locations. Problems frequently identified include inadequate facility maintenance, faded road markings, damaged signs, lack of supporting infrastructure, and low compliance among motorists with speed restrictions.

Several studies conducted in Indonesian cities, including Manado, Tomohon, Yogyakarta, Jakarta, Kendari, and Sumbawa, have found that although School Safety Zones may contribute to speed reduction, vehicle speeds often remain above the recommended limits (Lefrandt & Rumayar, 2024; Novalira & Susilo, 2024; Utary et al., 2022). Furthermore, many evaluations focus primarily on vehicle speed or pedestrian behavior while giving limited attention to the operational performance of the road network. As a result, the interaction between traffic performance and school zone effectiveness remains insufficiently understood.

This issue becomes particularly important when School Safety Zones are implemented on major arterial roads that accommodate high traffic volumes and regional mobility functions.

Unlike local streets, arterial roads must balance traffic efficiency with safety requirements. Consequently, evaluating school zone performance solely from a safety perspective may not provide a comprehensive understanding of its operational effectiveness.

The present study addresses this research gap by evaluating the implementation of a School Safety Zone located along A.A. Maramis Road in Manado City, Indonesia. The study area encompasses SMP and SMA Pertiwi Manado, which are situated on a national arterial road characterized by relatively high traffic volumes and mixed traffic conditions. The research integrates safety-oriented indicators with traffic operational indicators through the analysis of vehicle speed, road capacity, degree of saturation, and Level of Service (LOS).

The novelty of this study lies in three aspects. First, it applies the latest Indonesian Road Capacity Guidelines (PKJI 2023) in evaluating School Safety Zone performance. Second, it integrates speed compliance analysis with operational road performance assessment through LOS and degree of saturation indicators. Third, it investigates the effectiveness of School Safety Zones located on a national arterial road, a context that remains underrepresented in previous Indonesian studies.

Therefore, this study aims to: (1) evaluate the compliance of School Safety Zone facilities with current technical regulations; (2) examine the effectiveness of the School Safety Zone in reducing vehicle speeds; and (3) assess road operational performance using capacity analysis and Level of Service indicators. The findings are expected to provide practical recommendations for transportation authorities, urban planners, and educational institutions in improving road safety around schools while maintaining efficient traffic operations.

LITERATURE REVIEW

School Safety Zones and Road Safety

School Safety Zones are specialized traffic management areas designed to provide priority protection for students and pedestrians around educational facilities (Lefrandt & Rumayar, 2024; Li et al., 2023; Martiskainen et al., 2021). Their primary objective is to reduce conflicts between vehicles and vulnerable road users by implementing traffic calming measures and safety-oriented infrastructure (Chacko & Pawar, 2025; Emanuel-Cristian et al., 2025; Parajuli et al., 2024).

Internationally, School Safety Zones commonly include speed limit reductions, flashing warning lights, pedestrian crossings, speed humps, traffic signs, and pavement markings (Bahrami et al., 2025; Lefrandt & Rumayar, 2024; Novalira & Susilo, 2024). Previous research indicates that these measures contribute to lower vehicle speeds, improved driver awareness, and enhanced pedestrian safety.

Traffic Calming Measures

Traffic calming refers to engineering interventions designed to reduce vehicle speeds and improve safety conditions. Common traffic calming measures include speed humps, raised pedestrian crossings, rumble strips, lane narrowing, and visual speed reduction treatments. Studies have shown that traffic calming strategies are effective in reducing average vehicle speed and crash severity (Damsere-Derry et al., 2019; Distefano & Leonardi, 2019; Magkafas et al., 2025; Pirdavani et al., 2025; Torres et al., 2020). However, their effectiveness depends on roadway characteristics, traffic composition, enforcement levels, and driver compliance.

Vehicle Speed and Pedestrian Safety

Vehicle speed is one of the most critical determinants of traffic safety. The probability of severe pedestrian injury increases substantially as vehicle speed rises. Research demonstrates that collision severity increases exponentially beyond 30 km/h, particularly for children and elderly pedestrians (Damsere-Derry et al., 2019; Distefano & Leonardi, 2019; Pichayapan et al., 2020).

Consequently, many school safety regulations worldwide establish maximum speed limits ranging from 20 km/h to 30 km/h during school operating hours. Compliance with these limits is considered a key indicator of School Safety Zone effectiveness.

Road Capacity and Level of Service

Road performance is commonly evaluated through capacity analysis and Level of Service (LOS) indicators. Capacity represents the maximum sustainable traffic flow under prevailing roadway conditions, while LOS reflects the operational quality experienced by road users (Cui et al., 2022; Dewi et al., 2024; Lefrandt & Rumayar, 2024; Susilowati et al., 2021; Utary et al., 2022; Wibisono & Hernanda, 2025).

According to PKJI 2023, road performance can be evaluated through the Degree of Saturation (DS), which is calculated as the ratio between traffic volume and road capacity. Lower DS values indicate better operational conditions and higher service quality.

Integrating LOS analysis into School Safety Zone evaluations provides a more comprehensive understanding of the interaction between safety interventions and traffic operations.

Previous Studies

Previous studies in Indonesia have generally reported mixed outcomes regarding School Safety Zone effectiveness. Several investigations found reductions in vehicle speed but observed continued non-compliance with prescribed speed limits. Other studies reported inadequate facility conditions and deficiencies in supporting infrastructure.

Most previous studies utilized MKJI 1997 as the primary analytical framework. Relatively few investigations have applied PKJI 2023 or examined School Safety Zones on national arterial roads. Therefore, further research is needed to evaluate contemporary School Safety Zone performance under updated traffic analysis frameworks.

Conceptual Framework

The conceptual framework of this study assumes that the effectiveness of School Safety Zones is influenced by:

- Compliance of safety facilities with technical standards.
- Driver response reflected through speed reduction.
- Road operational performance represented by capacity, degree of saturation, and Level of Service.

These factors collectively determine the effectiveness of School Safety Zones in improving traffic safety around educational facilities.

METHODOLOGY

Study Area

The study was conducted at the School Safety Zone serving SMP and SMA Pertiwi Manado, located along A.A. Maramis Road, Manado City, Indonesia. The road functions as a national arterial corridor connecting major urban and regional transportation movements.

Data Collection

Primary data were collected through field surveys consisting of:

- Vehicle speed observations.
- Traffic volume counts.
- Road geometric measurements.
- Facility inventory surveys.
- Pedestrian crossing observations.

Secondary data included technical regulations, roadway classifications, and supporting traffic information obtained from relevant governmental agencies.

Evaluation of ZoSS Facilities

The existing School Safety Zone facilities were evaluated based on the technical requirements specified in Directorate General of Land Transportation Decree No. SK. 3582/ AJ.403/DRJD /2018. The assessment covered:

- Traffic signs
- Road markings
- Warning lights
- Pedestrian crossings
- Rumble strips
- Sidewalks
- Supporting safety facilities

1.1. Traffic Volume Analysis

Traffic volume was calculated as:

$$Q = N / T$$

where:

Q = traffic volume (veh/h)
N = number of vehicles
T = observation period (h)

Vehicle classifications followed PKJI 2023 standards.

Capacity Analysis

Road capacity was calculated according to PKJI 2023:

$$C = C0 \times FCW \times FCSP \times FCSF \times FCCS$$

where:

C = road capacity
C0 = base capacity
FCW = lane width adjustment factor
FCSP = directional separation factor
FCSF = side friction adjustment factor
FCCS = city size adjustment factor

1.2. Degree of Saturation

Road performance was evaluated using:

$$DS = Q / C$$

where:
DS = degree of saturation
Q = traffic volume
C = road capacity

Level of Service

Level of Service (LOS) was determined according to PKJI 2023 classification standards based on the calculated DS values.

Speed Analysis

Spot speed observations were conducted before and after vehicles entered the School Safety Zone. Mean speed values were compared to evaluate speed reduction performance and compliance with the mandatory 30 km/h speed limit.

Statistical Analysis

A Two-Sample T-Test was employed to determine whether significant differences existed between vehicle speeds recorded before and after entering the School Safety Zone.
The hypotheses were defined as:

H_0 : There is no significant difference between vehicle speeds before and after entering the School Safety Zone.
H_1 : There is a significant difference between vehicle speeds before and after entering the School Safety Zone.

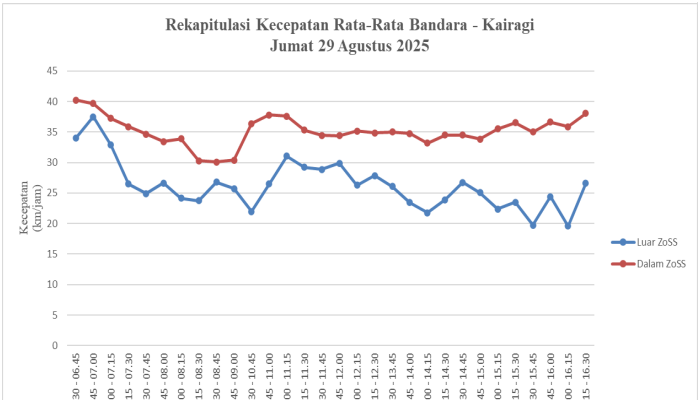
A significance level of $\alpha = 0.05$ was adopted for all statistical analyses.

RESULTS AND DISCUSSION

Existing Condition of School Safety Zone Facilities

Field observations revealed that the School Safety Zone (ZoSS) surrounding SMP and SMA Pertiwi Manado has been implemented with several essential traffic safety facilities. The existing infrastructure includes warning signs, speed limit signs, pedestrian crossing markings, and supporting traffic control devices. These facilities indicate that efforts have been made by local authorities to improve pedestrian safety within the school environment.

However, the evaluation based on the Directorate General of Land Transportation Decree No. SK.3582/AJ.403/DRJD/2018 identified several deficiencies that potentially reduce the effectiveness of the School Safety Zone. Some road markings were found to be faded and less visible to motorists. Several traffic signs were partially obstructed by vegetation or exhibited signs of physical deterioration. Furthermore, some supporting facilities required by the regulation were either absent or inadequately maintained.



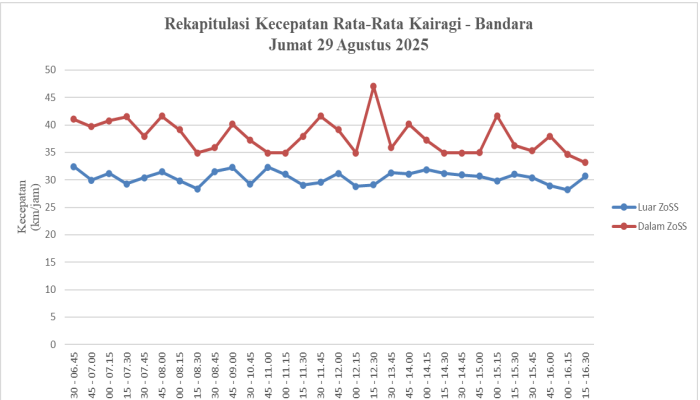


Figure 1. Average Vehicle Speeds Inside and Outside the School Safety Zone (ZoSS) for Both Travel Directions on 29 August 2025

The two travel directions exhibit similar temporal patterns in vehicle speed, suggesting that driver behavior remained relatively consistent regardless of travel direction. Despite some fluctuations during specific observation periods, vehicle speeds generally exceeded the recommended operational speed of 30 km/h within the School Safety Zone. These findings indicate that the current School Safety Zone implementation has not yet achieved optimal speed compliance. The persistence of relatively high vehicle speeds suggests that the existing traffic control devices alone may be insufficient to encourage substantial speed reduction, particularly on a national arterial road where traffic demand and operating speeds are naturally higher. Consequently, additional engineering measures, routine maintenance of School Safety Zone facilities, and stronger enforcement strategies should be considered to improve driver compliance and enhance pedestrian safety around schools.

Vehicle Speed Analysis

Vehicle speed constitutes one of the most important indicators of School Safety Zone effectiveness because lower vehicle speeds directly contribute to reduced crash severity and improved pedestrian safety.

The analysis revealed that average vehicle speeds inside the School Safety Zone were lower than those recorded before entering the zone. This indicates that the presence of School Safety Zone facilities influenced driver behavior and encouraged some degree of speed reduction.

To determine whether the observed speed differences were statistically significant, a Two-Sample T-Test was conducted.

Table 1. Summary of Independent Sample *t*-Test Results for Vehicle Speed Comparison

Direction	Period	Date	*t* Statistic	Result
Kairagi → Airport	Non-operating Hours	25 Aug 2025	1.541	Not Significant
		27 Aug 2025	10.710	Significant
		29 Aug 2025	8.851	Significant
	Operating Hours	25 Aug 2025	0.761	Not Significant
		27 Aug 2025	7.927	Significant
		29 Aug 2025	10.168	Significant
Airport → Kairagi	Non-operating Hours	25 Aug 2025	2.620	Significant
		27 Aug 2025	6.332	Significant
		29 Aug 2025	8.953	Significant
	Operating Hours	25 Aug 2025	1.842	Not Significant

Direction	Period	Date	*t* Statistic	Result
		27 Aug 2025	4.048	Significant
		29 Aug 2025	6.676	Significant

Note: The study was conducted at the School Safety Zone (ZoSS) of SMP and SMA Pertiwi Manado. Statistical significance was determined at the 95% confidence level ($p < 0.05$).

The results demonstrated significant differences between vehicle speeds recorded before and after entering the School Safety Zone during most observation periods. Therefore, the null hypothesis stating that no difference exists between the two speed conditions was rejected.

Although the School Safety Zone successfully reduced vehicle speed, the magnitude of reduction was insufficient to achieve full compliance with the prescribed speed limit of 30 km/h. A substantial proportion of vehicles continued to travel above the recommended speed threshold. This finding indicates that while drivers respond to the School Safety Zone, the existing traffic calming measures are not strong enough to ensure adequate speed control.

Traffic Volume and Road Performance

Traffic volume observations indicate that A.A. Maramis Road experiences relatively high traffic demand due to its function as a national arterial corridor. The roadway serves both local and regional traffic movements, resulting in substantial traffic activity during school arrival and dismissal periods.

Road performance analysis using PKJI 2023 demonstrated that the Degree of Saturation (DS) ranged from 0.456 to 0.681 during the observation periods. These values indicate that traffic demand remained below roadway capacity and that the traffic stream continued to operate under stable conditions.

Based on the calculated DS values, the roadway consistently operated at Level of Service (LOS) C. This level of service represents stable traffic flow conditions where vehicle movements remain relatively unrestricted, although interactions among vehicles begin to influence operating speeds.

The findings indicate that the School Safety Zone implementation does not significantly disrupt the operational performance of the arterial road. Traffic flow remains stable despite the presence of speed control measures and pedestrian activities within the school environment.

DISCUSSION

Effectiveness of School Safety Zones in Reducing Vehicle Speed

The results demonstrate that the School Safety Zone exerts a measurable influence on driver behavior by reducing vehicle speeds within the school environment. Similar findings have been reported in previous studies conducted in Indonesia and internationally, where School Safety Zones contributed to lower average speeds but often failed to achieve complete compliance with mandated speed limits (Hu et al., 2024; Novalira & Susilo, 2024).

One explanation for the limited effectiveness observed in this study is the functional classification of A.A. Maramis Road as a national arterial route (Bahrami et al., 2025; Lefrandt & Rumayar, 2024; Novalira & Susilo, 2024). Drivers traveling on arterial roads generally maintain higher operating speeds because these facilities are designed to support regional mobility and traffic efficiency. Consequently, drivers may perceive the reduced speed limit as inconsistent with the roadway environment.

Another contributing factor may be the condition of the School Safety Zone facilities (Lefrandt & Rumayar, 2024; Novalira & Susilo, 2024). Faded markings, partially obstructed signs, and incomplete supporting infrastructure reduce the visual impact of the School Safety

Zone and weaken its ability to influence driver behavior (Huang et al., 2025; Karimpour et al., 2021; Pichayapan et al., 2020; Pirdavani et al., 2025).

The findings suggest that passive traffic control measures alone may be insufficient to achieve the desired level of speed compliance. Additional interventions such as raised pedestrian crossings, enhanced warning lights, speed feedback displays, and enforcement mechanisms may be necessary.

Relationship Between Road Performance and School Safety

An important contribution of this study is the integration of traffic operational performance with School Safety Zone evaluation. While previous studies primarily focused on speed reduction and pedestrian behavior, the present study demonstrates that safety interventions can coexist with acceptable traffic performance.

The LOS C condition indicates that the roadway maintains stable operating conditions despite the implementation of speed control measures (Farid et al., 2025; Wibisono & Hernanda, 2025). This finding is significant because transportation authorities often face concerns that additional safety measures may reduce roadway efficiency.

The results suggest that improving school safety does not necessarily require sacrificing traffic performance. Instead, properly designed School Safety Zones can achieve a balance between safety objectives and mobility requirements.

Implications for Transportation Planning

The findings highlight the importance of adopting a comprehensive approach to School Safety Zone management. Infrastructure installation alone is insufficient unless accompanied by regular maintenance, enforcement, and public awareness initiatives Anagnostopoulos, 2024; Yao et al., 2022)

For arterial roads serving educational facilities, transportation planners should consider context-sensitive design approaches that address both traffic operations and pedestrian safety. Future School Safety Zone programs should prioritize integrated engineering, education, and enforcement strategies to maximize effectiveness.

CONCLUSIONS

This study evaluated the implementation of the School Safety Zone (ZoSS) surrounding SMP and SMA Pertiwi Manado using facility assessments, vehicle speed analysis, and road performance evaluation based on PKJI 2023.

The results indicate that several School Safety Zone facilities do not fully comply with the technical requirements established by national regulations. Deficiencies include faded road markings, damaged or obstructed traffic signs, and the absence of certain supporting safety facilities.

Vehicle speed analysis revealed statistically significant differences between speeds recorded before and after entering the School Safety Zone. These findings confirm that the School Safety Zone contributes to speed reduction. Nevertheless, the reduction achieved remains insufficient to ensure compliance with the prescribed speed limit of 30 km/h.

Road performance analysis showed that Degree of Saturation values ranged from 0.456 to 0.681, corresponding to Level of Service C. These results indicate stable traffic flow conditions and demonstrate that School Safety Zone implementation does not adversely affect the operational performance of the arterial roadway.

Overall, the School Safety Zone at SMP and SMA Pertiwi Manado has not yet achieved optimal effectiveness in improving traffic safety. Further improvements in facility quality, maintenance, and driver compliance are required to maximize safety benefits.

POLICY IMPLICATIONS

For Transportation Authorities

Transportation agencies should conduct periodic inspections and maintenance of School Safety Zone facilities to ensure continued compliance with technical standards. Particular attention should be given to road markings, traffic signs, and warning devices that directly influence driver awareness.

For Local Government

Local governments should allocate dedicated funding for School Safety Zone maintenance and improvement programs. School safety initiatives should be integrated into broader urban transportation and road safety policies.

For School Management

Schools should actively participate in safety promotion activities by educating students regarding safe pedestrian behavior and encouraging adherence to established crossing procedures. Collaboration between schools and transportation agencies can strengthen safety outcomes.

For Traffic Enforcement Agencies

Law enforcement agencies should consider targeted enforcement activities during school operating hours. Visible enforcement can improve compliance with School Safety Zone speed limits and reinforce the effectiveness of engineering measures.

For Urban Planners

Future planning of educational facilities should incorporate road safety considerations during the site selection and design stages. Additional traffic calming measures may be necessary for schools located along high-volume arterial corridors.

STUDY LIMITATIONS AND FUTURE RESEARCH

This study is subject to several limitations. First, the analysis was conducted at a single School Safety Zone location, limiting the generalizability of the findings. Second, data collection was restricted to a limited observation period and may not fully capture seasonal variations in traffic behavior. Third, the study focused primarily on operational performance and speed characteristics without incorporating detailed crash history data. Finally, behavioral factors influencing driver compliance were not explicitly examined.

Future research should expand the investigation to multiple School Safety Zones across different roadway classifications and incorporate advanced behavioral analysis techniques. Studies examining the effectiveness of additional traffic calming interventions and long-term crash reduction impacts would further contribute to improving School Safety Zone performance.

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