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SEGURIDAD VIAL Y VULNERABILIDAD DE LOS USUARIOS EN CORREDORES URBANOS: EVIDENCIA EMPÍRICA DE LA CIUDAD DE JIPIJAPA

ROAD SAFETY AND USER VULNERABILITY IN URBAN CORRIDORS: EMPIRICAL EVIDENCE FROM THE CITY OF JIPIJAPA

Moreno-Ponce Luis Alfonso [1]; Solórzano-Villegas Lucy Elizabeth [2]; Álvarez-Álvarez Martha Johana [3]; Castro-Chilán Dayana Michelle [4]

[1] Universidad Estatal del Sur de Manabí. Jipijapa, Ecuador.
Correo: luis.moreno@unesum.edu.ec. ORCID ID: https://orcid.org/0009-0000-9026-1009

[2] Universidad Estatal del Sur de Manabí. Jipijapa, Ecuador.
Correo: lucy.solorzano@unesum.edu.ec. ORCID ID: https://orcid.org/0000-0002-9903-5304

[3] Universidad Estatal del Sur de Manabí. Jipijapa, Ecuador.
Correo: martha.alvarez@unesum.edu.ec. ORCID ID: https://orcid.org/0000-0002-9879-0367

[4] Universidad Estatal del Sur de Manabí. Jipijapa, Ecuador.
Correo: dayana.castro@unesum.edu.ec. ORCID ID: https://orcid.org/0000-0001-5245-167X

Resumen

La seguridad vial urbana representó un desafío crítico en las ciudades intermedias de Ecuador, donde peatones, ciclistas y motociclistas estaban altamente expuestos. Este estudio evaluó la Avenida La Prensa en Jipijapa, un corredor urbano de 948 m con usos residenciales y comerciales e intensa interacción modal. El objetivo fue evaluar la seguridad vial y la vulnerabilidad de los usuarios mediante una auditoría de seguridad vial, utilizando listas de verificación estandarizadas y triangulación con registros oficiales de accidentes y datos de exposición vehicular. Se aplicó un diseño observacional transversal, que incorporó inspecciones diurnas y nocturnas, formularios estandarizados, registros fotográficos georreferenciados y matrices de riesgo que combinan probabilidad y consecuencia. Se utilizaron datos de accidentes policiales de 2019 a 2023, aforos de tráfico para el tráfico promedio diario anual (TPDA) y levantamientos topográficos para el contexto geométrico. Los resultados revelaron una alta criticidad en usuarios vulnerables (85 puntos), visibilidad y control de velocidad (82), y señalización vertical y horizontal (79). Los registros de accidentes destacaron colisiones laterales y frontales, junto con atropellos de peatones en áreas sin cruces designados. Las velocidades de operación superaron la velocidad de diseño de 50 km/h en hasta 9 km/h, lo que incrementó la exposición al riesgo y la gravedad de los accidentes. La consolidación de matrices y registros permitió identificar subsecciones críticas (0+000–0+200 m y 0+200–0+400 m) y proporcionó evidencia empírica para respaldar intervenciones técnicamente sólidas. Se concluyó que la integración de los resultados de las auditorías, los niveles de exposición y los registros de accidentes ofreció evidencia sólida para fortalecer la gestión municipal y la planificación de medidas de seguridad eficaces en corredores urbanos comparables.

Palabras clave: auditoría de seguridad vial; usuarios vulnerables; velocidad de operación; historial de accidentes; matriz de riesgos.

Abstract

Urban road safety represented a critical challenge in intermediate cities of Ecuador, where pedestrians, cyclists, and motorcyclists were highly exposed. This study evaluated La Prensa Avenue in Jipijapa, a 948 m urban corridor with residential and commercial uses and intense modal interaction. The aim was to assess road safety and user vulnerability through a road safety audit, using standardised checklists and triangulation with official crash records and vehicle

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exposure data. A cross-sectional observational design was applied, incorporating daytime and night-time inspections, standardised forms, georeferenced photographic records, and risk matrices combining probability and consequence. Police crash data from 2019 to 2023, traffic counts for annual average daily traffic (AADT), and topographic surveys for geometric context were utilised. The results revealed high criticality in vulnerable users (85 points), visibility and speed control (82), and vertical and horizontal signage (79). Crash records highlighted side and frontal collisions, along with pedestrian crashes in areas lacking designated crossings. Operating speeds exceeded the 50 km/h design speed by up to 9 km/h, increasing risk exposure and crash severity. The consolidation of matrices and records enabled the identification of critical sub-sections (0+000–0+200 m and 0+200–0+400 m) and provided empirical evidence to support technically sound interventions. It was concluded that integrating audit results, exposure levels, and crash records offered robust evidence to strengthen municipal management and planning of effective safety measures in comparable urban corridors.

Keywords: road safety audit; vulnerable users; operating speed; crash records; risk matrix.

1. Introduction

Urban road safety faces a critical problem due to the high vulnerability of pedestrians and two-wheeled vehicle users such as cyclists and motorcyclists. These groups, referred to as vulnerable road users, lack the physical protection afforded by motorised vehicles, which exposes them to a higher risk of serious or fatal injuries in the event of a collision. In many cities, approximately two-thirds of traffic deaths involve pedestrians, cyclists, and motorcyclists, particularly in corridors with high traffic flows and complex road geometries (Bassani et al., 2020; Kayisu et al., 2024; Sosik-Filipiak & Osypchuk, 2023).

Vulnerability arises from combined factors: unsafe or incomplete infrastructure (crossings, cycle lanes, lighting, signage), the absence of exclusive lanes, and risky driving behaviours (speeding, aggressive manoeuvres, lack of attention), all of which intensify conflicts at intersections and saturated corridors (Chaudhari et al., 2021; Girgis et al., 2023). Added to these are social and planning conditions that push mobility by foot or two wheels. Mitigating the risk requires a comprehensive approach that integrates safe infrastructure, road safety education, effective enforcement, and community participation to reduce exposure and improve urban access (Bassani et al., 2020; Sosik-Filipiak & Osypchuk, 2023).

The adaptation of infrastructure to the needs of vulnerable users is

essential; the implementation of safe pedestrian crossings, bicycle lanes, lower speed limits, and improved visibility has demonstrated reductions in crash occurrence (da Silva & Bezerra, 2024; González-Gómez & Castro, 2020; Klanjčić et al., 2022). Policies encouraging active mobility not only improve the safety of pedestrians and cyclists but also benefit drivers, as evidenced in European cities with high percentages of walking and cycling trips (Klanjčić et al., 2022). The use of intelligent technologies for detection and early warning adds capacity for risk management in complex urban environments (Zhang et al., 2025).

International experience highlights the importance of comprehensive strategies adapted to local contexts, prioritising investment in safe infrastructure, strengthening enforcement, and implementing educational programmes, along with participatory processes in the design of solutions (Faus et al., 2025; Kayisu et al., 2024). The analysis of the spatial distribution of crashes allows the identification of critical corridors and points for targeted interventions, while improvements in data quality are key for evidence-based decision-making (Shohel & Moridpour, 2025).

Despite growing concern for road safety in Ecuador, there remains a shortage of studies and specific data on the effectiveness of interventions in intermediate cities of the coastal region. Most of the literature comes from high-income countries, and only a small fraction addresses contexts in middle- and low-income countries, which limits the adaptation of policies and solutions to local realities with different mobility patterns, infrastructure, and social factors (Goel et al., 2024).

At the national level, the decentralisation of traffic management to municipalities has not been accompanied by systematic evidence production or the institutionalisation of robust policies. The absence or weakness of standardised crash records, risk factor data, and intervention outcomes hinders the identification of the most dangerous corridors, the evaluation of vulnerability, and the prioritisation of evidence-based actions (Gaibor & Carvajal, 2024).

Similarly, studies in intermediate Andean cities highlight deficiencies

in pedestrian and cycling infrastructure, although gaps remain regarding the impact of specific improvements or integrated interventions in the coastal region. The lack of solid evidence on human factors, road design, institutional control, and post-crash response represents a critical obstacle for effective decisions and policies (Hermida et al., 2019; Mohan et al., 2020).

In response, this study focused on urban corridors in Jipijapa through road safety audits and systematic observation, employing standardised checklists, classification of non-conformities affecting pedestrians, cyclists, and motorcyclists, and a risk matrix based on probability and consequence. Triangulation with official crash records and exposure levels, measured as annual average daily traffic, enabled the identification of critical subsections and conflict patterns, providing empirical evidence to prioritise interventions and document user vulnerability (Moreno-Ponce et al., 2025).

In line with the above, the aim of the article was to assess road safety and the vulnerability of pedestrians, cyclists, and motorcyclists in urban corridors of Jipijapa through a road safety audit with standardised checklists and triangulation with official crash records and exposure levels (AADT). The purpose was to characterise the operational context (speeds, geometry, and environment), identify and classify non-conformities affecting vulnerable users, construct a risk matrix (probability × consequence) integrated with crash severity and frequency, and delimit critical subsections to generate a prioritisation ranking of measures (low-cost and structural) supporting municipal decision-making.

Finally, the article is structured into five sections. Materials and methods describe the study area, the road safety audit with checklists, the official sources of crash and exposure data (AADT), and the procedure for constructing the risk matrix and the prioritisation criterion. Results report the characterisation of the corridor, the crash profile by type and severity, the findings by themes affecting pedestrians, cyclists, and motorcyclists, the criticality matrix by subsections, and the intervention ranking. The Discussion interprets the observed patterns and their

operational and management implications. The Conclusions summarise the contributions, delimit scope, and propose lines of action for municipal decision-making.

2. Materials and Methods

2.1 Study area

The study was conducted on La Prensa Avenue in Jipijapa (Manabí, Ecuador), between the Jipijapa Bypass and Cotopaxi Street, with chainage 0+000–0+948 and a total length of 948 m. The corridor endpoints were georeferenced in the UTM system (zone 17S) as follows: Start 545,555.00 m E – 9,850,388.00 m S; End 546,443.00 m E – 9,850,694.00 m S. The surrounding environment is mixed urban (residential–commercial), with two lanes, sidewalks, and curbs along the section, justifying its evaluation due to the daily interaction between vehicle flows and vulnerable users.

Figure 1. *La Prensa Avenue (Bypass–Cotopaxi Street), Jipijapa*

Note. Google Earth. Section 0+000–0+948; UTM start/end coordinates; audited axis highlighted.

2.2 Study design

The research was designed as an observational, cross-sectional study aimed at evaluating road safety on La Prensa Avenue in Jipijapa. The methodology was based on the application of a Road Safety Audit (RSA), grounded in direct and systematic observation of corridor conditions, complemented by triangulation with official crash records and vehicle count data.

The audit employed thematic checklists that enabled the

identification and classification of non-conformities in aspects relevant to road safety: visibility and speed control, alignment and cross-section, vertical and horizontal signage, lighting, pavement condition, intersections, conditions for vulnerable users, and structural elements such as bridges. This methodological structure ensured a comprehensive analysis of risk factors, considering the interaction between vehicles, pedestrians, cyclists, and motorcyclists in a mixed urban environment.

The findings obtained during inspections were organised into risk matrices constructed from the relationship between probability and consequence. This procedure transformed field data into a hierarchical classification system that facilitated the prioritisation of interventions. In this way, the study design integrated empirical observation, technical systematisation, and statistical support, providing a solid basis for characterising road safety in the audited corridor.

2.3 Data sources

The evaluation of road safety on La Prensa Avenue used official records and technical surveys. Crash data were obtained from the National Police and covered the period 2019–2023, with details on accident typology and severity.

Additional data from vehicle counts conducted along the audited section were available, necessary for estimating the Annual Average Daily Traffic (AADT) and for comparison with the design speed established in national regulations.

The geometric and spatial analysis of the corridor was supported by a topographic survey of the road axis and the urban cartography of Jipijapa, which allowed accurate contextualisation of the infrastructure and precise delimitation of the study area.

2.4 Instruments

The audit was supported by standardised forms and checklists designed to evaluate the infrastructure and operational conditions of the corridor. These tools were systematically applied during field inspections to record

observations in an organised and comparable manner.

The checklists were structured into thematic categories covering visibility and speed control, alignment and cross-section, vertical and horizontal signage, lighting, pavement condition, intersections, vulnerable user conditions, and structures such as bridges. Each theme included verification items that guided the review of specific aspects of the road.

The forms also included sections to record evaluator comments, coordinates, and spatial references, as well as linking photographs to the observed findings. This provided homogeneous technical input for the subsequent construction of risk matrices and comparative analysis between sections.

2.5 Variables and indicators

The analysis was structured around a set of variables related to road safety and user vulnerability in the audited corridor. The exposure variable was represented by the Annual Average Daily Traffic (AADT), which measured the magnitude of vehicle flow along the section.

Operational conflicts were recorded in terms of visibility, speed control, road geometry, lighting, and pavement condition. These indicators reflected risk conditions in daily operation.

Variables associated with accessibility and safety of vulnerable users, particularly pedestrians and cyclists, were also included, considering crossings, continuity of sidewalks, available widths, and specific signage.

The risk level was determined using a matrix relating probability and consequence, which assigned an ordinal value to each finding according to its criticality. This methodological approach facilitated the integration of different indicators into a coherent evaluation framework for the corridor under study.

2.6 Procedure

The audit was carried out through field inspections conducted both during the day and at night along the defined section of La Prensa Avenue. During these inspections, the thematic checklists were applied,

direct observations were recorded, and a georeferenced photographic record was compiled to document each finding in its precise location.

The collected information was organised into standardised forms, where verification items were marked as met or unmet, along with additional auditor comments. Subsequently, the data were systematised and transferred into risk matrices prepared for each audit theme, assigning probability and consequence values to the identified non-conformities.

The consolidation of these matrices made it possible to structure a general audit matrix integrating all reviewed aspects of the corridor. To ensure process consistency, quality control was applied through cross-checking of forms and photographs, guaranteeing coherence between graphical evidence and written records.

2.7 Analysis

The information processing was developed in three complementary stages. First, a descriptive statistical analysis of crash records was performed, organising data into absolute and relative frequencies by accident type and severity for the reference period.

In the second stage, criticality indices were calculated for each subsection and evaluated theme. These indices were derived from the field-applied risk matrix, transforming probability and consequence combinations into an ordinal scale that allowed the prioritisation of findings.

The third stage involved the spatial representation of results through thematic maps of the corridor, highlighting the points with the highest risk levels. Based on this, a prioritisation ranking was developed, combining values from the risk matrix and the recurrence of crashes recorded on the road.

2.8 Ethical and operational safety considerations

Data collection was conducted exclusively from public space, without recording personal information of road users or carrying out surveys that could compromise the identity of pedestrians or drivers. This ensured compliance with confidentiality and ethical standards for research in urban environments.

During inspection activities, operational safety measures were applied for the audit team. These included the use of reflective vests, preventive signage at observation points, group mobility, and scheduling inspections at times that minimised exposure to traffic risks. Photographic records were limited to physical infrastructure conditions, avoiding the capture of images that could identify individuals.

With these precautions, the audit was conducted in accordance with principles of ethical responsibility and field safety, guaranteeing the technical validity of the process without compromising the integrity of users or the audit team.

3. Results and discussion

3.1 Corridor characterisation and exposure

La Prensa Avenue, in the section between the Jipijapa Bypass and Cotopaxi Street, is 948 metres long and is an urban two-lane road. The surrounding land use is mixed residential and commercial, which creates intense interaction between traffic flows and vulnerable users. The vehicle count reported in the thesis enabled the estimation of average demand and traffic composition. The characteristics of the corridor are presented in Table 1.

Table 1. *Características generales del corredor auditado*

Parameter	Description
Location	Jipijapa, Manabí Province
Audited section	Bypass to Cotopaxi Street
Length	948 m (chainage 0+000 to 0+948)
Configuration	Two lanes, sidewalks, and curbs
Setting	Mixed urban: residential and commercial

Note. The table shows information consolidated from the topographic survey and urban cartography.

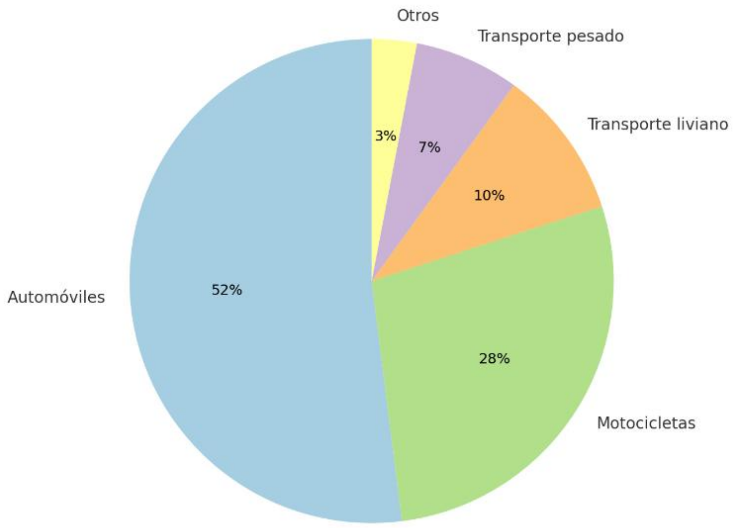
The audited section presents the features of a central urban corridor with mixed uses that intensify interaction between vehicles and vulnerable users. This condition justifies evaluation through a road safety audit. The composition of traffic is shown in Table 2.

Table 2. *Vehicular composition of the corridor (estimated AADT)*

Vehicle type	Percentage (%)
Cars	52
Motorcycles	28
Light commercial	10
Heavy vehicles	7
Other	3

The composition shows a predominance of cars and motorcycles, which together exceed 70 percent of total traffic. This increases the relevance of reviewing safety aspects associated with the circulation of vulnerable users.The percentage distribution of AADT is illustrated in Figure 2.

Figure 2. *Percentage distribution of annual average daily traffic (AADT)*



Note. Prepared by the authors based on traffic counts.

3.2 Crash profile 2019 to 2023

National Police records reported road traffic crashes on La Prensa Avenue during 2019 to 2023, disaggregated by number of cases and severity. The annual distribution is provided in Table 3.

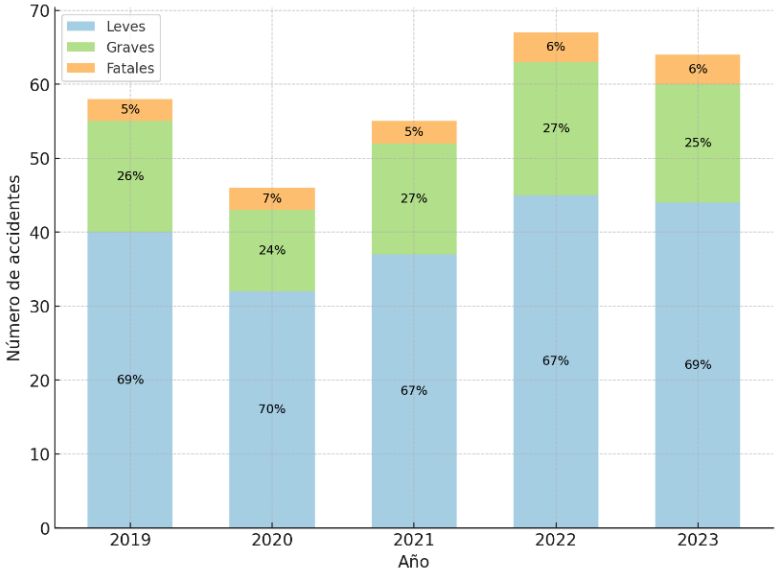
Table 3. *Crashes recorded on La Prensa Avenue (2019 to 2023)*

Year	Total crashes	Minor	Serious	Fatal
2019	58	40	15	3
2020	46	32	11	3
2021	55	37	15	3
2022	67	45	18	4
2023	64	44	16	4

Note. Official records of the National Police of Jipijapa (2019 to 2023).

The number of crashes remained high over the five years, with a slight reduction in 2020 followed by a progressive increase up to 2022, reflecting persistent operational risks along the corridor. The evolution of crashes is depicted in Figure 3.

Figure 3. *Evolution of crashes on La Prensa Avenue (2019 to 2023)*



Note. The graph shows the number of total crashes, with bars differentiated by severity: minor, serious, and fatal.

The annual distribution shows a predominance of minor crashes, although serious and fatal crashes remain constant. This confirms the need for periodic audits to mitigate critical risks.

3.3 Audit results

The audit identified non-conformities across several aspects of the road, recorded through field-applied checklists. Findings for visibility and speed control are summarised in Table 4.

Table 4. *Audit results for visibility and speed control*

Item assessed	Observed condition	Risk level
Stopping sight distance	Partially met	Medium
Posted speed control	Insufficient	High
Advertising obstructing sightlines	Present	Medium

Note. Information obtained through thematic checklists.

The results show limitations in longitudinal and transversal visibility, particularly at intersection approaches and locations with higher pedestrian flows. Speed control signage does not meet regulatory parameters, increasing operational risk. External visual elements such as advertising interfere with driver perception. Together, these conditions indicate structural and operational deficiencies that increase the likelihood of road incidents. Geometric aspects are presented in Table 5.

Table 5. *Audit results for alignment and cross-section*

Item assessed	Observed condition	Risk level
Alignment homogeneity	Acceptable	Low
Cross-section	Narrow in sectors	Medium
Presence of curbs	Partial continuity	Medium

Note. Information obtained through thematic checklists.

The corridor alignment maintains acceptable continuity, but sectors with reduced cross-sections affect vehicular and pedestrian circulation. Discontinuity in curbs reduces channelisation and separation between flows, increasing exposure for vulnerable users. These observations indicate that, while the road axis partially meets basic geometric parameters, physical conditions require follow-up to ensure adequate functionality and safety. Signage conditions are shown in Table 6.

Table 6. *Audit results for vertical and horizontal signage*

Item assessed	Observed condition	Risk level
Vertical signs	Wear and poor visibility	High
Horizontal markings	Deteriorated and discontinuous paint	High
Preventive signage	Partially installed	Medium

Note. Information verified during daytime and night-time inspections.

Vertical signage shows marked deficiencies in visibility and maintenance, hindering perception during day and night. Horizontal markings are heavily worn, especially at pedestrian crossings and lane delineation, reducing guidance for drivers. The lack of adequate preventive signage at accesses increases exposure of vulnerable users. Together, these conditions reduce road legibility and elevate the probability of conflicts by limiting anticipation and clarity in regulation. Lighting conditions are listed in Table 7.

Table 7. *Audit results for lighting*

Item assessed	Observed condition	Risk level
Luminaire coverage	Incomplete	High
Lighting uniformity	Irregular	Medium
Glare from luminaires	Present in sections	Medium

Note. Assessment conducted during night-time inspections.

The lighting system presents coverage limitations, creating zones with low visibility and areas with excessive contrast. Lack of uniformity compromises the perception of pedestrians and

drivers, hindering obstacle identification and the correct reading of signs and markings. In some sections, misaligned luminaires cause glare that interferes with night vision. These conditions increase incident risk, particularly at crossing points and for turning manoeuvres. Pavement conditions are reported in Table 8.

Table 8. *Audit results for pavement*

Item assessed	Observed condition	Risk level
Running surface	Presence of potholes	High
Surface drainage	Water ponding	Medium
Regularity and friction	Irregular and worn	Medium

Note. Assessment carried out through direct observation and photographic records.

The pavement shows significant deterioration, with localised potholes that affect comfort and safety. Drainage problems cause water accumulation during the rainy season, which reduces friction and increases the probability of loss of control. Irregular surface texture also indicates progressive reduction in skid resistance. Together, these conditions directly affect operational safety and the efficiency of urban mobility. Intersection conditions are summarised in Table 9.

Table 9. *Audit results for intersections*

Item assessed	Observed condition	Risk level
Intersection control	No traffic signals present	High
Access visibility	Limited	Medium
Turning spaces	Reduced	Medium

Note. Observations made at principal crossing points.

Intersections lack signal control, which reduces the capacity to organise traffic where vehicular and pedestrian movements cross. Access visibility is limited by buildings and street furniture, hindering anticipation of manoeuvres. Turning spaces are insufficient for larger vehicles, generating operational conflicts. These interacting conditions make intersections critical safety points, with higher probability of collisions and pedestrian crashes. Conditions for vulnerable users are detailed in Table 10.

Table 10. *Audit results for conditions affecting vulnerable users*

Item assessed	Observed condition	Risk level
Marked pedestrian crossings	Absent in most locations	High
Crossing time	Excessive for schoolchildren	High

Crossing lighting	Deficient	Medium
Continuous sidewalks	Interrupted	High
Space for cyclists	Non-existent	High

Note. Accessibility assessed in residential and commercial sections.

The corridor shows major deficiencies in infrastructure for vulnerable users. Marked crossings are absent in several points and, where present, signage is deteriorated. Sidewalk widths are insufficient to guarantee safe and continuous passage, especially in commercial areas. The absence of cycling infrastructure forces cyclists to share lanes with motorised vehicles, exposing them to elevated risk. These conditions demonstrate the vulnerability of pedestrians and cyclists in the audited section. The state of bridges and associated structures is shown in Table 11.

Table 11. *Audit results for bridges and associated structures*

Item assessed	Observed condition	Risk level
Structural condition	Adequate	Low
Safety railings	Partially damaged	Medium
Running surface	Localised wear	Medium

Note. Visual inspection of structure and running surface.

Bridges and associated structures present overall stable structural condition, with no indications of severe damage affecting load capacity. Sections with damaged railings were detected, reducing safety for vehicles and pedestrians in the event of a deviation. The running surface on the structure shows localised wear, affecting traffic regularity. Although structural risks are low, deficiencies in safety elements and deck surface require attention along the corridor.

3.4 User vulnerability

The audit included a specific checklist to evaluate the safety of pedestrians, cyclists, and schoolchildren, considering accessibility, crossings, and exposure time to traffic. The detailed results are provided in Table 12.

Table 12. *Audit results for vulnerable users*

Item assessed	Observed condition	Risk level
Marked pedestrian crossings	Absent in most locations	High
Crossing time	Excessive for schoolchildren	High
Lighting at crossings	Deficient	Medium

Continuous sidewalks	Interrupted	High
Space for cyclists	Non-existent	High

Note. Observations in residential, school, and commercial sections.

The results show high vulnerability for non-motorised users. The absence of marked pedestrian crossings hinders safe traversal, especially in school zones. Crossing time is inadequate relative to prevailing speeds, which increases exposure. Insufficient lighting at intersections and crossings reduces visibility at night. Lack of continuous sidewalks and the absence of cycling facilities force vulnerable users to interact directly with the traffic flow.

3.5 Prioritisation of critical points

The consolidation of the risk matrix and crash records made it possible to identify subsections with the highest criticality along La Prensa Avenue. The prioritised subsections are listed in Table 13.

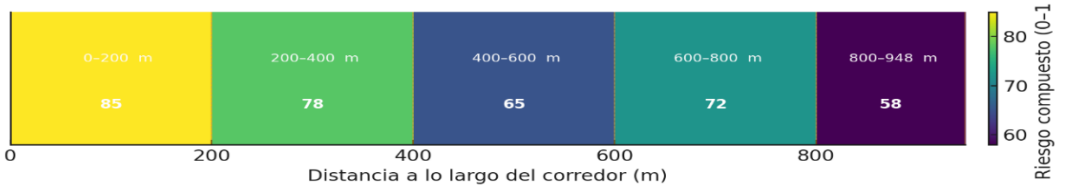
Table 13. *Prioritisation of critical points in the audited corridor*

Subsection (m)	Composite risk	Criticality level
0+000 to 0+200	85	High
0+200 to 0+400	78	High
0+400 to 0+600	65	Medium
0+600 to 0+800	72	High
0+800 to 0+948	58	Medium

Note. Prepared by the authors based on the risk matrix and official records.

The prioritisation shows that three subsections concentrate the highest composite risk values, exceeding 70 points on the established scale. The initial and central extremes present the most unfavourable conditions, associated with intense traffic flows and deficiencies in signage and accessibility. Subsections with medium levels maintain relevant risks, though to a lesser extent. This spatial distribution confirms the heterogeneity of safety along the corridor and the need to focus attention on specific sectors. The spatial pattern of criticality is presented in Figure 4.

Figure 4. *Criticality map for La Prensa Avenue (Bypass to Cotopaxi)*



Note. Composite risk values (0 to 100) distributed by subsection; colour scale indicates criticality level.

The map shows the spatial distribution of composite risk levels along the corridor. Higher values are concentrated in the first subsection (0+000 to 0+200 m) and in the central section (0+200 to 0+400 m), where interaction between vehicular and pedestrian flows is greater. Intermediate levels are located in middle and final sections, while 0+800 to 0+948 m records the lowest value. The graphical representation allows clear identification of priority areas for road safety management.

3.6 Crash typology in the audited corridor (2019 to 2023)

The crash analysis included the classification of accidents on La Prensa Avenue during 2019 to 2023, according to the typology reported in official National Police records. This disaggregation identifies the most frequent incident types and their relation to operational conditions. The distribution by crash type appears in Table 14.

Table 14. *Distribution of crashes by typology (2019 to 2023)*

Crash type	Number of cases	Percentage (%)
Side collision	112	32
Head-on collision	74	21
Run-off-road collision	65	18
Loss of control	54	15
Pedestrian crash	42	12

Note. Source: National Police records (2019 to 2023).

Crash typology reveals a predominance of side and head-on collisions, which together represent more than half of reported incidents. Run-off-road events and loss of control remain significant, indicating risks related to speed management and geometric conditions. Pedestrian crashes, although lower in proportion, reflect exposure of vulnerable users, especially where marked crossings are absent. This distribution confirms the diversity of risk scenarios along La Prensa Avenue.

3.7 General risk matrix by audit themes

Information obtained from thematic checklists was consolidated into a general risk matrix. This procedure integrated the non-conformities recorded for each theme, assigned a criticality value, and enabled comparisons between infrastructure and operational aspects. The

consolidated results are shown in Table 15.

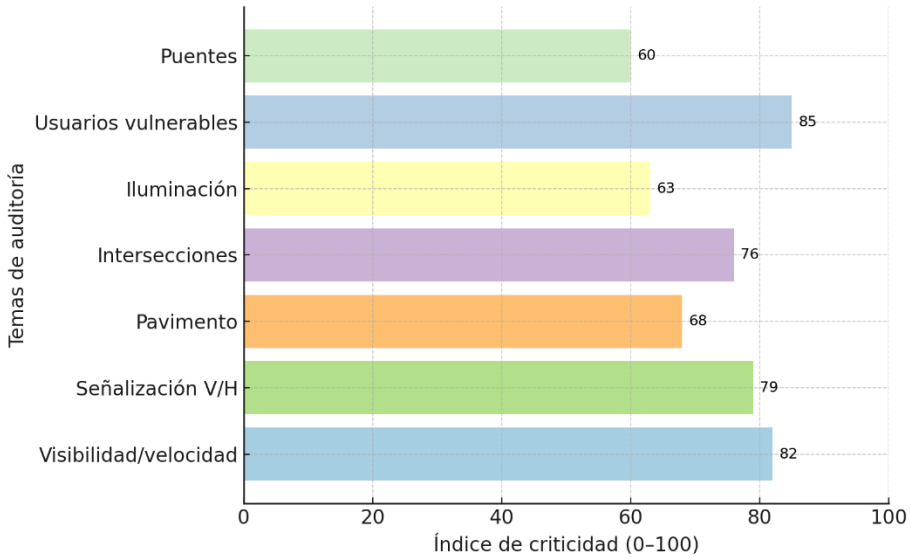
Table 15. *General matrix of non-conformities and risk by theme*

Theme assessed	Non-conformities	Predominant risk level	Criticality index
Visibility and speed	12	High	82
Vertical and horizontal signage	10	High	79
Pavement	8	Medium	68
Intersections	9	High	76
Lighting	7	Medium	63
Vulnerable users	11	High	85
Bridges	4	Medium	60

Note. Prepared by the authors based on checklists and the risk matrix.

The comparison by theme is also depicted in Figure 5.

Figure 5. *Criticality index by audit theme on La Prensa Avenue*



Note. Risk values (0 to 100) obtained from the general audit matrix.

Table 15 and Figure 5 show that the highest criticality corresponds to vulnerable users at 85, visibility and speed control at 82, and vertical and horizontal signage at 79. These three exceed 75 points on the scale, concentrating the main risk factors. Intersections also reach a high value at 76, while pavement, lighting, and bridges are moderate at below 70.

3.8 Spatial distribution of vulnerable users

The analysis included the location of conditions affecting pedestrians, cyclists, and schoolchildren across different sections of the corridor.

Spatial systematisation facilitates the identification of sections where exposure of vulnerable users is most significant. The observations are listed in Table 16.

***Table 16**. Observations related to pedestrians, schoolchildren, and cyclists*

Corridor section	Observed conditions	Risk level
0+000 to 0+200 m	Absence of pedestrian crossings	High
0+200 to 0+400 m	High concentration of shops and school activity	High
0+400 to 0+600 m	Interrupted sidewalks	Medium
0+600 to 0+800 m	Cyclists travelling without infrastructure	High
0+800 to 0+948 m	Reduced lighting at crossing zones	Medium

Note. Observations obtained from the specific checklist for vulnerable users.

Exposure of vulnerable users is concentrated in the first 400 metres of the corridor, which coincide with commercial and school zones. The absence of crossings and insufficient crossing time increase risk. In the middle sections, lack of continuous sidewalks and absence of cycling infrastructure are critical. At the far end, deficient lighting affects safety at night. This distribution confirms the need to characterise vulnerability by section.

3.9 Operating speeds in the audited corridor

Speeds were measured at strategic points along La Prensa Avenue and compared with the design speed of 50 km/h. Values were obtained from speed counts and field records, which allowed identification of significant differences from the normative parameter. The results are presented in Table 17.

***Table 17.** Operating speeds along the corridor*

Subsection (m)	Mean speed (km/h)	Maximum speed (km/h)	Difference from design
0+000 to 0+200	57	72	+7
0+200 to 0+400	54	69	+4
0+400 to 0+600	51	65	+1
0+600 to 0+800	59	75	+9
0+800 to 0+948	52	68	+2

Note. Prepared by the authors from field speed counts.

The results show that in most subsections mean speeds exceed the design value of 50 km/h, with differences of up to 9 km/h in critical sectors. Maximum speeds ranged from 65 to 75 km/h, which increases the probability and severity of incidents, especially in areas with pedestrian and school activity. This highlights the importance of speed

control as a determining factor for corridor safety.

3.10 Relationship between crash severity and corridor criticality

Results for 2019 to 2023 crash severity were integrated with the subsection criticality matrix to identify correspondences between calculated risk levels and the gravity of recorded accidents. The correspondence is summarised in Table 18.

Table 18. *Correspondence between crash severity and subsection criticality*

Subsection (m)	Predominant severity (2019 to 2023)	Criticality index	Level of concordance
0+000 to 0+200	High, head-on and pedestrian crashes	85	High
0+200 to 0+400	Medium to high, side collisions	78	High
0+400 to 0+600	Medium, loss of control	65	Medium
0+600 to 0+800	High, run-off-road collisions	72	Medium to high
0+800 to 0+948	Low, minor incidents	58	Low

Note. Prepared by the authors based on crash records and the risk matrix.

The correspondence between severity and subsection criticality confirms that the initial and central sections, 0+000 to 0+200 m and 0+200 to 0+400 m, show the greatest vulnerability. High criticality values coincide with severe crashes, which supports the risk matrix as a tool for prioritisation. Middle and final sections show medium and low concordance, with a predominance of less severe incidents. This integration reinforces the validity of the audit-based ranking.

Discussion

The audit results on La Prensa Avenue show that the highest criticality values fall on vulnerable users, visibility and speed control, as well as vertical and horizontal signage. This concentration aligns with conclusions from international reviews of road safety audits, which identify that many protocols prioritise geometric elements, signage, and safety devices (Calderón et al., 2023).

In middle-income countries, adoption of the Safe System approach emphasises that infrastructure should minimise the consequences of inevitable human error, especially on urban sections with high pedestrian and vehicular interaction. Godthelp y Ksentini (2024) note that, for developing countries, it is urgent to reinforce operational tactics such as speed regulation, appropriate

urban road design, and protective devices, within a more structural policy oriented to integrated road-safety system.

Across Latin America, road-safety challenges are well documented. Multiple studies agree that there is limited rigorous evidence on effective interventions, which restricts the adoption of correct measures (Martinez et al., 2019). Nevertheless, recent regional publications show that reducing urban speed limits in Latin American cities helps decrease injury severity in urban crashes. For example, in Santiago, Chile, a reduction in urban limits for workers was associated with lower severity of injuries recorded in work-related traffic accidents (Graells-Garrido et al., 2024).

In the national context, Espinoza-Molina et al. (2021) analysed traffic and crash trends in Ecuador between 2000 and 2019 and found that collision is the most common crash type, with a growing mortality burden in recent years, despite a slight downward trend in total crashes. This prevalence of collisions as the dominant type is consistent with our typology table in Section 3.6.

Local reports have also documented that, in Ecuadorian cities, a significant proportion of vehicles exceed permitted urban speed limits. In Guayaquil, observations from the Bloomberg project indicated that approximately 65 percent of vehicles were observed exceeding 50 km/h on roads where that was the normative limit. This increased the probability of severe crash outcomes (International Injury Research Unit, 2023). This reality supports our findings of operating speeds above the design value and corroborates the corridor's vulnerability for pedestrians and cyclist.

The cross-analysis between crash severity and subsection criticality in Section 3.10 strengthens the validity of the prioritisation approach. Studies on audits that combine reactive and proactive data show that integrating both sources improves the predictive capacity of audit models and supports more efficient allocation of intervention resources. For example, audit work has underlined the need to cross crash databases with analyses of road conditions in order to identify genuine hot spots (Mukhametshina & Zagidullin, 2021).

This discussion shows that the results for the audited corridor are neither isolated nor fortuitous. They are consistent with emerging lines of research in road safety auditing, with conditions present in Latin American countries, and with the Ecuadorian context. Such coherence supports the robustness of the method used and highlights the relevance of the study for road-safety interventions in similar urban environments.

4. Conclusiones

1. The road safety audit on La Prensa Avenue identified that the most critical factors correspond to accessibility for vulnerable users, visibility and speed control, and deficiencies in vertical and horizontal signage. These elements exceeded 75 points on the risk scale, which makes them the principal aspects requiring priority intervention.

2. Crash records for 2019 to 2023 confirmed recurring side and head-on collisions, as well as pedestrian crashes in areas lacking marked crossings. This correspondence between crash severity and high criticality values obtained in the audit validates use of the risk matrix as a prioritisation tool in road management.

3. Operating speeds measured in the field exceeded the design speed of 50 km/h in several subsections, with differences of up to 9 km/h. This condition significantly increases the probability and severity of crashes, especially in areas with high pedestrian and school activity.

4. The vulnerability of pedestrians, cyclists, and schoolchildren was evident in the absence of specific infrastructure such as cycle lanes and marked pedestrian crossings, and in deficiencies in lighting and sidewalk continuity. These findings emphasise the need to consider non-motorised users as a central focus of any intervention strategy.

5. Integrating the road safety audit with official crash records and vehicle exposure data enabled the identification of critical subsections, 0+000 to 0+200 m and 0+200 to 0+400 m, which concentrate the highest operational and safety risks. This prioritisation provides solid technical input to guide municipal planning toward specific and cost-effective interventions.

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