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GIS-Based Assessment of Spatial Distribution of Road Signs and Markings in Selected School Zones of an Urban Metropolis, Nigeria

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Abstract
Road safety is an essential part of the transportation planning process that is particularly important around school settings, especially in less developed cities where the pedestrian infrastructure is not in place. In this study, the spatial distribution, adequacy, condition and placement compliance of road safety signs and markings in five selected school zones of Jos, Nigeria were assessed using the Geographic Information Systems (GIS). Signs were mapped with a GPS and observed in the field as to condition and visibility of the signs and their types. Schools and road networks around schools were mapped with the help of digital maps and satellite imagery. Buffer, proximity, nearest neighbour and density analyses were performed using ArcGIS. A total of fifteen (15) signs and markings were identified and classified as 40.00% warning, 33.33% informational and 26.67% regulatory. Spatial analysis (proximity, hotspot mapping) showed that most signs were located on main roads and were clustered in specific school areas, with few signs along internal access roads. From the results of the studied signs, 66.67% were within 20 m, 20% were within 20-49 m from the assessed school entrances or crossings, only 13.33% were in good placement range adopted (50-210 m before crossings) in line with Federal Road Safety Corps (FRSC)/Ministry of Works and Manual on uniform traffic control devices for streets and highways (MUTCD). It was determined that the school-zone level included three zones (60%) with partially visible signage, one zone (20%) with faded paint and one zone (20%) with visible signage. No zone (or 100%) had all three sign categories present. These results show that the signage coverage is not even, visibility is not sufficient, and there is limited compliance with the placement criterion used. The study offers spatial proof for targeted installation, repainting, replacement and maintenance. Regular infrastructure audits using GIS are recommended to enhance signage provision, maintenance and pedestrian safety around schools.
Keywords: Geographic information system, Road signs and markings, School zones, Spatial distribution, Road safety.

1. Introduction

Road traffic injuries (RTI) disproportionately affect low and middle-income countries (LMICs) and continue to be one of the most important public health and development issues in the world. The World Health Organization (WHO, 2018) estimates that around 1.35 million people die annually as a result of a road traffic collision, and 20-50 million are injured but do not die, which includes many that suffer some permanent disability. These losses are not merely personal; they also have significant social and economic consequences for families, health services and nations. A significant proportion of these casualties are vulnerable road users, such as pedestrians, cyclists, children and older adults, which has been identified as a symptom of major inequities in the way road infrastructure is provided, managed, and planned for the benefit of all road users (Hyder et al., 2017; WHO, 2023; Yasin et al., 2020).

Children are particularly vulnerable to traffic risks, particularly in school proximity areas. The development stage of a child's perceptual-motor abilities often impedes coordination between crossing maneuvers and the gaps available in passing vehicles. Younger children have less room for safety when they cross the road due to this characteristic (O'Neal et al., 2018). Therefore, these aspects require that kids rely heavily on other forms of safety provided by things like road signs, markings, or traffic calming devices to offset their poor risk perception. School areas constitute some of the most critical traffic situations since their inadequate safety infrastructure could lead

to adverse outcomes. Road traffic accident is rank amongst the leading causes of fatality globally for those aged between five and twenty-nine years (World Health Organization [WHO], 2018).

Pedestrian children are a major proportion of road traffic victims in many African cities including Nigeria. Urbanization rates, the growth of urban population and the large number of vehicles in use have led to the widespread presence of many schools in the vicinity of motorized corridors or urban areas that were not planned for such increased vehicular traffic in addition to pedestrian traffic by children (Poswayo et al., 2024). High speeds during the school rush hour, and the unpredictability of traffic during the school day, further increases the risk, making traffic conditions congested at school areas/crossings. In spite of the above, elementary safety features such as warning signs, speed limit signs, pedestrian crossings and pavement markings are still lacking or poorly maintained in many school zones in LMICs.

Road signs and marking are a fundamental basis to control the behavior of traffic and to improve pedestrian safety. Signs like School Zone, Children Crossing and speed-limit signs can warn motorists about potential hazards, prompt them to slow down, and enhance situational awareness (Mussone et al., 2017). The Manual on Uniform Traffic Control Devices (MUTCD also stresses uniformity of traffic-sign design and location, visibility and clear communication to help road users understand and respond to traffic control signals (Federal Highway Administration [FHWA], 2023). But the effectiveness of road safety signage is also influenced by the spatial distribution, visibility, condition and adherence to placement standards of these signs. Signs that are out of place, faded, blocked or missing can have no effect on driver behavior, and sometimes lead drivers to believe they are safe.

The evidence and case studies from LMICs demonstrate low infrastructure levels for school-zone safety in all cases. Studies have been conducted to document lack of warning sign, lack of pedestrian crossing facilities, vegetation that blocks views, lack of professional advertising and lack of enforcement of traffic laws around schools (Katoch et al., 2025). Anecdotal observation and some studies indicate that the same problem is also occurring in Jos and other cities in Nigeria, however, there is no systematic and spatially explicit evidence to guide the targeted actions and allocation of resources. The assessment of road safety infrastructure has been based traditionally on manual field surveys and descriptive analysis. Although these are useful techniques, they can be time consuming, costly, and they don't have sufficient capacity to capture the complexities of the spatial relationship between pedestrian movement patterns, safety infrastructure, schools, and road networks (Yao et al., 2015). This can make it challenging for whoever is making decisions to determine which areas are priorities and to assess compliance with the standard or changes over time.

These limitations are addressed by Geographic Information Systems (GIS) that offer a powerful analytical tool. GIS can integrate the spatial and attribute data in order to identify the precise location of schools, the road network, safety signs and markings, and explore and analyze the spatial relationships between them (Campbell et al., 2019). GIS-based methods (buffer analysis, kernel density estimation, proximity analysis, hotspot mapping) have become popular for locating crash hot spots, analyzing infrastructure distribution, spatial clustering and gaps in safety provision, and other uses (Briz-Redón et al., 2019). Most importantly, GIS can help in evidence-based planning by providing objective information which is repeatable and can inform policy making and most effective use of limited resources. The use of GIS in resource-limited urban settings has been boosted by recent developments in GIS technology and the widespread availability of digital spatial data. GIS-based evaluations can be implemented to track the level of security of infrastructure continuously, to evaluate compliance with security standards and to identify areas in danger and requiring immediate attention (Alegimenlen, 2023). These are particularly beneficial in school zone applications to define the placement of safety sign and marking in relation to school entrances, pedestrian crossing areas, junctions and other major traffic corridors.

Automated traffic-sign detection, classification and mapping from street view images and mobile mapping (MM) systems have been shown in previous studies (Balado et al., 2020; Campbell et al., 2019). This study builds on this, with a new integrated assessment of selected school zones in Jos, Nigeria which included GPS-based inventories, GIS analyses of proximity, spatial distribution, and visual assessments of sign condition and visibility in the field. The novelty is the ability to tie these complementary evaluations together to form a picture of where gaps are in the school-zone safety environment. Although there is an expanding international research base documenting the use of GIS for road safety, the use of GIS for assessing safety signage in developing cities is limited. The literature contains methods to find and classify traffic signs (Balado et al., 2020; Campbell et al., 2019) but there is no clue from the literature on whether the traffic signs and markings satisfy the criteria for pedestrian crossing and entry into school in developing cities in Africa such as Jos. To fill this contextual evidence gap, this study explores signage distribution, placement and state, and visibility throughout the five (5) school zones. The aim is to demonstrate the empirical evidence that would support data-driven decision, improve pedestrian safety for children and contribute to sustainable urban traffic safety planning in developing cities by

explicitly relating spatial analysis to clearly defined goals. This is novel as the combination of the spatial patterns and the deficiencies found in the field, is used for guiding targeted installation of signs and maintenance.

2.0 Study Methodology

In this study, a descriptive and spatial analysis research design was chosen for the purpose of assessing the distribution, adequacy and compliance of road safety signs and markings within school zones in Jos metropolis, Nigeria. Descriptive research helped in capturing the type, condition and visibility of safety signs whereas Geographic Information Systems (GIS) were used to carry out spatial analysis of safety signs in terms of their distribution, coverage and conformity to prescribed road safety standards by (FRSC 2019; WHO 2018, 2023) and (FHWA 2023). Spatial statistical techniques (Nearest Neighbor Analysis and Kernel Density Estimation) were used to examine the spatial pattern and level of concentration of road safety signs. Adequacy and compliance of safety signs were studied through comparison of presence, location, visibility and condition of observed safety signs within a 100m buffer zone of schools according to road safety standards such as MUTCD. GIS was used for the visualization of spatial relationship of school locations, road networks and safety signs and for carrying out spatial analysis using buffering, proximity analysis and density mapping.

2.1 Study Area and Sampling

The study area consisted of the entire Jos metropolis including Jos North, Jos South, and Jos East Local Government Areas. A purposive sampling method was employed to choose five schools located in areas of high pedestrian movement along high traffic roads. These include Police Children School and University of Jos Permanent Site in Jos North, Obasanjo Model Primary School and Plateau State Polytechnic Jos Campus in Jos South, and Zion High International School in Jos East.

2.2 Data Sources and Collection

Primary and secondary data was used. Primary data were collected using field surveys, with locations of road safety signs and markings being recorded by using handheld Global Positioning System (GPS) devices set to the WGS84 coordinate system. GPS coordinates were obtained as latitude and longitude in the geographic system WGS84. Data were projected to UTM Zone 32N where distances were measured in metres for distance-based spatial analysis in ArcGIS. The 100 m buffers and proximity calculations were created based on the projected coordinates, as were the nearest neighbour distances. Structured observation checklists were used to assess each sign, which included sign type, sign physical condition, sign visibility, and sign placement standards. Visual documentation was done by taking photographs. The previously mentioned secondary data were road network maps, the locations of schools and administrative boundaries from OpenStreetMap, and high-resolution satellite imagery for feature identification and verification.

The compliance assessment was informed by relevant policy documents and guidelines by the World Health Organization (WHO), Vienna convention, Federal Highway Administration (FHWA, 2023) and Federal Road Safety Corps (FRSC) on road signs, signals and markings. The GIS was integrated with high-resolution satellite imagery to digitize the road networks, confirm the location of the schools and assess the presence or absence of road safety infrastructure. The images also aided in the field validation and the accuracy of spatial mapping of features. The Google Earth Pro high-resolution satellite data has been utilized for features identification, digitization and spatial checking of road networks, school areas and safety signs, with spatial resolution of 0.5 - 1.0 m.

2.3 Data Processing and GIS Analysis

Collected GPS data was added into ArcGIS and created thematic layers out of the data for schools, road networks, and safety signs. Base maps were digitized and all spatial data were transformed to UTM Zone 32N to assess distance and proximity.

Spatial analyses included:

- Perform buffer analysis (100 m) around school locations to determine if and how much safety signs are in place in a school safety zone;
- Nearest Neighbor Analysis to check the sign distribution for clustering, randomness or dispersion, and;
- Kernel Density Estimation (KDE) to define regions of high and low sign concentration.

Data were analysed descriptively in terms of frequencies and percentages of sign types, conditions and visibility levels in Microsoft Excel and SPSS.

3.0 Result and Discussion

3.1 Identification and Classification of Road Safety Signs and Markings

Signs and markings observed during field survey are presented in Table 1. The classification is based on the Federal Road Safety Corps (FRSC, 2019), Vienna Convention and Manual on uniform traffic control devices for streets and highways (FHWA, 2023) that classify traffic control devices into three broad categories: warning, regulatory

and informational. This distinction is used to assess the presence of the correct mix of signs in school environments to alert, regulate and guide road users.

Table 1: Classification of Road Safety Signs and Markings in School Zones

Sign Category	Observed Signs	Frequency	Percentage (%)
Warning Signs	Children crossing, speed bump	6	40
Regulatory Signs	Speed limit, centreline	4	26.67
Informational Signs	Bus stop, edge lines	5	33.33
Total Signs		15	100

From Table 1, warning signs are the most available, followed by informational signs, while regulatory signs are the least. This means that enforcement signs are not used as much as they should be, and there is an overemphasis on awareness signs, meaning that there is a lack of the balance between warning and regulatory signs that is promoted by FRSC and (FHWA, MUTCD, 2023) in school zones. It can be seen that warning signs are the largest percentage (40%) of all signs observed, followed by informational signs (33.33%) and then regulatory signs (26.67%). This imbalance indicates a greater focus on drivers' awareness of hazards to be avoided than on compliance enforcement or direction. The imbalance of the distribution suggests some level of compliance with FRSC recommendations that call for a mix of all three types of signs to ensure thorough road safety in school zones.

3.2 Spatial Distribution and Proximity to School Entrances and Crossings

Table 2 shows the geographic coordinates of the five (5) selected schools and recorded sign locations used in producing the maps of geographic distribution of the signs. It is noted that the distribution of these records within the listed inventory is not even, four of these records are from Police Children School and each of the other schools has one record. These georeferenced records can be used to explore signage proximity and coverage near schools. This aligns with (Campbell et al. 2019) who showed the benefits of using GIS to locate and classify traffic signs for use in infrastructure inventories and maintenance planning. The distance, visibility and particular site requirements however, must be supplemented by the coordinates to determine the adequacy of signage.

Table 2: Inventory of Schools and Signs Coordinates

School Name	School Coordinate	Sign Observed	Sign Coordinate
Police Children School	Lat. 9.917014 Long. 8.878381	Children crossing	Lat. 9.9169813 Long. 8.879457
		First speed limit	Lat. 9.9157897 Long. 8.8794497
		Second speed limit	Lat. 9.9169813 Long. 8.8794497
		Speed Bump	Lat. 9.916959 Long. 8.879511
Obasanjo Model Primary School	Lat. 9.882358 Long. 8.873762	Bus Stop	Lat. 9.881740 Long. 8.874037
Plateau State Polytechnic, Jos Campus	Lat. 9.883107 Long. 8.874636	Bus stop	Lat. 9.883367 Long. 8.874408
Zion High International School	Lat. 9.8816971 Long. 8.963529	Speed Bump	Lat. 9.885781 Long. 8.962823
University of Jos Permanent Site	Lat. 9.959031 Long. 8.882269	Speed Bump	Lat. 9.958685 Long. 8.883270

Figure1 displays GIS-generated maps for the distribution of signs within 100-meter buffer zones around schools and also shows the distribution on a standard map base.

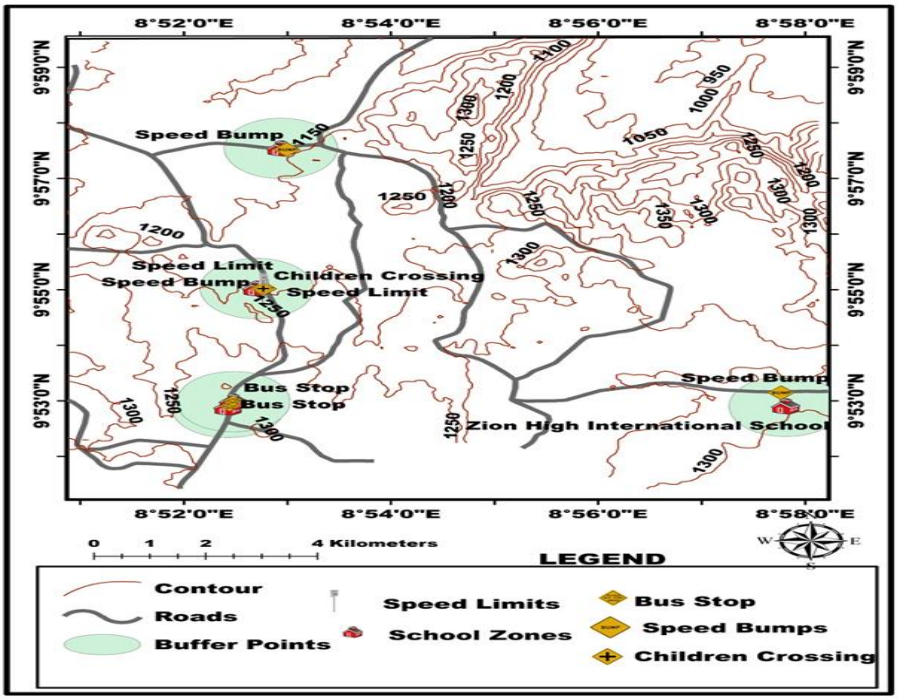


Figure 1: Buffer Map for the Spatial Distribution of Signs in School Locations

Figure 1 indicates that most of the signs are located along main roads like Joseph Gomwalk Road and Yakubu Gowon Road while minor roads and internal access roads have little or no signage. High numbers in areas adjacent to main roads suggest that planning and provision of safety features are not consistent. Manual on uniform traffic control devices for streets and highways (FHWA, 2023) and (FRSC 2019) suggest that signs should be spaced and distributed evenly and strategically positioned so that a driver can see them and comply to them around pedestrian areas such as school entrances. Table 3 shows how close (proximity) road safety signs and markings are to the school entrances and pedestrian crossings. This study adopted a range of about 50 - 210 meters (depending on approach speed) that such signs be installed before a crossing or school entrance to allow drivers adequate reaction time.

Table 3: Proximity of Signs to School Entrances and Crossings

Distance Category	Frequency of Signs & Markings	Percentage (%)	Approx. recommendation (FRSC & FHWA)	Compliance Status
< 20 M (Too Close)	10	66.67	50-210 m	Non-compliant
20-49 M (Below Standard)	3	20	50-210 m	Non-compliant
50-210 M (Within Standard)	2	13.33	50-210 m	Compliant
> 210 (Too Far)	-	-	50-210 m	Non-compliant
Total	15	100	-	-

Based on the results in Table 3, only two of the 15 signs and markings (13.33%) lie within the 50m and above placement range and 10 (66.67%) within the 20 m placement range from the assessed entrances or crossings and 3 (20%) within the 20-49 m placement range. Newly developed warning signs will need to be further investigated at the shorter distances, as in the case of an approach speed, sign legibility and driver reaction time, as outlined in (FHWA, 2023).

3.3 Spatial Pattern Analysis of Road Safety Signs

Table 4 presents the Nearest Neighbor Index (NNI) results derived from GIS spatial statistical analysis. The NNI measures whether features (in this case, road signs and markings) are distributed randomly, uniformly, or clustered within the study area.

Table 4: Nearest Neighbor Index (NNI) Result

Parameters	Value	Interpretation
Observed Mean Distance	32.4m	-
Expected Mean Distance	47.4m	-
NNI Value	0.72	Clustered Pattern

Results in Table 4 shows NNI value of 0.72 which is considered to be clustered. The results indicate that the installation was focused on certain roads with low and high density, while other areas were not adequately covered. Figure 2 presents the map of the hotspot analysis based on the NNI results. Red areas on the map are hotspots identified as having a high number of signs, yellow areas are cold spots identified where there are few or no signs.

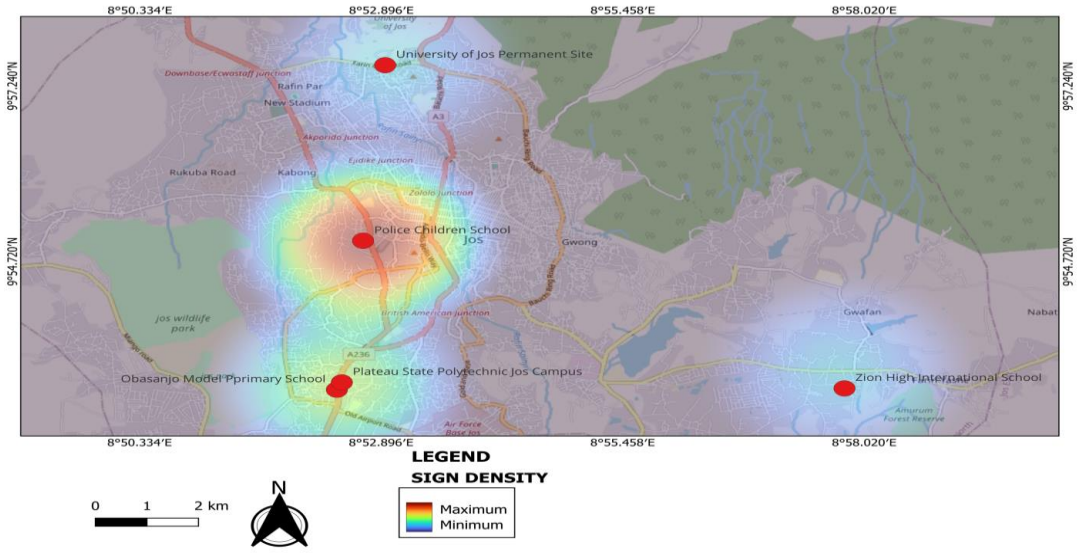


Figure 2: Hotspot Map for Cluster Distribution of Road Safety Signs and Markings

The density of the signs was highest in the vicinity of Police Children School while it was low in the vicinity of University of Jos Permanent site and Zion High International School. This pattern suggests inequitable provision in the places surveyed, and suggests areas where further assessment of signage provision should be made. The planning benefit of this spatial representation is also in line with (Campbell et al., 2019), who showed the advantages of using a georeferenced traffic sign inventory for infrastructure monitoring and maintenance. But when it comes to providing sufficient protection, sign density is not the only factor, as walker needs, placement, visibility and sign function are also important factors. This visualization also illustrates the NNI conclusion that the road safety signs in the study area are not evenly distributed, but concentrated.

3.4 Identification of Gaps in Sign Coverage and Visibility

Table 5 presents the gap analysis for the selected school zones. The analysis compares observed signage conditions with FRSC and FHWA (2023) standards, assessing whether each school zone has complete sets of warning, regulatory, and informational signs and their overall visibility.

Table 5: Gap Analysis of Road Safety Signage in Selected School Zones

School Names	Signs Present	Missing Signs (Based on FRSC/FHWA)	Visibility Condition	Compliance Status
Obasanjo Model Primary School	Informational	Warning &Regulatory	Partially Visible	Non-Compliant
Plateau State Polytechnic Jos Campus	Informational	Warning and Regulatory	Partially Visible	Non-Compliant
Police Children School Jos	Warning & Regulatory	Informational	Visible	Non-Compliant
University Of Jos Permanent Site	Regulatory	Informational and Warning	Faded Paint	Non-Compliant
Zion High International School	Warning	Informational and Regulatory	Partially Visible	Non-Compliant

Table 5 shows that one or more of the sign categories were not available in all five school zones. 60% of the three had partially visible signage, 20% of the one had faded paint and 20% of the one had visible signage. While Police Children School had relatively high visibility, informational signs were not found. This information shows how important it is to evaluate signage condition in conjunction with signage availability. They also suggest that they fall short in terms of the guidance of the MUTCD (FHWA, 2023) on element visibility, legibility, and placement. However, the mix of signs needs to be based on the traffic and pedestrian conditions for each school zone. Figure 3 shows a GIS Map Showing Gaps in Road Safety Signage across School locations.

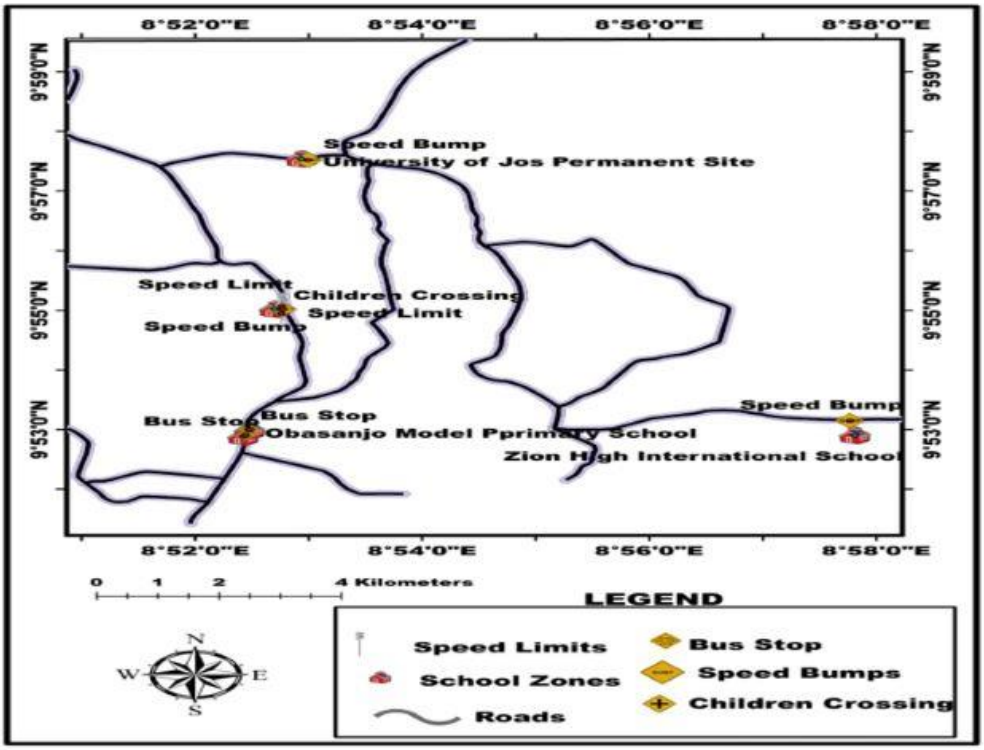


Figure 3: GIS map showing gaps in road safety signage across school locations

The state of signage conditions as observed at various schools in Jos as reflected in Figure 3 which shows that the warning and regulatory signage are in a state of major deficiency at Zion High International School, Plateau State Polytechnic Jos campus and Obasanjo Model Primary School while Police Children School Jos shows relatively good signage condition. The spatial visualization clearly shows that there is a lack of consistency across signage usage within school zones and further demonstrates the value of strategic signage placement based on FRSC standards (FRSC, 2019). Figure 3 also corroborates Table 5 by mapping the identified signage issues in the schools inspected and using this spatial information to guide inspections and maintenance efforts. This use of this application aligns with (Campbell et al. 2019) who showed the use of georeferenced traffic-sign inventories for infrastructure monitoring and asset management. The map provides a visual reference to assist in understanding the inventory results and helps identify action priorities, but should also take into account pedestrian activity, vehicle speeds and crossing facilities. The map should therefore be understood not as an indication of crash risk but rather as a mapping of infrastructure needs.

3.5 Awareness and Visibility of Road Safety Signs and Markings

The results on the safety education, training and familiarity of signs and markings are presented in Tables 6(a) and (b) based on the responses from 70 participants of the questionnaire. The responses reflect the local community's understanding and perception of signage effectiveness around school environments.

Table 6: Formal Road Safety Education/Training and Familiarity with Road Safety Signs and Markings

(a) Formal Road Safety Education/Training			(b) Familiarity with Road Safety Signs and Markings		
Response	**Frequency**	**Percentage (%)**	**Response**	**Frequency**	**Percentage (%)**
Yes	31	44.29	Yes	57	81.43
No	39	55.71	No	10	14.29
Total	70	100.00	Not sure	3	4.28
			Total	70	100.00

Table 6(a) reveals that there is a significant gap in formal road safety training among the road users as the majority (55.71%) have never received any formal training in road safety. Road safety training can enhance knowledge of road safety signs and guidance on traffic laws and safe behaviours. This is in line with (Maulina et al. 2022), who showed that traffic sign understanding among young motorcyclists in Jakarta is enhanced with the training, especially regarding warning signs. There is not much involvement in formal road safety education as only 44.29% of respondents indicated that they had undertaken training. The findings should not be used to conclude that informal learning is the primary source of awareness, although it contributes to awareness. Therefore, more training programs should be implemented to enhance awareness and promote safer road usage. To further support this, the results of (Maulina et al. 2022) indicate that programmes should focus on specific sign categories, particularly on the warning signs which are related to school settings. Road safety sign awareness is good with the majority of respondents (81.43%) indicating that they know the road safety signs as shown in Table 6(b). However, 18.57% do not have or believe they have this knowledge, which is a concern for safety. They may not be familiar with the signs that are located near schools, which can be the cause of the misunderstanding. This concern is in line with the study of (Babić et al. 2020), which they found that more unfamiliar traffic signs need more time to be seen and fixed on, which can create traffic hazard. Their research reveals the need to not only recognise signs, but to understand them quickly and accurately. Some of the reported familiarity is encouraging but not necessarily correct interpretation or compliance. It is important to remember that, together with Table 6(a), the results indicate that there is a high level of awareness reported across the board but a low level of formal training. So, there is a general awareness but there is still a need for structured education. Factual instruction for school zone warnings, pedestrian crossing, and speed regulation signs may be helpful in overcoming these gaps in knowledge and ensure the right response around school. Tables 7(a) and (b) present the results on how road users notice and their visibility of signs and markings based on the responses from participants of the questionnaire.

Table 7: Noticed and Visibility of Road Safety Signs and Markings Around Schools

(a) Noticed Road Safety Signs/Markings Around Schools

Response	Frequency	Percentage (%)
Yes	59	84.29
No	11	15.71
Total	70	100.00

(b) Visibility of Road Safety Signs and Markings

Visibility Level	Frequency	Percentage (%)
Very clear	15	21.43
Fairly clear	13	18.57
Faded	30	42.86
Not visible	12	17.14
Total	70	100.00

From the results presented in Table 7, majority (84.29%) have noticed signs or markings around schools which means that there is positive presence of infrastructure. But 15.71% haven't, indicating uneven coverage or visibility. There is need for physical verification using GIS mapping to identify missing areas. It also exposes the differences in maintenance between schools. All of these may be addressed to improve students' consistent protection. Only 21.43% rate “very clear” for signs, and 42.86% say the signs are faded or invisible (Table 7(b)). This demonstrates that poor visibility negatively affects the effectiveness of safety signs and warnings. Weather and maintenance neglect also destroys signs and warnings effectiveness. Signs and markings clarity is moderate (18.57%) but it is still not ideal. Therefore, there is a need for a maintenance and repainting. Summary of opinions on whether the signage and markings are visible, adequate or not is presented in Figures 4 and 5.

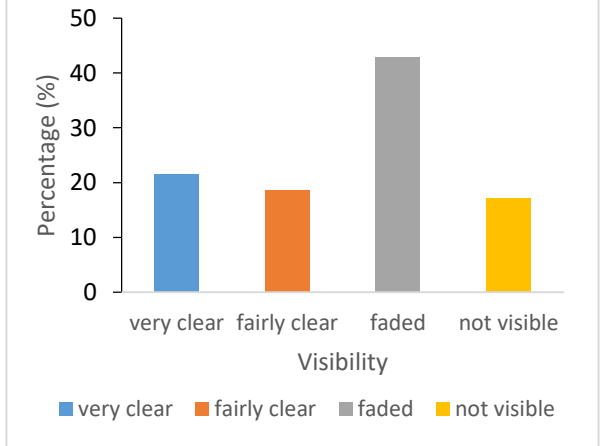


Figure 4: Visibility of Road Safety Signs and Markings Around School Locations

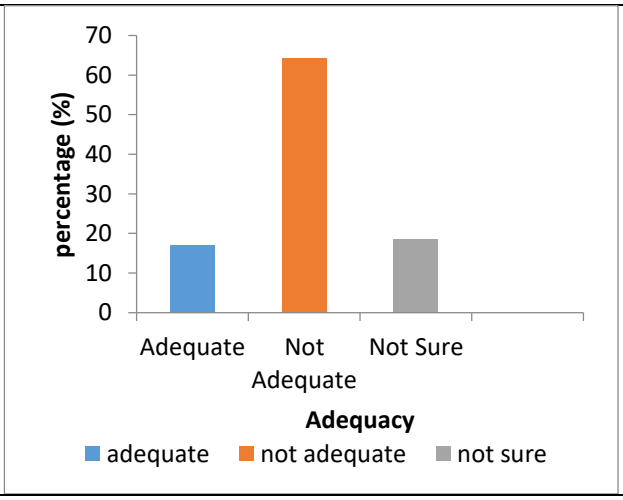


Figure 5: Adequacy of Road Safety Signs and Markings Around School Locations

The visibility results displayed in Figure 4 shows that the existence of a sign does not guarantee its visibility to road users. This issue is consistent with the emphasis placed by (FHWA 2023) in MUTCD on visible and legible traffic-control devices that provide enough time for their identification and appropriate reaction. The results call for targeted inspection and maintenance, although the perceptions of respondents should not be confused with the objective measures of sign legibility and retroreflectivity. As shown in Figure 5, 64.29% of respondents believed the available signs and markings were inadequate, while 35.71% found them adequate. This perception, to a large extent, is congruent with the findings from the field inventory regarding the absence of certain categories of signs within the five school zones which could serve as a benchmark data for installation and or maintenance purposes around school zones in developing cities. This agrees with (Balado et al. 2020) who stressed the need for proper traffic sign inventories for maintenance purposes and proposed a framework for detection, classification, and georeferencing of signs. Thus, the perception of respondents can serve as a basis for combining community input with spatial inventories to identify areas for additional investigation.

4.0. Conclusion

The study examined the spatial distribution, adequacy and placement of road safety signs and markings in five selected school zones in Jos, Nigeria using GIS and field observations in accordance with the standards set by FRSC (2019), Vienne Convention and MUTCD, (FHWA 2023). The main premise is that the effectiveness of the signs and markings in the school zone should take into account the location, coverage, condition and visibility along with its presence. The survey led to the identification of 15 signs and markings, including 40% warning, 33.33% informational and 26.67% regulatory. The spatial distribution was clustered (Nearest Neighbour Index (NNI)=0.72) and installations were located along the main roads with sparse coverage along internal access roads. Faded, obstructed and missing signage were identified by field assessment, only 13.33% of the signs met the placement criterion applied during the study. The results of this research identify issues with the distribution of signs in the areas surveyed and offer a spatial basis for sign installation, replacement, and maintenance. The study adds to the school-zone infrastructure assessment process by combining georeferenced inventories with spatial analysis and field observations to detect certain deficiencies that need attention. Periodic audits based on GIS should be conducted to help transport authorities make improvements to signage coverage, placement, and visibility. Future research should include additional schools, add in vehicle speeds, pedestrian activity, and crash data, and include pre and post assessments for corrective interventions to capture their impact on road user behaviors and safety.

Declaration of Generative AI and AI-assisted Technologies

In the cause of preparing this manuscript, the authors used Grammarly to improve grammar and clarity. After using the tools/services, the authors reviewed and edited the content as needed and took full responsibility for the content of the publication.

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