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Spatiotemporal evaluation and acoustic criticality of environmental noise in a mobility corridor in Manta, Ecuador

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ABSTRACT

The research evaluated the spatiotemporal variability and acoustic criticality of environmental noise in the Terminal Terrestre corridor, El Palmar–Tohallí, Manta canton, Manabí province, Ecuador. Six points associated with transport, commerce, public facilities and spaces of urban permanence were selected. The design included 90 LAeq monitoring units, 15 min (6 points × 3 operating periods × 5 days); Supplementary Material S1 retains 450 associated analytical records, identified by provenance and not treated as additional independent observations. The instrumental control included 30 pre- and post-measurement tests at 94.0 dB and 1 kHz, with a maximum drift of 0.1 dB and an expanded operational uncertainty of the instrumental component of ±0.7 dB (k = 2). The reference weather conditions were compatible with the protocol, with no rain during the measurement windows and with wind less than 5 m/s. The levels were contrasted with Ecuadorian environmental regulations and were complemented with temporal amplitude, time shift of critical areas, spatial gradient and IDW interpolation. Spatial cross-validation produced RMSE of 3.05, 3.33 and 4.00 dB(A) for morning, noon and afternoon, respectively, so the maps were interpreted with exploratory scope. The Urban Acoustic Criticality Index (ICAU) integrated regulatory exceedance, sound intensity, temporal amplitude, spatial gradient and functional sensitivity. The six points did not comply with the applicable limits, with averages between 82.1 and 87.3 dB(A). The sensitivity analysis using 19 scenarios maintained the order P5–P1–P2. An AHP technical-documentary scenario, with CR = 0.0189, maintained the same priority group and showed a Spearman correlation of 0.943 with respect to the operational scheme. In addition, internal temporal validation by successive exclusion of each day retained those top three positions in five of five iterations and produced Spearman correlations between 0.943 and 1.000. It is concluded that the corridor has high and spatially differentiated acoustic pressure; the AHP justification, the sensitivity analysis and the temporal verification support the coherence and stability of the ICAU as a technical-operational tool within the corridor studied.

Keywords: environmental noise, urban noise pollution, equivalent sound level (LAeq), spatiotemporal variability, acoustic mapping, Urban Acoustic Criticality Index (ICAU).

INTRODUCTION

Noise pollution has established itself as one of the most relevant urban environmental pressures for public health, environmental comfort and territorial planning. In this study, the term environmental noise is used to refer to the unwanted urban phenomenon associated with mobile sources, commercial activities and the operation of facilities; on the other hand, the expression sound pressure level is used when describing the physical quantities recorded instrumentally, expressed in dB(A). This distinction makes it possible to separate the environmental problem from the measured acoustic variable and avoids an imprecise interpretation of the results (Basner et al., 2014; World Health Organization Regional Office for Europe, 2018).

In high-mobility urban corridors, ambient noise acquires a complex expression because the sound sources do not act in isolation, but overlap in time and space. Road traffic, motorcycles, public transport, road nodes, commercial edges and citizen service facilities tend to raise the equivalent noise level and generate relevant time variations, especially in periods of start of the day, concentration of users and return to work (McAlexander et al., 2015; Rey Gozalo et al., 2020; Montenegro et al., 2024).

Recent literature on urban noise emphasizes that static maps are not always sufficient to understand acoustic exposure, because sound levels change according to traffic intensity, vehicular speed, road configuration, and land-use dynamics. Therefore, spatiotemporal approaches make it possible to interpret noise as a changing urban process, identify critical zones by schedule, and recognize acoustic transitions over short distances (Lan et al., 2020; Nasser et al., 2023). From this perspective, acoustic mapping, spatial gradients and criticality indices provide applied information for urban environmental management.

The Manta parish is a relevant scenario for this analysis due to its population growth, concentration of commercial and institutional activities, road connectivity, public transport and the presence of sectors of social permanence. In addition, local planning instruments promote a vision of a sustainable, resilient, and well-being-oriented city, which makes it necessary to generate useful environmental evidence for municipal decision-making (Municipal Decentralized Autonomous Government of the Canton of Manta, 2024; National Institute of Statistics and Censuses, 2023). In this framework, the objective of the study was to evaluate the spatiotemporal variability and acoustic criticality of urban environmental noise in the Terminal Terrestre–El Palmar–Tohlallí corridor, through instrumental monitoring, normative analysis, spatial indicators, exploratory cartography, structured justification of the weightings, sensitivity analysis and internal temporal validation of the ICAU.

MATERIALS AND METHODS

Study area

The study was developed in the canton of Manta, province of Manabí, Ecuador, within a connectivity axis associated with public transport, vehicular circulation, commerce, institutional facilities, urban services and population permanence. The area was referenced in the WGS 1984 / UTM zone 17S system for spatial and cartographic representation. The six points were georeferenced in the field; their projected coordinates, approximate geographical equivalences, positional accuracy and altitude are presented in Table 1. The delimitation of the corridor and its location within the Manta canton are shown in Figure 1.

The research was structured under an observational, cross-sectional and analytical-exploratory approach, aimed at recording existing acoustic conditions in daytime slots and the interpretation of their spatial and temporal variability.

Preliminary recognition and point selection

The preliminary reconnaissance consisted of systematic tours of the urban corridor at times of different intensity of activity, with the purpose of identifying dominant sources of environmental noise, mobility patterns, concentration of users, presence of commerce, urban facilities, physical barriers, vegetation, reflective buildings and safety conditions for surveying. Based on this observation, monitoring points were defined through intentional sampling, prioritizing sites with high population exposure, presence of emitting sources, and functional diversity of the urban space (Margaritis and Kang, 2016).

Table 1. Coordinates and location characteristics of acoustic monitoring points

Point	Site	This	North	Accuracy	Altitude	Latitude approx.	Approx. length
P1	Hostal Black White	534609	9893773	±18 m	21 m	-0,961054	-80,688936
Q2	Land Terminal	534373	9893745	±13 m	21 m	-0,961307	-80,691057
Q3	Plaza Oliva	533971	9893915	±4 m	18 m	-0,959770	-80,694670
Q4	La Barca Rodonor	535312	9893873	±14 m	21 m	-0,960149	-80,682617
Q5	Conserva y Saber Association Court	534801	9894008	±7 m	16 m	-0,958928	-80,687210
Q6	Transit Agency	534089	9894337	±12 m	12 m	-0,955952	-80,693610

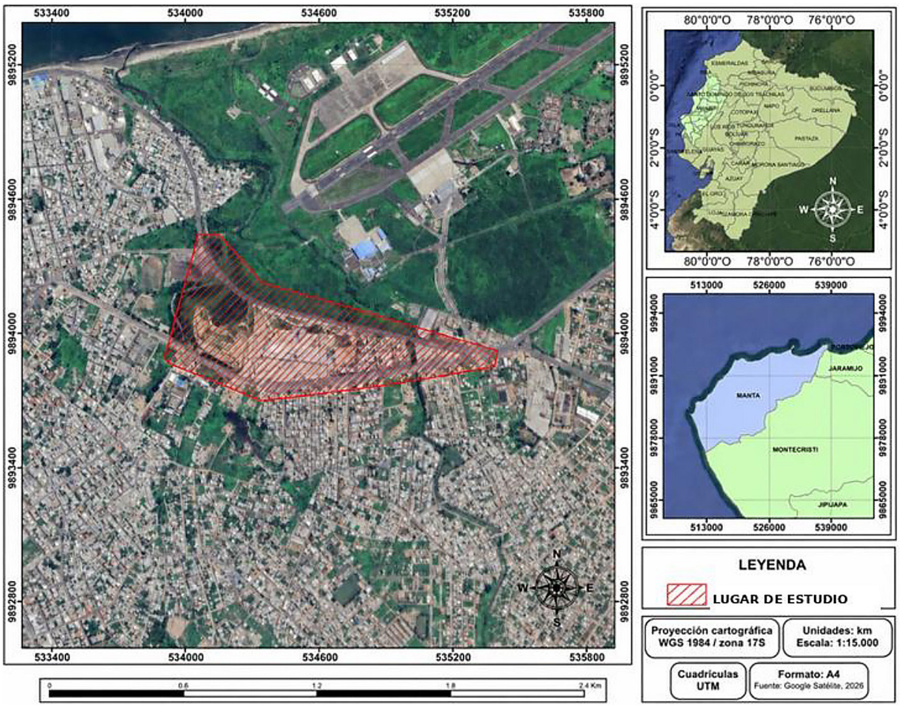

Figure 1. Study area of the Terminal Terrestre-El Palmar-Tohallí, Manta, Manabí

Functional classification of land use

The monitoring points were classified according to the predominant urban function observed in the field and with the land use categories used for the normative comparison (Table 2). This classification made it possible to differentiate commercial sectors, public facilities and social facilities, so that the interpretation of sound pressure levels was related to urban activity, population exposure and the applicable daytime limit. In sectors with coexistence of uses, the most restrictive limit was applied, under a precautionary logic of protection of human receptors and sensitive equipment (Ministry of the Environment of Ecuador, 2015).

Acoustic monitoring

Sound pressure level measurements were performed with a SPER Scientific digital sound level meter, model 850014, serial number SSM-850014-23041, in accordance with the performance criteria established for sound level meters in the IEC 61672 series. The equipment operated with automatic measuring range and mounting on a tripod during the data collection. The main descriptor of analysis was the equivalent continuous sound level, LAeq,T dB(A), methodologically reported as LAeq,15 min dB(A), because each monitoring unit corresponded to a continuous interval of 15 minutes. This descriptor was complemented with Lmax and Lmin to characterize both the equivalent energy level and the extreme values observed during the measurement interval (IEC, 2013; ISO, 2017).

The acoustic monitoring was carried out for five consecutive days, from September 17 to 21, 2025, at six points and three daytime operating periods: morning (approximately 07:30–10:15), noon (11:50–14:15) and afternoon (15:50–18:10). These intervals correspond to the sequential path required to complete the six sites and not to simultaneous measurements within a single hour. In each point-period-day combination, a 15-minute monitoring unit was carried out. The five days constituted independent temporary repetitions, so the design included 90 units (6 points × 3 periods × 5 days). For each unit, the LAeq,15 min was obtained by energy average of five associated registers: $L_{Aeq,15\,min} = 10 \log_{10}[(1/5)\ \Sigma\ 10^{(Lr/10)}]$. Supplementary Material S1 preserves the 450 associated analytical records, organized by date, point, period and record number, with identification of origin and traceability. These records supported the calculation of the 90 units and were not treated as 450 independent temporal or spatial observations.

The microphone was located approximately 1.20 to 1.50 m above ground level, on a tripod and without manipulation during reading. Measurements were avoided in rain, wind greater than 5 m/s or during extraordinary non-representative

Table 2. Functional classification of the monitoring points according to land use and applicable regulatory limit

Point	Site	Assigned Land Use	Code	Daytime limit	Description
P1	Hostal Black White	Commercial	CM	60 dB	Lodging and service activity, associated with economic exchange, user mobility and commercial urban dynamics.
Q2	Land Terminal	Utility Equipment	EQ2	60 dB	Public transport infrastructure, mobility and concentration of users.
Q3	Plaza Oliva	Commercial	CM	60 dB	Predominant function of commerce and services, with circulation of users and economic activity.
Q4	La Barca Rodonor	Utility Equipment	EQ2	60 dB	Road and urban mobility infrastructure, associated with vehicular flow and territorial connectivity.
Q5	Conserva y Saber Association Court	Social services equipment	EQ1	55 dB	Community, recreational/sports and social permanence space; a more restrictive criterion is applied.
Q6	Transit Agency	Utility Equipment	EQ2	60 dB	Public institution linked to the management of traffic, mobility and citizen service.

events, such as sirens, accidents, demonstrations, unusual works or other accidental sources (ISO, 2017; Ministry of the Environment of Ecuador, 2015). The instrumental recording in the field is presented in Figure 2.

Instrument control, weather conditions and uncertainty

Before and after each monitoring session, an acoustic check was carried out on the system consisting of the SPER Scientific 850014 sound level meter and the CAL200/850016 calibrator, using a reference signal of 94.0 dB at 1 kHz. 30 checks were documented, corresponding to 15 initial and 15 final verifications, distributed between the five days and the three time slots. The readings ranged from 94.0 to 94.2 dB, remained within the acceptance criterion of ±0.5 dB, and had a maximum pre/post drift of 0.1 dB. These controls were developed in accordance with the principles of periodic verification of sound level meters and acoustic calibrators set out in IEC 61672-3 and IEC 60942:2017.

The atmospheric conditions of the days of September 17 to 21, 2025 were documented through the project's reference meteorological record, contrasted with historical information for the urban area of Manta and the Eloy Alfaro airport station (SEMT). For the daytime windows, a contextual temperature range of 21 to 27 °C, relative humidity of approximately 70 to 90%, absence of precipitation during sampling, and wind speed of less than 5 m/s were considered. These data were used to check the overall compatibility

Figure 2. Instrumental recording of acoustic monitoring in the field

of atmospheric conditions with the protocol and were not interpreted as continuous measurements next to the microphone (Hersbach et al., 2020; Open-Meteo, 2026). The reference conditions per working day are summarised in Table 3.

The uncertainty of the instrumental control was evaluated following the JCGM 100:2008 type A and type B component approach. The repeatability of the 30 test readings presented a standard deviation of 0.07 dB. Type B contributions were considered to be the acceptance criteria of the acoustic control (±0.5 dB, rectangular distribution), the maximum observed drift (±0.1 dB, rectangular distribution) and the reading resolution of 0.1 dB. The associated standard uncertainties were 0.289, 0.058 and 0.029 dB, respectively. Their quadratic combination produced an instrumental standard uncertainty of 0.30 dB and an expanded uncertainty of 0.61 dB for k = 2. For the environmental interpretation, ±0.7 dB was conservatively adopted, incorporating a residual meteorological margin. This value represents the operational component of the measurement system and does not absorb the real variability of the urban environment, which was characterized separately by the 90 monitoring units, the repetitions per day and the spatiotemporal indicators.

Normative assessment of urban environmental noise

The sound pressure levels were contrasted with the maximum permissible limits established in Ministerial Agreement 097-A, Annex 5, considering the land use of each point and the daytime evaluation period. Given that the sites received simultaneous contributions from vehicular traffic, motorcycles, commercial activity, loudspeakers, pedestrian circulation and other sources of urban dynamics, the results were interpreted as total environmental noise from the sector and not as emissions attributable to a single fixed source. The limits used for comparison are presented in Table 4.

When the regulations express the limits in terms of LKeq, the comparison was presented as a referential environmental verification based on the measured descriptor LAeq,15 min dB(A), without assuming tonal corrections, impulsives or other acoustic penalties not recorded in the field. This precision made it possible to maintain methodological transparency and avoid overinterpretation of the normative assessment (ISO, 2017; Ministry of the Environment of Ecuador, 2015).

Spatiotemporal variability

Descriptive indicators and three derived indicators were calculated to interpret the spatiotemporal variability of environmental noise: temporal amplitude per point, hourly displacement of critical areas and spatial acoustic gradient between nearby points. The temporal amplitude was calculated as the difference between the highest and lowest LAeq.15 min dB(A) recorded in the time slots of each point; the hourly displacement of critical areas was determined by identifying the point with the highest noise level within each strip; and the acoustic gradient was estimated as the ratio between the absolute change of LAeq,15 min and the Euclidean distance between nearby points expressed in kilometers (ISO, 2017; WHO Regional Office for Europe, 2018).

$$\begin{gathered} Temporal\ amplitude = \\ = LAeq{,}15\ min\ major - LAeq{,}15\ min\ minor \end{gathered} \quad (1)$$

$$\begin{gathered} Spatial\ acoustic\ gradient = \\ = |LAeq{,}15\ min2 - LAeq{,}15\ min1| \ / \\ / \ distance\ between\ nearby\ points\ (km) \end{gathered} \quad (2)$$

Mapping and exploratory evaluation of interpolation

The mapping representations were developed in ArcGIS Desktop 10.x, using ArcMap and the inverse distance weighting (IDW) tool. As spatial

Table 3. Daily weather during the acoustic monitoring campaign

Date	Reference temperature (°C)	Reference relative humidity (%)	Wind during sampling	Precipitation during sampling	Monitoring condition
17-09-2025	21–27	70–90	<5 m/s	Not observed	Compatible
18-09-2025	21–27	70–90	<5 m/s	Not observed	Compatible
19-09-2025	21–27	70–90	<5 m/s	Not observed	Compatible
20-09-2025	21–27	70–90	<5 m/s	Not observed	Compatible
21-09-2025	21–27	70–90	<5 m/s	Not observed	Compatible

Table 4. Maximum permissible limits of environmental noise in the daytime period according to land use

Land use	Daytime 07:01-21:00, LKeq dB(L)
Residential (R1)	55
Social Services Equipment (EQ1)	55
Utility Equipment (EQ2)	60
Commercial (CM)	60
Residential Agricultural (AR)	65
Industrial ID1/ID2	65
Industrial ID3/ID4	70
Multiple use	Apply the lowest limit of the uses that make up the combination.

Note: For sectors with multiple uses or functional combinations, the most restrictive limit between the present uses is adopted.

input, the energy averages of LAeq.15 min corresponding to the six points in morning, noon and afternoon were used. These 18 point-period values were obtained from the 90 monitoring units; The 450 associated records were retained for traceability and verification of calculations, not as 450 spatial locations. According to the geoprocessing record, the original configuration maintained power 2 and variable radius with a maximum of 12 neighbors; As there are six locations, the six available points were used. The extent was defined by the Area_puntos_monitoreo.shp layer, between -80.695277 and -80.681803 longitude and between -0.961763 and -0.955002 latitude.

The cell size was automatically set by ArcGIS from the shortest dimension of the extension divided by 250, which produced a resolution of approximately 0.000027° (about 3 m in the assessed area). The chromatic ramp was inverted to represent the highest acoustic values through warm tones and facilitate the visual interpretation of the areas with the highest sound pressure. Because interpolation was based on six locations, the maps were interpreted as exploratory representations of spatial trends (Li and Heap, 2014; Esri, n.d.; Nasser et al., 2023).

In addition, a post hoc diagnosis was carried out with the original table of coordinates and averages by strip. The IDW equation was applied with Euclidean distances calculated in meters, without barriers and using, in each estimate, the remaining five locations. To examine the sensitivity of the interpolator, powers of 0.5 were evaluated; 1,0; 1,5; 2,0; 2.5 and 3.0; the diagnostic power selected was the one that produced the lowest RMSE, without assuming that this configuration exactly reconstructed the original cartographic raster (Esri, n.d.).

Estimation capacity was examined by cross-validation by exclusion of a location (leave-one-location-out). In each iteration, one of the six points was removed, its LAeq,15 min was estimated with the remaining five points, and the predicted value ($\hat{y}i$) was compared with the observed value (yi). The mean error was calculated, $ME = (1/n)\ \Sigma(\hat{y}i - yi)$; the mean absolute error, $MAE = (1/n)\ \Sigma|\hat{y}i - yi|$; and the root of the mean square error, $RMSE = \sqrt{[(1/n)\ \Sigma(\hat{y}i - yi)^2]}$. This procedure quantified the internal robustness of the available network, but was not interpreted as independent validation or as an exact reconstruction of the original raster. Due to the low spatial density, the maps were used only to visualize general trends within the evaluated polygon (Li and Heap, 2014; Nasser et al., 2023).

Urban acoustic criticality index

To establish a comparative prioritization of the monitoring points, the Urban Acoustic Criticality Index (ICAU) was constructed, conceived as a composite indicator of an operational and exploratory nature. The index integrated dimensions representing magnitude, non-compliance, temporal variability, spatial transition, and functional sensitivity, following the stages of selection, normalization, weighting, and aggregation recommended for the transparent construction of composite indicators (OECD and Joint Research Centre, 2008; Ranjan et al., 2023; Singh et al., 2023).

The ICAU incorporated five components: regulatory exceedance (EN), average sound intensity (IS), temporal amplitude (TA), spatial acoustic gradient (GE) and functional sensitivity of land use (SF). The normative exceedance was calculated as ENi = max(LAeq,i - Li, 0), where LAeq,i corresponds to the average sound level of point i and Li to the applicable daytime limit. The sound intensity corresponded to the average LAeq, 15 min; the temporal amplitude, to the difference between the highest and lowest average of the three bands; and the spatial gradient, to the greatest acoustic change per unit distance associated with the nearby sections of each point. Functional sensitivity was initially coded as commercial = 50, public equipment = 75, and social equipment = 100.

To make the components comparable, EN, IS, AT, GE and SF were transformed to a common scale from 0 to 100 by min-max normalization: Xni = [(Xi - Xmin) / (Xmax - Xmin)] × 100. In the case of functional sensitivity, this transformation produced normalized values of 0 for commercial use, 50 for public equipment, and 100 for social equipment. The procedure avoids directly adding variables expressed in different units and ranges and allows interpreting the relative contribution of each dimension within the set of points analyzed (OECD and Joint Research Centre, 2008).

The initial operational scenario assigned the weights 0.30 to EN, 0.20 to IS, 0.20 to AT, 0.15 to GE and 0.15 to SF, so that ICAU = 0.30(ENn) + 0.20(ISn) + 0.20(ATn) + 0.15(GEn) + 0.15(SFn). This structure prioritized regulatory non-compliance and was retained as a reference for sensitivity analysis. The classification adopted was low (<25), medium (25–49.9), high (50–74.9), and very high (≥75). The operationalization of the components and weights of the initial scenario is summarized in Table 5.

AHP weightings

The hierarchical analytical process organized the five components of the ICAU in a structure of peer comparisons, following the principles of Saaty (1980). The selection of the judgments was based on a history of hierarchical evaluation of urban noise and multi-criteria prioritization of acoustic actions, in which the sound magnitude is integrated with land use, the sensitivity of the receiver and other territorial conditions (Abbaspour et al., 2015; Ruiz-Padillo et al., 2014, 2016), the result was interpreted as a methodological contrast to the initial operational scheme.

The hierarchy adopted was EN > SF > IS > AT > GE. Regulatory leave of absence received the highest priority because it directly expresses the distance from the applicable legal limit; Functional sensitivity occupied the second position because the same acoustic level does not represent the same criticality in commercial areas, public facilities and sensitive social spaces. Sound intensity was considered the direct physical descriptor, while temporal amplitude and spatial gradient were incorporated as complementary dimensions. The gradient received the least relative importance due to its dependence on a spatial network limited to six locations and the exploratory nature of the cartography.

Based on this hierarchy, a reciprocal matrix of order 5 × 5 was formulated using the fundamental comparison scale of the AHP (Table 6). The priority vector was obtained from the normalized principal eigenvector. Mathematical coherence was verified by the consistency index and the consistency ratio:

$$CI = (\lambda max - n) / (n - 1) \quad (3)$$

$$CR = CI / RI \quad (4)$$

For five components, RI = 1.12 was adopted and CR < 0.10 was established as a criterion of acceptable consistency. The weights obtained were applied to the same standardized components of the initial operational scenario. Subsequently, the values, categories and the order of the six points

Table 5. Components and weighting of the base scenario of the Urban Acoustic Criticality Index (ICAU)

Component	Operationalization	Base weight
Regulatory leave of absence	ENi = max(LAeq,i - Li, 0), where Li is the applicable diurnal limit according to land use.	0.30
Sound Intensity (IS)	The average LAeq,15min recorded at each monitoring point.	0.20
Temporal amplitude (TA)	ATi = max(LAeq,i,t) - min(LAeq,i,t), considering morning, noon and afternoon.	0.20
Spatial gradient (GE)	GEij = |LAeq,i - LAeq,j| / dij; The largest gradient associated with the sections near the point is used.	0.15
Functional sensitivity (FS)	Initial coding: commercial = 50, public equipment = 75 and social equipment = 100; Final Min-Max normalization: 0, 50 and 100.	0.15
ICAU classification	Down <25; mean 25-49.9; high 50-74.9; very high ≥75.	-

were compared; concordance between hierarchies was evaluated using Spearman's correlation of ranks. This contrast was incorporated as an additional test of the robustness of the weighting scheme, in accordance with the recommendations of transparency and sensitivity for composite indicators (OECD and Joint Research Centre, 2008; Saisana et al., 2005).

ICAU sensitivity and robustness analysis

The internal robustness of the ICAU was examined using 19 deterministic scenarios built with the same component base: the base scenario; a scenario of equal weights (0.20 per component); ten scenarios obtained by individually increasing or reducing the weight of each component by 20%, with proportional readjustment of the remaining weights to maintain a sum equal to one; five scenarios of successive elimination of each component, with renormalization of the remaining weights; and two alternative functional sensitivity scales (50-75-100 and 25-50-75). In addition, the classification thresholds were shifted by ±5 points to assess the stability of the categories. The inclusion of alternative scenarios responds to the recommendation to evaluate how weighting and scale decisions condition the results of a composite indicator (Saisana et al., 2005; OECD and Joint Research Centre, 2008; Saltelli et al., 2008). In a complementary way, the AHP technical-documentary scenario was analyzed separately as a methodological contrast of the operational weighting, without including it in the count of the 19 scenarios.

For each scenario, the ICAU, the category and the six-point range were recalculated. The concordance of the order of priority with the base scenario was estimated using Spearman's correlation of ranks; The permanence of each point between the first three positions and the interval of variation of its values and ranges were also determined. Due to the small number of points, the procedure was interpreted as a deterministic test of internal stability and not as an external validation of the index. For the AHP scenario, the correlation of ranges with respect to the initial operational scenario was also calculated and the changes in category and position were recorded.

ICAU internal temporal validation

To assess the temporal generalization capacity of the ICAU with data not used simultaneously in each estimate, a cross-validation was applied by exclusion of one day (leave-one-day-out). In each of the five iterations, the 18 units corresponding to a date were reserved as a validation sample and the min–max normalization parameters were calculated with the 72 units of the remaining four days. The same weights of the base scenario were applied later to the excluded day, without recalibrating the index with the validation data.

For each iteration, the order of the six points obtained with the training set was compared with the order produced by the reserved day. The exact correlation of Spearman ranks, the conservation of the first three positions, and the rank changes of P3, P4, and P6 were calculated. The procedure was interpreted as internal temporary validation by reservation, because the excluded day did not intervene in the corresponding estimate, although it belonged to the same corridor and the same campaign. Its purpose was to check the stability of the hierarchy outside the calculation sample of each iteration, without confusing it with the AHP justification or sensitivity analysis (Field, 2018; OECD and Joint Research Centre, 2008).

Statistical analysis

The inferential analysis was performed on the 90 units of LAeq,15 min obtained by

Table 6. Pairwise comparison matrix of the AHP technical-documentary scenario

Criteria	PT	IS	AT	GE	Shadow fiend
PT	1	2	3	4	2
IS	1/2	1	2	2	1/2
AT	1/3	1/2	1	2	1/2
GE	1/4	1/2	1/2	1	1/3
Shadow fiend	1/2	2	2	3	1

Note: EN: regulatory leave of absence; IS: sound intensity; TA: temporal amplitude; GE: spatial gradient; SF: functional sensitivity. Reciprocal values represent the inverse preference between criteria.

energy average. Means, medians, standard deviations, and ranges were calculated. Normality and homogeneity were assessed using Shapiro–Wilk and Levene. Subsequently, an exploratory factorial ANOVA was applied to examine the effects of the point, the period and their interaction, using the five days as temporal repetitions. Due to the heterogeneity between points, the results were contrasted with Kruskal–Wallis tests by point and period. $\alpha = 0.05$ was adopted and a prudent interpretation was maintained in accordance with the observational nature of the study (Field, 2018).

RESULTS

Acoustic monitoring points

Figure 3 shows the spatial location of the acoustic monitoring points established in the evaluated urban corridor, with a strategic distribution over sectors with high mobility, presence of urban facilities, commercial activity and constant vehicular flow. Points P1, P2, P3, P4, P5 and P6 were located in such a way as to cover different conditions of the environment, from areas near main roads and consolidated areas to sectors close to relevant infrastructures.

Regulatory compliance with sound pressure levels

Table 7 shows that all acoustic monitoring points do not comply with the applicable daytime regulatory limit, registering $L_{Aeq,15\,min}$ values between 82.1 and 87.3 dB(A). The highest average sound pressure level was presented at the Black White Hostel with 87.3 dB(A), followed by the Conserva y Saber Association Court with 86.6 dB(A) and Plaza Oliva with 86.0 dB(A). Although the Transit Agency recorded the lowest value, with 82.1 dB(A), it also far exceeded the permitted limit. The most critical case for regulatory exceedance corresponds to the Conserva y Saber Association Court, due to the fact that, having a more restrictive limit of 55 dB(A), it presented an excess of 31.6 dB(A). The results reflect a condition of high acoustic pressure throughout the urban corridor evaluated, mainly associated with vehicular mobility, concentration of users and functional dynamics of the facilities present.

Statistical analysis of sound pressure levels

The statistical analysis of the 90 monitoring units, presented in Table 8, did not show a significant overall deviation from normality ($p = 0.189$), although it did show heterogeneity between points

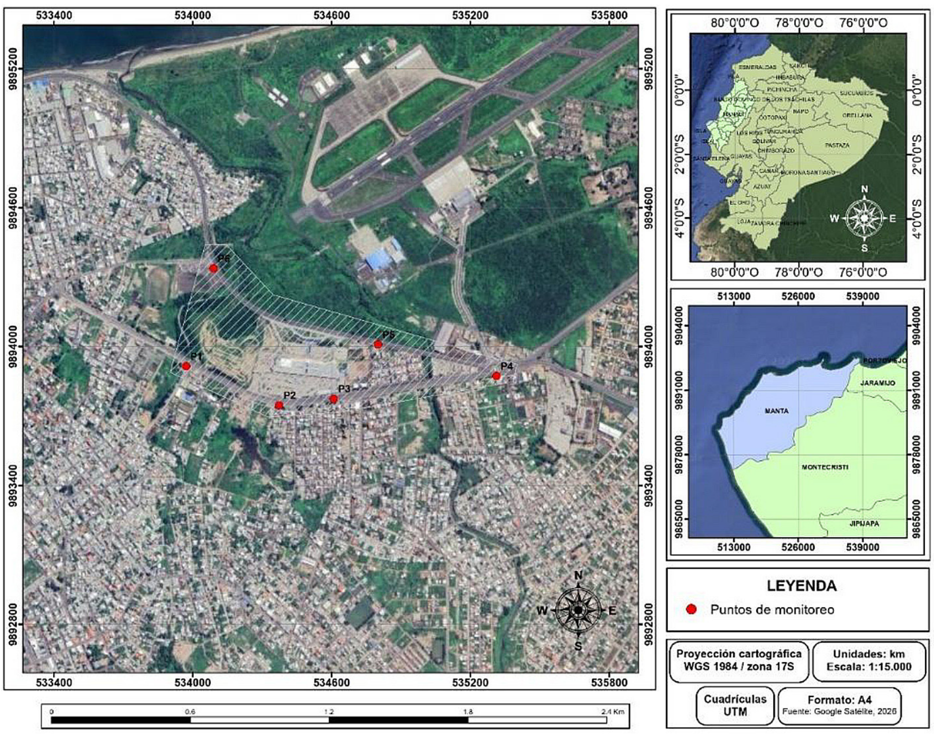

Figure 3. Spatial location of the acoustic monitoring points in the urban corridor evaluated

(p = 0.006). ANOVA confirmed significant effects of point, period and their interaction ($p < 0.001$ in all three cases). The Kruskal–Wallis tests confirmed differences by point ($p < 0.001$) and by period (p = 0.019). Overall, the results indicate that the sound pressure is location-dependent and that the time pattern is not reproduced in the same way at all sites.

Spatiotemporal dynamics of urban noise

Table 9 shows that the temporal variation was not homogeneous between the points. The greatest amplitude was recorded in P5, with 9.21 dB(A), due to the difference between the afternoon (89.99 dB(A)) and noon (80.78 dB(A)). P1 and P6 presented amplitudes of 6.54 and 6.11 dB(A), while P3 registered the least variation, with 1.37 dB(A). The displacement of the point of greatest sound pressure between the three periods is summarized in Table 10.

As shown in Table 10, the critical point did not remain fixed: in the morning it was located at the Redondel La Barca, at noon at the Hostal Black White and in the afternoon at the Cancha Asociación Conserva y Saber. This displacement shows that the acoustic pressure is redistributed according to mobility, commerce, permanence and functional use of the urban space.

Table 11 shows that the sound intensity presented differentiated spatial changes between the evaluated sections of the urban corridor. The highest acoustic gradients were recorded between P2-P1 (11.95 dB/km) and P6-P3 (8.90 dB/km), evidencing significant increases in sound levels over relatively short distances, suggesting the influence of changes in traffic intensity, road configuration and urban activities present in these sectors. In contrast, the P1-P5 (2.31 dB/km) and P5-P4 (2.37 dB/km) sections showed reduced gradients, indicating a more uniform acoustic transition between consecutive points. These results show that the spatial distribution of noise is not homogeneous, but responds to the functional and mobility characteristics of each segment of the urban corridor.

Acoustic mapping of the urban corridor

Figure 4 shows that the six points of the corridor registered high sound pressure levels in the three time slots, so that the surfaces are predominantly concentrated in the upper classes of the legend. During the morning, the highest punctual values were associated with P4 and P3; at noon, the maximum corresponded to P1; and in the afternoon, P5. The representation allows the hourly

Table 7. Daytime regulatory compliance by monitoring point

Site	LAeq,15 min dB(A)	Limit dB(A)	Status
Land Terminal	84.4	60.0	Not compliant
Hostal Black White	87.3	60.0	Not compliant
Plaza Oliva	86.0	60.0	Not compliant
Transit Agency	82.1	60.0	Not compliant
Conserva y Saber Association Court	86.6	55.0	Not compliant
La Barca Rodonor	85.3	60.0	Not compliant

Table 8. Statistical synthesis of acoustic variation by point and time slot

Analysis	Result	Interpretation
Normality of 90 units	Shapiro–Wilk = 0.980; p = 0.189	No significant overall deviation from normal was detected.
Homogeneity by point	Levene = 3.489; p = 0.006	Homogeneity between points was not met.
Homogeneity by period	Levene = 0.228; p = 0.796	Homogeneity was maintained between periods.
ANOVA: dot effect	F(5.72) = 32.260; p < 0.001	Spatial differences were confirmed.
ANOVA: Period Effect	F(2.72) = 26.802; p < 0.001	Temporal differences were confirmed.
ANOVA: Point×period interaction	F(10.72) = 28.786; p < 0.001	The time variation depended on the point.
Kruskal–Wallis by point	H = 21,938; p < 0.001	The robust contrast confirmed spatial differences.
Kruskal–Wallis by period	H = 7.929; p = 0.019	Robust contrast confirmed temporal differences.

Table 9. Time amplitude of noise per monitoring point

Point	Site	Longer period	The largest	Shorter period	The smallest	Breadth
P1	Hostal Black White	Noon	89.93	Morning	83.39	6.54
Q2	Land Terminal	Noon	85.81	Morning	79.87	5.94
Q3	Plaza Oliva	Afternoon	86.65	Morning	85.28	1.37
Q4	La Barca Rodonor	Morning	86.54	Noon	84.39	2.15
Q5	Conserva y Saber Association Court	Afternoon	89.99	Noon	80.78	9.21
Q6	Transit Agency	Noon	84.95	Afternoon	78.84	6.11

Table 10. Displacement of critical areas according to time slot

Time slot	Critical point	Site	LAeq,15 min dB(A)
Morning	Q4	La Barca Rodonor	86.54
Noon	P1	Hostal Black White	89.93
Afternoon	Q5	Conserva y Saber Association Court	89.99

redistribution of the values within the polygon to be visualized, but the transitions between points must be interpreted as spatial approximations conditioned by the availability of six locations.

Exploratory assessment of IDW interpolation

Table 12 summarizes the evaluation by exclusion of a location. The comparison of the powers showed that $p = 0.5$ produced the lowest RMSE in the three bands: 3.05 dB(A) in the morning, 3.33 dB(A) at noon and 4.00 dB(A) in the afternoon. The EM remained close to zero, but absolute errors showed difficulties in reproducing local extremes, especially P1 and P5 at noon and P6 during the afternoon.

The results show that the network reproduces the general patterns of the morning and noon with greater stability, while the afternoon presents the greatest uncertainty, associated with pronounced local contrasts between P5 and P6. Therefore, mapping is useful for communicating the relative distribution and time shift of areas of higher sound pressure.

Urban acoustic criticality and point prioritization

Table 13 presents the results of the ICAU base scenario. Unlike a reading based exclusively on the average LAeq, the indicator combined normative exceedance, sound intensity, temporal amplitude, spatial gradient and functional sensitivity. The baseline scenario identified P5 as the point of greatest criticality, followed by P1 and P2.

Weighting of the ICAU by AHP

The pairwise comparison matrix produced a maximum eigenvalue of $\lambda max = 5.0848$, a consistency index of $CI = 0.0212$, and a consistency ratio of $CR = 0.0189$. Because the latter was less than 0.10, the comparisons maintained satisfactory

Table 11. Spatial acoustic gradient between nearby points

Section	Spatial reference	Distance (km)	LAeq (dB)	Gradient dB/km
P6-P3	Transit Agency - Plaza Oliva	0.44	3.90	8.90
P3-P2	Plaza Oliva - Terminal Terrestre	0.44	-1.57	3.60
P2-P1	Terminal Terrestre - Hostal Black White	0.24	2.84	11.95
P1-P5	Hostal Black White - Cancha Asociación Conserva y Saber	0.30	-0.70	2.31
P5-P4	Conserva y Saber Association Court - Redondel La Barca	0.53	-1.25	2.37

Note: The highest gradients were observed in the P2-P1 and P6-P3 sections, indicating marked acoustic transitions over short distances.

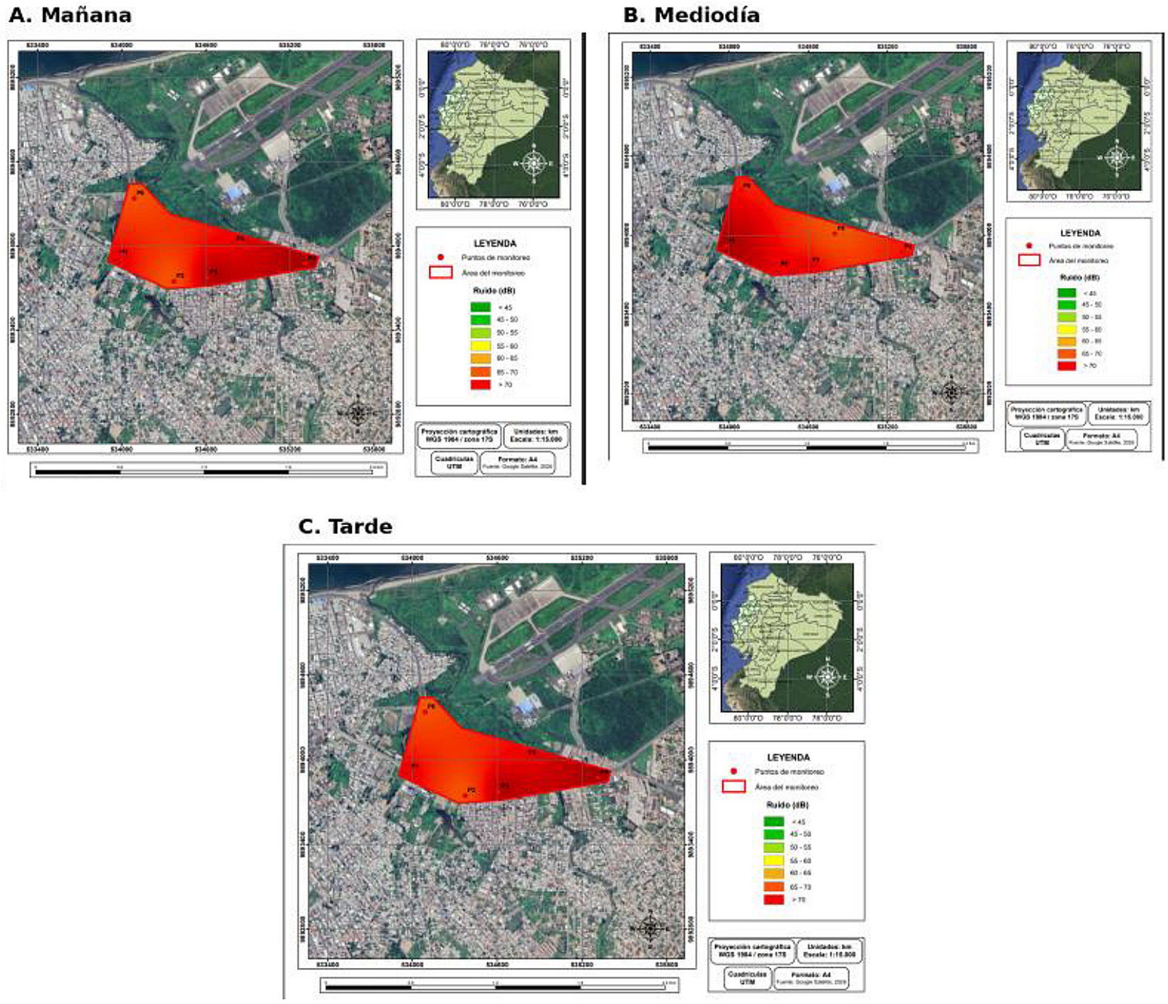

Figure 4. Exploratory cartographic representation of urban environmental noise by time slot using IDW interpolation

Table 12. Cross-validation diagnosis by excluding a location for IDW interpolation

Strip	Power	ME dB(A)	MAE dB(A)	RMSE dB(A)	Highest absolute error
Morning	0.5	-0.13	2.69	3.05	3.99 dB(A), P4
Noon	0.5	0.12	2.26	3.33	5.71 dB(A), P5
Afternoon	0.5	0.19	2.79	4.00	7.77 dB(A), P6

Note: The power was selected between 0.5 and 3.0 using the lowest RMSE. The error was calculated as predicted value minus observed value. In each iteration, the remaining five locations were used, without barriers and with Euclidean distance in WGS 1984/UTM zone 17S.

mathematical consistency. The normalized eigenvector assigned a weight of 0.3748 to the normative exceedance, 0.2494 to functional sensitivity, 0.1748 to sound intensity, 0.1215 to temporal amplitude, and 0.0796 to the spatial gradient.

Consequently, the technical-documentary scenario was expressed as ICAU-AHP = 0.3748(ENn) + 0.1748(ISn) + 0.1215(ATn) + 0.0796(GEn) + 0.2494(SFn). Compared to the initial operational scheme, the contribution of regulatory excess and functional sensitivity increased, while the influence of temporal amplitude and spatial gradient decreased. This redistribution was consistent with the technical-regulatory nature of the index and with the need not to oversize a spatial variable derived from a reduced monitoring network.

The application of the AHP weights kept P5 as the point of greatest criticality, with 89.69 points, followed by P1 with 53.96 and P2 with 44.31. P4, P3 and P6 reached 37.06, 33.92 and

Table 13. Urban Acoustic Criticality Index by monitoring point in the base scenario

Point	Site	Exceeds. dB(A)	LAeq dB(A)	Amp. dB(A)	Grad. dB/km	ICAU	Class
Q5	Conserva y Saber Association Court	31.6	86.6	9.21	2.37	82.3	Very high
P1	Hostal Black White	27.3	87.3	6.54	11.95	64.6	High
Q2	Land Terminal	24.4	84.4	5.94	11.95	50.3	High
Q3	Plaza Oliva	26.0	86.0	1.37	8.90	37.5	Media
Q4	La Barca Rodonor	25.3	85.3	2.15	2.37	31.9	Media
Q6	Transit Agency	22.1	82.1	6.11	8.90	29.8	Media

Note: Values corresponding to the base scenario: EN = 0.30; SI = 0.20; AT = 0.20; GE = 0.15; SF = 0.15. The five components were normalized by min-max. Rating: low (<25), medium (25–49.9), high (50–74.9) and very high (≥75).

25.23 points, respectively. The comparative results are presented in Table 14.

The correlation of Spearman ranges between the operational scenario and the AHP scenario was ρ = 0.943, which evidenced a very high agreement. The first three positions retained the order P5–P1–P2; the changes were limited to the exchange of P3 and P4 in the intermediate ranges and the reclassification of P2 from high to medium criticality. Therefore, the main inference of prioritization did not depend exclusively on the initial operational weights.

Robustness of the ICAU in the face of alternative scenarios

Table 15 summarizes the stability of the ICAU in the 19 scenarios. P5, P1 and P2 retained, respectively, positions 1, 2 and 3 in 100% of the scenarios. Spearman's correlations with the baseline scenario ranged from 0.829 to 1.000. The variations were concentrated in P3, P4 and P6, which swapped positions between ranks 4 and 6 without entering the top three priorities.

The categories were less stable than the order of priority at the points close to the thresholds. P5 remained very high in 18 of 19 scenarios, P1 as high in 18 of 19 and P2 as high in 15 of 19. P3 retained the medium category in all scenarios. The alternative functional sensitivity scales fully maintained the order P5-P1-P2-P3-P4-P6 and the categories of the base scenario. Shifting the thresholds by -5 points did not change; with 5-point stricter thresholds, P2 went from high to medium and P6 from medium to low, while P5 and P1 retained their categories. Consequently, the central inference was mainly based on the stability of the range and not only on the discrete category.

ICAU internal temporal validation

Internal leave-one-day-out time validation confirmed that the primary priority was not dependent on a particular date. In the five iterations, the practice set and the reserved day maintained the P5–P1–L2 order in the first three positions. The exact Spearman correlations between the two orders were 0.943 or 1.000, with exact p-values between 0.017 and 0.003. The only changes occurred between P3, P4 and P6, without affecting the priority group. The results are presented in Table 16.

This evidence demonstrated temporal stability within the corridor and confirmed that the

Table 14. Comparison of the operational ICAU and the AHP technical-documentary scenario

Point	Site	Operational ICAU	ICAU-AHP	AHP class	AHP range
Q5	Conserva y Saber Association Court	82.31	89.69	Very high	1
P1	Hostal Black White	64.61	53.96	High	2
Q2	Land Terminal	50.27	44.31	Media	3
Q4	La Barca Rodonor	31.90	37.06	Media	4
Q3	Plaza Oliva	37.54	33.92	Media	5
Q6	Transit Agency	29.82	25.23	Media	6

Note: ICAU classification: low (<25), medium (25–49.9), high (50–74.9), and very high (≥75).
Operational values are displayed to two decimal places for comparability with AHP recalculation.

main hierarchy did not depend on a particular matchday. Because the booked dates belonged to the same runner and the same campaign, the procedure was interpreted as internal validation by booking. Its function was to complement, and not replace, the justification of the weights by AHP and the sensitivity analysis of the 19 scenarios.

Table 17 presents the technical-acoustic prioritization derived from the instrumental results and the ICAU. P5 maintains a very high priority due to its leave of absence, length of time and sensitive social function; P1 and P2 reach high priority due to the combination of intensity, exceedance and gradients. This hierarchy is interpreted exclusively as a priority for acoustic intervention and not as a nuisance measure perceived by the population.

Implications for urban acoustic management

Tables 18 and 19 summarize the implications and management measures derived from technical-acoustic prioritization. The proposals do not constitute a definitive plan, but initial guidelines that must be submitted to technical feasibility, institutional coordination, acoustic monitoring and subsequent evaluation of results.

DISCUSSION

In urban corridors where public transport, motorcycles, commerce, pedestrian circulation and citizen service facilities converge, environmental noise acquires a condition of daily and cumulative exposure. The World Health Organization considers environmental noise, especially that associated with land transport, as a relevant risk factor for public health due to its effects on discomfort, sleep, well-being and cardiovascular disease (World Health Organization Regional Office for Europe, 2018). Along the same lines, recent epidemiological evidence has reinforced that transport noise can activate stress responses, alter rest, and contribute to cardiovascular processes through physiological mechanisms related to inflammation, vascular dysfunction, and circadian rhythm disruption (Münzel et al., 2024). Therefore, the sustained exceeding of daytime thresholds should not be read only as an environmental non-compliance, but as an urban condition that demands preventive management.

From a territorial perspective, the convergence of surpluses in commercial sectors, transport nodes and public facilities suggests that

Table 15. Stability of the ICAU in 19 weighting and scale scenarios

Point	Base ICAU	ICAU Interval	Base/Observed range	Top 3 (%)	Most frequent class
Q5	82.3	74.7-96.8	1 / 1-1	100	Very high (18/19)
P1	64.6	55.7-75.9	2 / 2-2	100	Added (18/19)
Q2	50.5	41.8-61.6	3 / 3-3	100	Added (15/19)
Q3	37.6	28.2-47.0	4 / 4-5	0	Medium (19/19)
Q4	32.1	24.6-37.8	5 / 4-6	0	Medium (18/19)
Q6	29.8	22.1-42.5	6 / 4-6	0	Medium (17/19)

Note: The ICAU interval and the observed range summarize the minimum and maximum obtained in the 19 scenarios. Top 3 indicates the percentage of scenarios in which the point remained in the top three positions. The most frequent class is accompanied by the number of scenarios in which it was observed.

Table 16. Internal temporary validation of the ICAU by successive exclusion of one day

Reserved day	Spearman's ρ	Exact P	Top 3 in validation	Change outside the top 3
17-09-2025	0.943	0.017	P5–P1–P2	P4 and P3 swap ranks 4–5
18-09-2025	0.943	0.017	P5–P1–P2	P6 and P4 swap ranks 5–6
19-09-2025	1.000	0.003	P5–P1–P2	No changes
20-09-2025	0.943	0.017	P5–P1–P2	P6 and P4 swap ranks 5–6
21-09-2025	1.000	0.003	P5–P1–P2	No changes

Note: In each iteration, the normalization parameters were obtained with four days and were applied without recalibration to the reserved date. The exact p was calculated on the six possible positions in the ranking.

Table 17. Technical-acoustic prioritization of critical areas based on instrumental evidence and ICAU

Point	Acoustic evidence	ICAU	Priority	Management criteria
P5 Conserva y Saber Association Court	Higher regulatory exceedance (31.6 dB(A)), longer time extension (9.21 dB(A)) and critical point during the afternoon.	82.3	Very high	Protection of social facilities, control of noisy activities, hours of use and plant barriers.
P1 Hostal Black White	Higher LAeq, 15min average (87.3 dB(A)) and high gradient associated with the P2-P1 section.	64.6	High	Road and commercial noise control; protection measures in lodging and permanence areas.
P2 Land Terminal	Sustained surplus, function of public transport equipment and high gradient associated with the P2-P1 section.	50.3	High	Operational management of the terminal, ordering of buses/taxis and control of horns and engines on.
P3 Plaza Oliva	Regulatory exceedance and relevant spatial gradient with respect to P6.	37.5	Media	Control of commercial sources, local transit, loading/unloading and loudspeakers.
P4 La Barca Roundabout	Critical point in the morning and daytime regulatory leave.	31.9	Media	Traffic flow ordering, speed control and noise reduction by motorcycles/horns.
P6 Transit Agency	Sustained regulatory leave and relevant spatial gradient towards Plaza Oliva.	29.8	Media	Acoustic signaling, horn control, temporary parking and periodic monitoring.

Table 18. Management implications by scale of acoustic intervention

Type of measurement	Proposed action	Application in the urban corridor	Expected result
Mobility Management	Implement speed control, controlled noise zone signage, regulation of the use of horns and ordering of taxis, buses and motorcycles.	Land Terminal, La Barca Roundabout, Transit Agency and connection roads.	Reduction of intense sound events and better organization of vehicular flow.
Mobile Font Control	Strengthen operations on motorcycles with modified exhausts, noisy public transport and vehicles with poor maintenance.	High traffic points and accesses to the terminal.	Decrease in sound pressure peaks and recurring sources of ambient noise.
Commercial and community management	Regulate loudspeakers, loudspeakers, loudspeakers, noisy commercial activities and loading/unloading schedules.	Plaza Oliva, Hostal Black White and nearby commercial sectors.	Reduction of non-vehicular noise and better urban coexistence.
Urban interventions	Incorporate plant barriers, edge trees, less reflective surfaces and acoustic buffer zones in spaces where they stay.	Conserva y Saber Association Court, waiting areas and road edges.	Partial mitigation of acoustic exposure and improvement of environmental comfort.
Institutional management	Coordinate actions between environmental authority, traffic, commerce and administration of public facilities.	Points with very high and high priority according to ICAU.	Sustained implementation of corrective and preventive measures.
Monitoring and planning	To update measurements, noise maps and acoustic criticality indicators every six months, incorporating them into municipal urban planning.	The entire Terminal-El Palmar-Tohallí-Transit Agency corridor.	Monitoring of critical areas and evidence-based decision-making.

noise pollution is not distributed accidentally, but rather accompanies the functional intensity of the space. Transportation areas, road nodes, and commercial edges often concentrate mobile sources and intermittent activities that raise the equivalent sound level and generate episodes of higher sound pressure. Vehicular traffic is recognized as one of the most widespread sources of urban noise, both because of its spatial permanence and because of its relationship with work activities, mobility and access to services (McAlexander et al., 2015; Welch et al., 2023).

The variation in sound pressure levels between time slots shows that urban corridors function as dynamic systems, in which the start of activities, the concentration of users, intermediate journeys and the return to work modify the acoustic pressure. Lan et al. (2020) argue that static maps are insufficient to represent the variation in traffic noise in different periods, which justifies the need to incorporate spatiotemporal readings. In the present study, the displacement of the critical point between morning, noon and afternoon confirms that the acoustic exposure does

Table 19. Indicative measures according to priority monitoring point

Prioritized point	Dominant problem	Recommended specific measures
P5 Conserva y Saber Association Court	Greater regulatory exceedance, high temporal variability and sensitive social/recreational function.	Define schedules of activities, avoid prolonged noisy events, reinforce perimeter trees, evaluate plant barriers and promote community agreements of sound coexistence.
P1 Hostal Black White	Higher LAeq, 15min average and commercial/road activity nearby.	Control of road sources, reduction of loudspeakers, punctual plant barriers and recommendations for acoustic conditioning on sensitive facades.
P2 Land Terminal	Public transport, concentration of users and vehicular operations.	Orderly waiting areas, control of engines on, internal bus/taxi routes, signage of no use of horn and operational inspection.
P3 Plaza Oliva	Commercial activity, local traffic and acoustic transition with respect to nearby points.	Regulate speakers and loading/unloading, promote orderly mobility and maintain monitoring in high activity slots.
P4 La Barca Roundabout	Continuous vehicular flow and morning critical point.	Speed control, traffic improvement, road maintenance, reduction of braking/acceleration and monitoring at peak hours.
P6 Transit Agency	Sustained regulatory leave and relevant spatial gradient towards Plaza Oliva.	Signaling of no use of horn, control of motorcycles, temporary parking order and periodic monitoring of the P6-P3 section.

not remain fixed, but is redistributed according to the dynamics of mobility and use of the space.

In addition, the gradients between nearby points show that acoustic exposure can change over short distances depending on the road configuration, the type of activity and the permanence of people. This condition is important because it avoids assuming that a single critical point represents the entire corridor or that the intervention should be concentrated only where the highest average appears. The literature on urban acoustic planning insists that sound should be analysed together with urban morphology, ground function and mobility patterns, given that these elements influence the propagation and concentration of noise (Margaritis and Kang, 2016; Montenegro et al., 2024).

Noise maps make it possible to visualise concentration patterns and relate the levels recorded to urban uses; however, their estimation capacity depends on the density and distribution of the points. Li and Heap (2014) point out that the selection and evaluation of an interpolator must respond to the objective of the analysis and the sample structure, while Esri (n.d.) warns that a scarce or irregular sampling may not adequately represent the surface. In this study, post hoc cross-validation produced RMSE between 3.05 and 4.00 dB(A). The best performance was obtained with a low power ($p = 0.5$), which favored a smoothed surface; however, the maximum errors of 5.71 dB(A) at noon and 7.77 dB(A) in the afternoon show that the local extremes are not accurately reproduced by a six-point network. Consequently, maps are interpreted as illustrative tools to recognize relative trends and guide future campaigns, not as robust predictive models or as substitutes for measurements in unsampled areas (Nasser et al., 2023).

Instrumental and meteorological control provides additional traceability to the interpretation of the results. The stability of the verifications at 94.0 dB, the maximum drift of 0.1 dB and the expanded operational uncertainty of ±0.7 dB indicate that the variation associated with the measurement system is reduced compared to the regulatory exceedances of 22.1 to 31.6 dB(A). Also, the exclusion of periods with rain and wind greater than 5 m/s decreased the risk of aerodynamic interference on the microphone. Although meteorological data correspond to a contextual reference and not to a station installed at each point, their incorporation makes it possible to document the general conditions of the campaign and delimit this source of uncertainty (ISO, 2017; JCGM, 2008).

The ICAU is an applied contribution because it avoids depending on a single criterion to decide where to intervene. The stability of P5, P1, and P2 across the 19 scenarios, with Spearman correlations between 0.829 and 1.000, shows that the primary priority does not depend on a single weight setting. This evidence was reinforced by the AHP technical-documentary scenario, whose correlation of ranges with the operational scheme was 0.943 and which preserved the order P5–P1–P2. The greater weighting of normative exceedance and functional sensitivity especially strengthened the priority of P5, while the reduction of the weight of the spatial gradient limited the influence of a variable dependent on a network of six locations. Together, sensitivity, AHP contrast, and temporal validation allow differentiating a structural priority from minor variations at midrange points (Saisana et al., 2005; OECD and Joint Research Centre, 2008).

Sensitivity analysis and temporal validation responded to different methodological problems and were interpreted in a complementary manner. The AHP provided an explicit and verifiable justification for the weightings; The 19 scenarios quantified the sensitivity of the index to changes in weights, scales, components and thresholds; and the leave-one-day-out procedure evaluated the stability of the hierarchy between days. This separation avoided presenting a single piece of evidence as sufficient evidence for all of the index's attributes. Overall, the results support the coherence and robustness of the ICAU within the corridor studied, although its application to other contexts will need to be tested through new campaigns and broader monitoring networks (Saisana et al., 2005; Saltelli et al., 2008).

Finally, the management implications raised must be understood as a gradual, intersectoral and verifiable response, derived from acoustic prioritization and not as a closed municipal program. International evidence shows that interventions on transport noise can be organized on the source, propagation route, infrastructure and receiver; however, their effectiveness depends on whether they are linked to the dominant problem of each territory and whether they are subsequently evaluated (Brown and van Kamp, 2017). Therefore, the suggested measures are presented as initial criteria to guide control, monitoring and acoustic planning actions at the points of greatest criticality of the corridor.

CONCLUSIONS

Daytime acoustic monitoring showed a high and sustained sound exposure condition in the urban corridor evaluated. The exceedances recorded in the six points indicate that the acoustic problem is not limited to an isolated site, but is expressed as a widespread environmental pressure associated with mobility, commerce, public transport and equipment for collective use.

The pre- and post-measurement verifications confirmed instrumental stability during the 15 sessions, with a maximum drift of 0.1 dB and an expanded operational uncertainty of ±0.7 dB. The reference meteorological conditions were compatible with the monitoring and no episodes of rain or wind greater than 5 m/s were recorded during the evaluated windows. Consequently, even considering uncertainty, the observed exceedances remain technically significant.

Spatiotemporal variability confirmed that urban environmental noise changes according to location and time of day. The differences between points, the variations by time slot, the displacement of critical areas and the spatial gradients allowed us to recognize relevant acoustic transitions within the corridor.

The cartographic representation using IDW provided an exploratory territorial reading of acoustic variation. Post hoc cross-validation showed RMSE of 3.05 to 4.00 dB(A) and showed greater errors in the points with pronounced local contrasts. Therefore, maps allow general trends and time shifts within the corridor to be communicated, but they should not be interpreted as high-resolution predictions or as verified values in sectors without direct monitoring.

The Urban Acoustic Criticality Index made it possible to prioritize the points by integrating regulatory exceedance, intensity, temporal variability, spatial gradient and functional sensitivity. P5, P1 and P2 retained positions 1, 2 and 3 in the 19 sensitivity scenarios, in the five iterations of internal temporal validation and AHP contrast. In the latter, the consistency ratio was 0.0189 and the agreement with the operational scenario reached $\rho = 0.943$. This convergence supports the consistency of the weightings, the robustness against alternative scenarios and the temporal stability of the ICAU within the corridor. Their extrapolation to other corridors requires new independent applications and denser spatial networks.

The management implications derived from the study should be oriented towards the control of mobile sources, the management of speed and horns, the ordering of public transport, the regulation of noisy commercial activities, the incorporation of damping elements and periodic acoustic monitoring. These actions should be interpreted as initial technical criteria for the urban environmental management of the corridor, subject to institutional validation and monitoring.

DATA AVAILABILITY AND TRACEABILITY

Supplementary Material S1 contains the 450 analytical records associated with the 90 monitoring units, with date, point, period, record number, coordinates, regulatory limit and provenance. The inferential analyses of the article were performed on the 90 units added energetically. ICAU coordinates, IDW parameters, spatial cross-validation, instrumental verifications, reference meteorological conditions, and temporal validation are described in the manuscript and its tables. The traceability of the associated records should be preserved when depositing the supplementary material together with the revised version.

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