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SPPAT-Recorded Road-Traffic Fatalities in Ecuador, 2016–2021: Denominator Audit, Rate Uncertainty and Typology Indeterminacy as Proposition-Based Evidence Coordinates

Muertes por accidentes de tránsito registradas por SPPAT en Ecuador, 2016–2021: Auditoría del denominador, incertidumbre de la tasa e indeterminación tipológica como coordenadas de evidencia basadas en proposiciones

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Abstract. Administrative registries of road-traffic deaths support territorial comparison only when their denominators, periods and missing values are audited. This study reanalysed the 16,526 records of victims registered by Ecuador's Public Service for Traffic Accident Payments (SPPAT) for fatal protection coverage (24 provinces; 208 territorial labels, many of them cantonal capitals rather than canton names). Every figure of the original analysis was reproduced: 1,767 records in Quito and 1,398 in Guayaquil; 163 DESCONOCIDO and 88 empty crash-type values (1.52 %); and, with the authors' denominators, annualised rates of 56.45 per 100,000 in Machachi (Mejía), 49.39 in Naranjal and 47.21 in Yaguachi against 10.79 in Quito and 8.71 in Guayaquil. The denominator audit found that the period used (5.89 years) does not correspond to the registry's creation window (5.64 years) or its crash-date window (5.85 years), that 163 events pre-date 2016, that several denominators are rounded approximations, and that the reported ranking was computed over seventeen selected cantons. Recomputing the rates as person-years from the contemporaneous INEC cantonal projections for 2010–2020, which matched every one of the 16,363 events in the period, Machachi reaches 54.9 per 100,000 per year (95 % Poisson 49.2–61.1) and ranks 6th of 207, behind Amazon and highland cantons such as Loreto, Patate and Colta that the original selection did not consider. Pre-specified rate ratios of the three corridor cantons to Quito and Guayaquil ranged from 4.5 to 6.2 and were robust to the denominator scenario. A documentary check against the published route of the two trunk roads confirms the corridor reading for Machachi, Latacunga, Naranjal and Quevedo and does not confirm it for Yaguachi, Babahoyo or Guano. Typology indeterminacy was analysed as proposition-based evidence coordinates: for each canton and crash type k, T_{ck}, I_{ck} and F_{ck} are the shares of records that assert k, are indeterminate (sentinel or empty), or assert another type; normalisation to one is a design choice here, and no independence is claimed. Indeterminacy propagates into identification bounds on typology rates that are narrow (30.2–31.8 % for run-overs nationally) and are reported separately from the Poisson sampling layer. The chi-square evidence for territorial clustering of indeterminacy survives a permutation test but with 56 % of expected cells below five and a Cramér's V of 0.17 (0.07 after grouping); the corridor membership of the high-rate cantons is asserted, not verified geospatially. Rates are SPPAT-recorded fatality rates, not mortality or risk.

Keywords: road-traffic fatalities; administrative registry; denominator audit; Poisson confidence intervals; partial identification; typology indeterminacy; neutrosophic evidence coordinates; SPPAT; Ecuador

Resumen. Los registros administrativos de muertes por accidentes de tránsito solo permiten la comparación territorial cuando se auditan sus denominadores, períodos y valores faltantes. Este estudio reanalizó los 16,526 registros de víctimas registrados por el Servicio Público de Pagos por Accidentes de Tránsito (SPPAT) de Ecuador para la cobertura de protección por muerte (24 provincias; 208 etiquetas territoriales, muchas de ellas capitales cantonales en lugar de nombres de cantones). Se reprodujo cada cifra del análisis original: 1,767 registros en Quito y 1,398 en Guayaquil; 163 DESCONOCIDO y 88 valores de choque vacío (1.52 %); y, con los denominadores de los autores, tasas anualizadas de 56.45 por 100,000 en Machachi (Mejía), 49.39 en Naranjal y 47.21 en Yaguachi frente a 10.79 en Quito y 8.71 en Guayaquil. La auditoría del denominador reveló que el período utilizado (5,89 años) no se corresponde con la ventana de creación del registro (5,64 años) ni con su ventana de fecha de colapso (5,85 años), que 163 eventos son anteriores a 2016, que varios denominadores son aproximaciones redondeadas y que la clasificación reportada se calculó sobre diecisiete cantones seleccionados. Al recalcular las tasas como persona-años a partir de las proyecciones cantonales contemporáneas del INEC para 2010-2020, que coincidieron con cada uno de los 16.363 eventos del período, Machachi alcanza 54,9 por 100.000 por año (95 % Poisson 49,2–61,1) y se ubica en el sexto lugar de 207, detrás de los cantones amazónicos y de tierras altas como Loreto, Patate y Colta, que la selección original no consideró. Las razones de tasas preespecificadas de los tres cantones del corredor hacia Quito y Guayaquil variaron de 4.5 a 6.2 y fueron robustas al escenario del denominador. Una verificación documental contra la ruta publicada de las dos carreteras principales confirma la lectura del corredor para Machachi, Latacunga, Naranjal y Quevedo y no la confirma para Yaguachi, Babahoyo o Guano. La indeterminación de la tipología se analizó como coordenadas de evidencia basadas en proposiciones: para cada cantón y tipo de choque k, T_ck, I_ck y F_ck son las proporciones de registros que afirman k, son indeterminados (centinela o vacío) o afirman otro tipo; la normalización a uno es una elección de diseño aquí, y no se afirma independencia. La indeterminación se propaga en límites de identificación en tasas de tipología que son estrechos (30.2–31.8 % para atropellos a nivel nacional) y se informan por separado de la capa de muestreo de Poisson. La evidencia de chi-cuadrado para la agrupación territorial de la indeterminación sobrevive a una prueba de permutación, pero con un 56 % de celdas esperadas por debajo de cinco y un V de Cramér de 0,17 (0,07 después de la agrupación); se afirma la pertenencia al corredor de los cantones con altas tasas, pero no se verifica geoespacialmente. Las tasas corresponden a las tasas de fatalidad registradas por el SPPAT, no a la mortalidad ni al riesgo.

Palabras clave: fatalidades por accidentes de tránsito; registro administrativo; auditoría del denominador; intervalos de confianza de Poisson; identificación parcial; indeterminación tipológica; coordenadas de evidencia neutrosófica; SPPAT; Ecuador

1 Introduction

Road-traffic fatalities are a leading external cause of death worldwide and in the Americas [1, 2], and in Ecuador they weigh on every source that records them: the police on-site statistics of the National Transit Agency [4], the vital statistics of INEC [3] and the administrative registry of the Public Service for Traffic Accident Payments (SPPAT), which records victims whose beneficiaries claimed the state's fatal protection coverage. Population-based studies of Ecuadorian road mortality exist for specific road users [5] and for attitudes [6], and the highway-safety literature has long distinguished the crash patterns of interurban corridors from those of urban networks [7, 8]. The SPPAT registry has not been characterised with the same care, and any use of it for territorial comparison depends on three things that are easy to get wrong: the denominator, the period, and the treatment of records whose crash type is unknown.

Administrative registries under-report and misclassify [9, 10], and their missing values are of different kinds: a field can be physically empty, it can hold a sentinel such as DESCONOCIDO that the schema uses for "not known", and the two may be produced by different processes [11, 12, 13]. A first version of this study treated the two kinds together as an indeterminacy share and attached the neutrosophic vocabulary of truth, indeterminacy and falsity to each field, with $T + I + F = 1$ and $F = 0$ by construction [17]. That representation is a completeness ratio with three names rather than three coordinates: F was never observed and I was 1 − T. Neutrosophic Paraconsistent Logic reads favourable evidence, contrary evidence and indeterminacy as separately grounded coordinates [18], the components of a neutrosophic triple need not sum to one [19], and four-valued reasoning distinguishes "told true", "told false", "both" and "neither" [20]; the present version applies that reading to a proposition that can actually be true, indeterminate or false for a record, namely the crash-type assertion, and keeps the sampling uncertainty of rates as a separate layer.

Four research questions are addressed. RQ1: Do the reported counts, shares and rates reproduce from the open file, and are the period and the denominators used for annualised rates valid? RQ2: How do canton rankings and rate ratios change when the period, the denominator source and the set of cantons ranked are corrected, and how precise are the resulting SPPAT-recorded fatality rates? RQ3: How is typology indeterminacy distributed across cantons and years, and does the evidence for its territorial clustering survive an audit of the chi-square assumptions? RQ4, the methodological question for this journal: can typology indeterminacy be represented as proposition-based evidence coordinates and propagated into identification bounds on typology-specific rates, separately from sampling uncertainty, and what does that add over complete-case analysis and over the earlier normalised triple?

Four contributions follow: a full reproduction of the original analysis with a documented denominator and period audit; a corrected, complete canton ranking with exact Poisson intervals, pre-specified rate ratios and a sensitivity denominator; a chi-square assumption audit with a permutation check; and a proposition-based evidence-coordinate representation of typology indeterminacy with identification bounds, compared with complete-case, category and exclusion treatments. No causal mechanism, no crime or risk estimate and no allocation recommendation is claimed.

2 Materials and Methods

2.1 Data source and provenance

The dataset is the open file Víctimas fallecidas por accidentes de tránsito registradas por el SPPAT (identifier DD-SPPAT-FA-01-2021-V01; metadata MD-SPPAT-FA-01-2021-V01; licence CC-BY-4.0; created 22 November 2021; annual update frequency; anonymised) [22]. It contains 16,526 rows and 10 fields: sequence number, victim gender, marital status, road-user condition, date of death, crash type, crash date, canton, province and date of creation of the protection file. The dictionary defines the crash-type field as "detail of the traffic accident" and the canton field as the canton where the accident occurred; the file's canton labels are in many cases the cantonal capital (Machachi for Mejía, Calceta for Bolívar, Puyo for Pastaza, Macas for Morona), which was reconciled to the INEC canton nomenclature through a documented alias table. The registry covers claims filed and processed by the SPPAT; it is not a census of road deaths, and every rate below is a SPPAT-recorded fatality rate, not a mortality or a risk rate.

2.2 Completeness and kinds of missing information

Every field was checked for empty values and for sentinel strings. Two kinds of non-information were kept apart: physical nulls (empty cells) and semantic sentinels (DESCONOCIDO), because they may arise from different recording processes [11, 13]. Dates were parsed and their ranges reported for the crash date, the death date and the file-creation date separately.

2.3 Period and denominators

The original analysis annualised canton counts with a single period Δt and a single population per canton:

$$R_c = \frac{n_c}{P_c\,\Delta t} \times 100\ 000 \qquad (1)$$

The valid exposure for a multi-year count is the sum of person-years, with P_{cy} the population of canton c in year y and e_y the fraction of year y covered by the registry:

$$PY_c = \sum_y P_{cy} e_y, \quad R_c = \frac{n_c}{PY_c} \times 100\ 000 \qquad (2)$$

Four scenarios are compared. A is the authors' scenario (all events, Δt = 5.89 years, the seventeen populations listed in their table). B keeps their populations but restricts the numerator to crash dates in 2016–2021 and sets Δt to the file-creation window (5.64 years). C ranks every canton on one common denominator, the 2026 cantonal projections of INEC's Revision 2024 [27], with Δt equal to the crash-date window ({per['dt_crash_window']:.2f} years); it uses a population five years after the period and is a sensitivity analysis. D applies Eq. (2) itself: person-years are accumulated from the contemporaneous INEC cantonal projections for 2010–2020 [27], with e_y = 1 for 2016–2020, the 2021 population obtained by linear extrapolation of the 2019–2020 increment and e_{2021} = {e2021:.3f} for the part of 2021 covered by the crash-date window. D is the corrected estimate and the one used for the complete ranking; A is kept because it reproduces the original numbers, and B and C isolate the effect of the period and of the denominator source. Cantonal labels of the source were mapped to INEC canton names through a published alias table (the source records the cantonal capital in many cases), and every one of the {n_ev_D:,} events in the period received a denominator.

2.4 Count uncertainty and rate ratios

Exact 95 % Poisson intervals for each rate were obtained from chi-square quantiles of the count [23, 24]:

$$\left[\frac{\chi^2(\alpha/2, 2n_c)}{2P_c\,\Delta t}, \frac{\chi^2(1-\alpha/2, 2n_c+2)}{2P_c\,\Delta t}\right] \times 100\ 000 \qquad (3)$$

The interval quantifies sampling variability of the count under a Poisson model; it does not quantify under-registration, denominator error or identification uncertainty of the crash type. For the comparisons stated in the original analysis (Machachi, Naranjal and Yaguachi against Quito and Guayaquil), rate ratios with log-normal 95 % intervals were computed under scenarios A, C and D:

$$RR = \frac{R_a}{R_b},\ \ exp(\ln RR \pm 1.96\sqrt{\frac{1}{n_a} + \frac{1}{n_b}}) \qquad (4)$$

Rankings of small areas are unstable [25]; the relative width of each interval is reported and shrinkage estimators [26] are left for a future version with yearly denominators.

2.5 Typology indeterminacy as proposition-based evidence coordinates

For canton c and crash type k ∈ {collision, run-over, rollover, fall} the proposition is A_{ck}: "the record's crash type is k". Each record provides evidence for exactly one of three states: it asserts k, it is indeterminate (sentinel or empty), or it asserts another known type, which is contrary evidence for A_{ck}. The canton coordinates are the corresponding shares:

$$T_{ck} = \frac{n_{ck}}{n_c},\ \ I_{ck} = \frac{n_{c,I}}{n_c},\ \ F_{ck} = \frac{n_c - n_{ck} - n_{c,I}}{n_c} \qquad (5)$$

$T_{ck} + I_{ck} + F_{ck} = 1$ by construction, because the three states partition the records of a canton for a given proposition. This normalisation is a design choice made explicit; it does not make T, I and F independent coordinates, and no claim of independence is made. The representation differs from the first version in two respects: F is now observed (records that assert a different type), and I is attached to a proposition that a record can make true or false, not to a field's completeness. Indeterminacy propagates into typology-specific rates as identification bounds [14, 15]: the lower bound assigns no indeterminate record to k and the upper bound assigns all of them to k,

$$R^L{}_{ck} = \frac{n_{ck}}{P_c\,\Delta t} \times 100\ 000 \le R_{ck} \le R^U{}_{ck} = \frac{n_{ck} + n_{c,I}}{P_c\,\Delta t} \times 100\ 000 \qquad (6)$$

so that the width of the identification interval is exactly the indeterminacy rate $n_{c,I}/(P_c\,\Delta t)$ and the bounds are lower and upper probabilities in the sense of a multivalued mapping [16]. Two uncertainty layers are reported separately: the identification interval $[R^L, R^U]$ (semantic layer) and the exact Poisson intervals of each bound (sampling layer); they are not combined, because no validated rule for their combination is available for these data. Three conventional treatments of indeterminate records are compared with the bounds: complete-case analysis, an explicit indeterminate category, and exclusion from the canton denominator.

2.6 Chi-square assumption audit

The original test of canton × indeterminacy independence was reproduced and audited: the number and share of expected cells below five, Cramér's V, a Monte-Carlo permutation p-value (1,000 permutations of the indeterminacy indicator across records), a grouped test pooling cantons with fewer than 100 records, and the year × indeterminacy test. Associations are read as recording-composition differences, not as institutional mechanisms.

2.7 Corridor classification

The original analysis attributed the highest rates to interurban corridors E35 and E25. Corridor membership of each named canton was recorded as asserted by the authors and marked as plausible from public knowledge of the national road network or unsupported; no geospatial verification was performed in this study, and the corridor reading is presented as a hypothesis (Table 6).

2.8 Dashboard and reproducibility

The three-module interactive dashboard of the original version (https://sppat-los-balas.ai.studio/) is retained as an application; its screenshots are moved to Appendix A. All quantities in this paper are produced by one script (analysis/01_reproduce_and_audit.py; Python, pandas, SciPy) from the open CSV and are distributed with the manuscript (RATE_RESULTS.csv, RATE_RATIOS.csv, CANTON_INDETERMINACY.csv, TYPOLO-

GY_EVIDENCE_COORDINATES.csv, TYPOLOGY_RATE_BOUNDS.csv, CORRIDOR_CLASSIFICATION.csv, CHI_SQUARE_ASSUMPTION_AUDIT.json).

3 Results

3.1 Composition and completeness

All 16,526 records had valid dates in the three date fields and complete gender, marital status, condition, canton and province. Crash dates ran from 2014-07-19 to 2021-11-07 and file-creation dates from 2016-04-01 to 2021-11-21; 163 events (0.99 %) pre-date 2016 (7 in 2014, 156 in 2015), not 154 as stated in the first version, whose own Table 2 already gave 163. Male victims were 13,542 (81.94 %), single 11,077 (67.03 %) and married 4,166 (25.21 %); vehicle occupants 11,438 (69.21 %), pedestrians 4,714 (28.52 %) and cyclists (condition BICICLETA) 374 (2.26 %). The crash-type field held 163 DESCONOCIDO sentinels and 88 empty cells, 251 indeterminate records (1.52 %); Table 1 cross-tabulates typology and condition with the two kinds of indeterminacy kept apart.

Table 1: Crash typology by road-user condition, SPPAT records 2016–2021 (N = 16,526), with sentinel and empty indeterminacy separated.

Crash typology	**Occupant**	**Pedestrian**	**Cyclist**	**Total**	**Share (%)**
Choque (collision)	8,328	86	113	8,527	51.60
Atropello (run-over)	241	4,515	242	4,998	30.24
Volcamiento (rollover)	2,324	15	2	2,341	14.17
Caída (fall from vehicle)	378	22	9	409	2.47
Indeterminate: sentinel DESCONOCIDO	101	56	6	163	0.99
Indeterminate: empty cell	66	20	2	88	0.53
Total	11,438	4,714	374	16,526	100.00

3.2 Period and denominator audit

Every rate of the original Table 3 was reproduced exactly with the authors' populations and Δt = 5.89 years (scenario A, Table 2). The audit found four problems. The period 5.89 corresponds to no window in the file: file creation spans 5.64 years and the crash dates of 2016–2021 events span 5.85 years. The counts included the 163 pre-2016 events, which belong to no year of the denominator. Several populations in the authors' table are rounded values (27,000; 42,000; 48,000; 65,000; 82,500) rather than published projections, while the large cantons carry projection-like figures. And the ranking was computed within seventeen selected cantons, so "rank 1" meant first among those seventeen. Scenario B (2016–2021 events over the creation window) raises every rate by about 4 %, because the shorter window outweighs the removed events; scenario C, with a common 2026 denominator for all cantons, lowers the rates of fast-growing cantons (Daule 31.3 → 21.7; Latacunga 37.2 → 32.7) and leaves the others within their Poisson intervals; the Spearman correlation between scenarios A and C over the seventeen cantons was 0.995. Scenario D, the person-year calculation of Eq. (2), matched all 207 province–canton pairs and all 16,363 events of the period; it places Machachi at 54.94 against the 56.45 of the original, Naranjal at 51.24 against 49.39, Quito at 11.03 against 10.79 and Guayaquil at 8.88 against 8.71 (Table 2, Figure 1). The corrected rates are within a few per cent of the originals for most cantons, because two errors of opposite sign (a period that was too long and a denominator that was too small) partly cancel; the ordering, not the level, is what the audit changes. Scenario D and scenario C rank cantons almost identically (Spearman 0.974), which is the sense in which the sensitivity scenario was informative.

The mapping to INEC cantons also exposed two territorial-label discrepancies in the source that no completeness check would show: Santiago de Méndez, the capital of the canton Santiago in Morona Santiago, is filed under the province of Azuay (28 records); La Concordia is filed under Santo Domingo de los Tsáchilas, whereas the 2010–2020 projections still carry it under Esmeraldas (57 records). Both were resolved by matching the canton name across provinces, and both are reported so that the data owner can correct them.

Table 2: Reproduction and correction of the seventeen cantons reported in the original analysis. A: all events, Δt = 5.89 y, authors' populations; B: 2016–2021 events, Δt = 5.64 y, same populations; C: 2016–2021 events, Δt = 5.85 y, 2026 INEC projections; D: person-years from the INEC 2010–2020 cantonal projections (Eq. 2). Rates per 100,000 inhabitants per year.

Label (canton)	**Records**	**2016–2021 events**	**Authors' population**	**A: rate (95 % Poisson)**	**B: rate**	**C: rate**	**D: person-years**	**D: rate (95 % Poisson)**	**Rank D (all cantons)**

Machachi	337	335	101,360	56.45 (50.58–62.81)	58.60	52.26	609,795	54.94 (49.21–61.15)	6
Naranjal	273	273	93,846	49.39 (43.70–55.61)	51.58	49.62	532,802	51.24 (45.34–57.69)	7
Yaguachi	218	218	78,393	47.21 (41.15–53.91)	49.31	46.75	443,270	49.18 (42.87–56.16)	9
Balao	75	75	27,000	47.16 (37.10–59.12)	49.25	45.01	149,328	50.22 (39.51–62.96)	8
Puebloviejo	109	108	42,000	44.06 (36.18–53.15)	45.59	39.85	255,299	42.30 (34.70–51.07)	15
Guano	114	114	48,000	40.32 (33.26–48.44)	42.11	39.28	280,010	40.71 (33.58–48.91)	18
El Guabo	151	148	65,000	39.44 (33.40–46.26)	40.37	39.34	361,452	40.95 (34.61–48.10)	16
Buena Fe	185	184	82,500	38.07 (32.78–43.97)	39.54	37.09	471,713	39.01 (33.57–45.07)	20
Latacunga	451	447	205,624	37.24 (33.88–40.84)	38.54	32.66	1,177,267	37.97 (34.53–41.66)	22
Babahoyo	355	354	175,281	34.39 (30.90–38.16)	35.81	30.92	1,012,288	34.97 (31.42–38.81)	24
Daule	320	320	173,684	31.28 (27.95–34.90)	32.67	21.73	966,501	33.11 (29.58–36.94)	29
Quevedo	297	293	213,842	23.58 (20.97–26.42)	24.29	21.77	1,219,724	24.02 (21.35–26.94)	58
Santo Domingo	575	569	458,580	21.29 (19.58–23.10)	22.00	20.45	2,609,997	21.80 (20.05–23.67)	67
Ambato	408	404	387,309	17.88 (16.19–19.71)	18.49	17.93	2,225,076	18.16 (16.43–20.02)	87
Quito	1,767	1,749	2,781,641	10.79 (10.29–11.30)	11.15	10.40	15,851,176	11.03 (10.52–11.56)	135
Cuenca	365	359	636,996	9.73 (8.76–10.78)	9.99	9.76	3,623,115	9.91 (8.91–10.99)	140
Guayaquil	1,398	1,394	2,723,665	8.71 (8.26–9.18)	9.07	7.92	15,690,765	8.88 (8.42–9.36)	148

Note: rank D is among the 207 cantons of scenario D, which covers every event of the period.

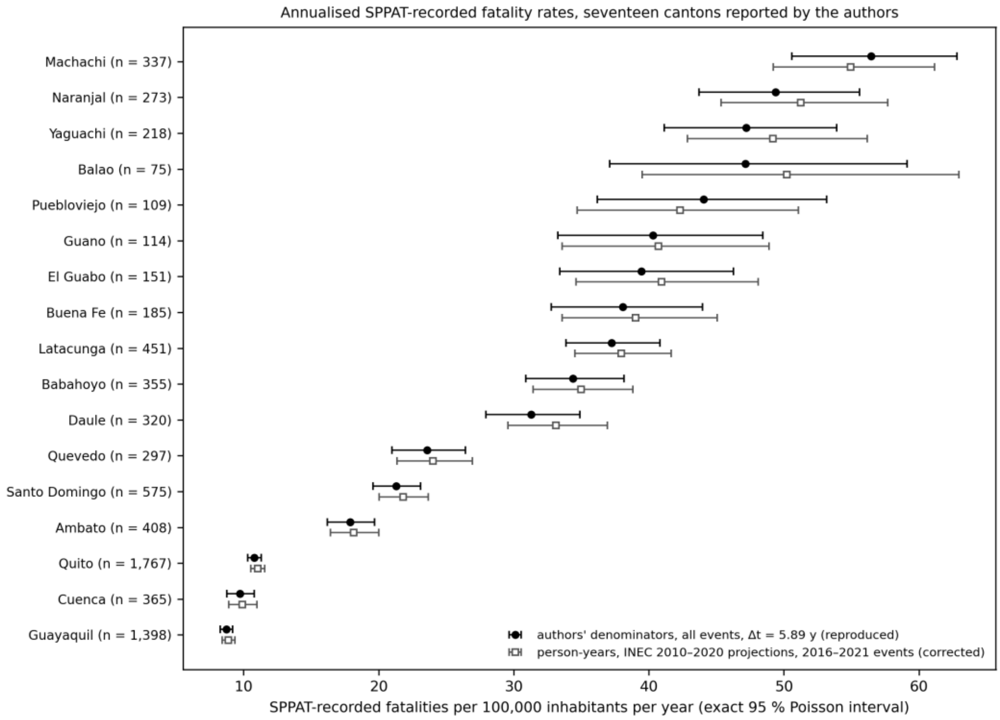

Figure 1: SPPAT-recorded fatality rates per 100,000 inhabitants per year for the seventeen cantons of the original analysis, with exact 95 % Poisson intervals: reproduction of the published figures (scenario A, circles) and the corrected person-year calculation on contemporaneous INEC projections (scenario D, squares).

3.3 Complete ranking and rate ratios

Over all 207 cantons of the person-year scenario (Table 3), the highest rates were Loreto (79.8; 65.8–96.0; 113 events); Olmedo (70.5; 41.8–111.4; 18 events); Patate (69.3; 53.2–88.6; 63 events); Pallatanga (61.3; 44.6–82.3; 44 events); Las Naves (56.5; 36.2–84.0; 24 events). Machachi (Mejía) ranked 6th (54.9; 49.2–61.1), Naranjal 7th and Yaguachi 9th; Quito ranked 135th (11.0) and Guayaquil 148th (8.9). The cantons above Machachi have between 18 and 113 events; their Poisson intervals overlap Machachi's, so the ordering at the top is not resolved by these data, whereas the separation between the corridor cantons and the two metropolitan cantons is. The pre-specified rate ratios (Table 4) ranged from 4.5 (Yaguachi versus Quito) to 6.2 (Machachi versus Guayaquil) under the corrected scenario, with lower interval limits above 3.9 in every case, and differed from the authors' scenario by less than 0.3. The relative width of the Poisson interval exceeded 0.5 in 144 of the 207 cantons, so most of the ranking above Machachi rests on fewer than 120 events per canton.

Table 3: Fifteen highest SPPAT-recorded fatality rates under the corrected person-year scenario (2016–2021 events; INEC cantonal projections 2010–2020 with s_{2021} = 0.849).

Label (cantonal capital or canton)	Province in the source	2016–2021 events	Person-years	Rate D	95 % Poisson	Relative width	Rank
Loreto	Orellana	113	141,539	79.8	65.8–96.0	0.38	1
Olmedo	Loja	18	25,529	70.5	41.8–111.4	0.99	2
Patate	Tungurahua	63	90,934	69.3	53.2–88.6	0.51	3
Pallatanga	Chimborazo	44	71,729	61.3	44.6–82.3	0.62	4
Las Naves	Bolivar	24	42,493	56.5	36.2–84.0	0.85	5
Machachi	Pichincha	335	609,795	54.9	49.2–61.1	0.22	6
Naranjal	Guayas	273	532,802	51.2	45.3–57.7	0.24	7
Balao	Guayas	75	149,328	50.2	39.5–63.0	0.47	8
Yaguachi	Guayas	218	443,270	49.2	42.9–56.2	0.27	9
Pedro Vicente Maldonado	Pichincha	47	96,817	48.5	35.7–64.6	0.60	10
Puerto Quito	Pichincha	63	142,392	44.2	34.0–56.6	0.51	11

Santiago De Mendez	Azuay	28	63,767	43.9	29.2–63.5	0.78	12
Colta	Chimborazo	116	264,757	43.8	36.2–52.6	0.37	13
Balsas	El Oro	22	51,976	42.3	26.5–64.1	0.89	14
Puebloviejo	Los Rios	108	255,299	42.3	34.7–51.1	0.39	15

Table 4: Pre-specified rate ratios with log-normal 95 % intervals under the authors' scenario (A), the common-denominator scenario (C) and the corrected person-year scenario (D).

Numerator canton	Reference canton	Rate ratio, scenario A (95 %)	Rate ratio, scenario C (95 %)	Rate ratio, scenario D (95 %)
Machachi	Quito	5.23 (4.66–5.88)	5.03 (4.47–5.65)	4.98 (4.43–5.60)
Machachi	Guayaquil	6.48 (5.75–7.30)	6.60 (5.86–7.43)	6.18 (5.49–6.97)
Naranjal	Quito	4.58 (4.03–5.20)	4.77 (4.20–5.42)	4.64 (4.09–5.28)
Naranjal	Guayaquil	5.67 (4.98–6.45)	6.26 (5.50–7.13)	5.77 (5.07–6.57)
Yaguachi	Quito	4.38 (3.80–5.04)	4.50 (3.91–5.18)	4.46 (3.87–5.13)
Yaguachi	Guayaquil	5.42 (4.70–6.25)	5.90 (5.12–6.81)	5.54 (4.80–6.39)

3.4 Indeterminacy: distribution and the chi-square audit

Among cantons with at least 100 records (Figure 2), the indeterminacy share was highest in La Troncal (6.25 %; 3.2–11.8; 3 sentinel, 5 empty), Guano (4.39 %; 1.9–9.9; 5 sentinel, 0 empty), Quevedo (4.38 %; 2.6–7.3; 9 sentinel, 4 empty), Pasaje (3.60 %; 1.4–8.9; 4 sentinel, 0 empty), against 1.13 % in Quito and 1.07 % in Guayaquil; the Wilson intervals of the leading cantons overlap the national value (1.52 %) except La Troncal, Guano and Quevedo. By crash year the share peaked in 2018 (2.23 %, 70 records) and was lowest in 2016 (0.72 %). The original chi-square ($\chi^2(207) = 488.23$, $p = 9.0\text{e-}25$) was reproduced, but 234 of its 416 expected cells (56 %) are below five, so the asymptotic p-value is not reliable; a permutation test gave $p < 0.001$ (0 of 1,000 permutations reached the observed statistic), Cramér's V was 0.17, and after pooling cantons with fewer than 100 records the association remained detectable ($\chi^2(45) = 87.1$, $p = 1.7\text{e-}04$) with $V = 0.07$; by year, $V = 0.04$. Territorial differences in indeterminacy are therefore real but small (Table 5); the earlier reading of a "heavily clustered" registry debt overstated a weak effect, and no institutional mechanism (delayed police reports, intake-system transitions) can be inferred from the file.

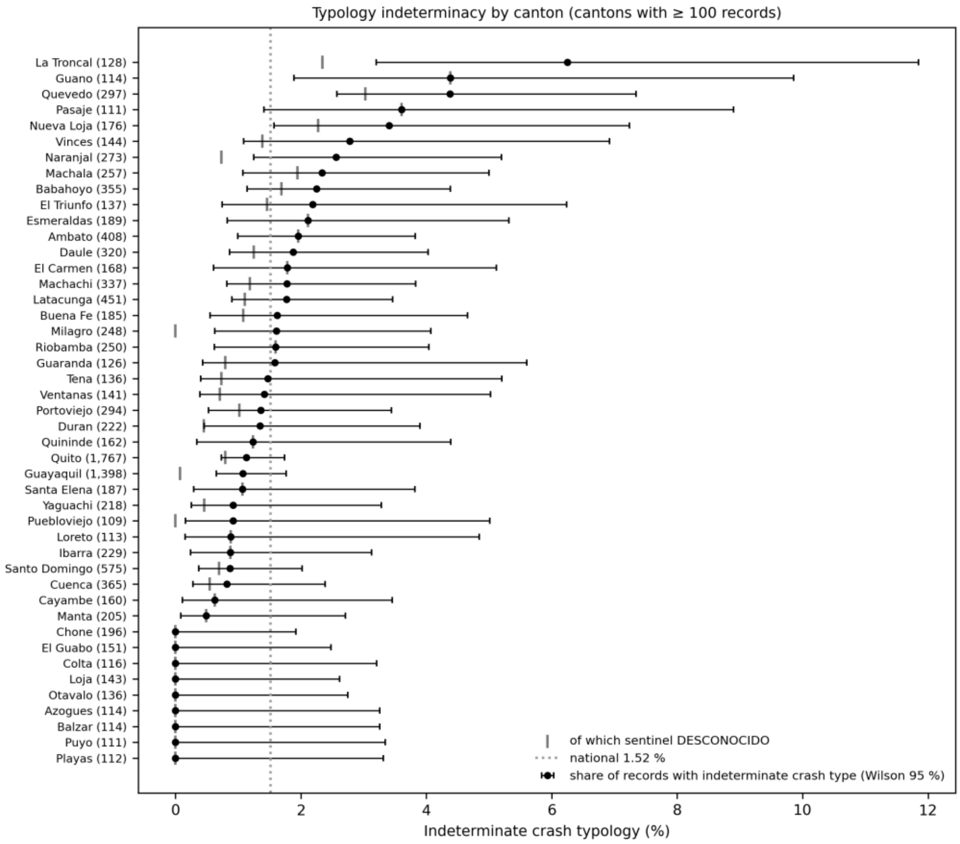

Figure 2: Share of records with indeterminate crash type (sentinel or empty) by canton, cantons with at least 100 records, with Wilson 95 % intervals; ticks mark the sentinel-only share; dotted line, national share.

Table 5: Chi-square assumption audit for the association between territory or year and typology indeterminacy.

Test	χ^2	df	asymptotic p	Cramér's V	expected cells < 5	Monte-Carlo p
Canton × indeterminacy (208 cantons)	488.23	207	9.0e-25	0.172	234 of 416 (56 %)	< 0.001 (permutation)
Canton × indeterminacy, cantons < 100 pooled	87.12	45	1.7e-04	0.073	37 of 92	—
Crash year × indeterminacy	25.73	6	2.5e-04	0.039	1	—

3.5 Typology evidence coordinates and identification bounds

Nationally the coordinates of the run-over proposition were $T = 0.302, I = 0.015, F = 0.682$, and of the collision proposition $T = 0.516, I = 0.015, F = 0.469$; I is the same for every proposition because indeterminate records are indeterminate for all of them. The identification interval for the national run-over share is [30.24, 31.76] %, against 30.71 % under complete-case analysis and 30.24 % with an explicit indeterminate category. Among cantons with at least 300 records (Table 6, Figure 3), I_c ranged from 0.008 to 0.023, so the identification intervals of run-over rates are narrow (Quito 4.4–4.5, Guayaquil 3.4–3.5, Santo Domingo 4.0–4.2, Latacunga 14.6–15.2 per 100,000 per year) and, in every canton, narrower than the Poisson interval of either bound. The two layers answer different questions: what the registry would show if indeterminate records were resolved either way, and how much a Poisson count of that size could vary. For these data the semantic layer is small and the sampling layer dominates.

Table 6: Evidence coordinates of the run-over proposition and identification bounds on run-over SPPAT-recorded rates (per 100,000 per year, 2016–2021 events, 2026 denominators) for cantons with at least 300 records.

Canton	Records	Run-over	Indeterminate	T	I	F	Share bounds (%)	Rate bounds $[R_L, R_U]$	Outer Poisson limits
Quito	1,767	749	20	0.424	0.011	0.565	42.4–43.5	4.41–4.53	4.10–4.86

Guayaquil	1,398	601	15	0.430	0.011	0.559	43.0–44.1	3.40–3.48	3.13–3.77
Santo Domingo	575	113	5	0.197	0.009	0.795	19.7–20.5	3.99–4.17	3.28–5.00
Latacunga	451	202	8	0.448	0.018	0.534	44.8–46.6	14.61–15.20	12.66–17.41
Ambato	408	188	8	0.461	0.020	0.520	46.1–48.0	8.21–8.57	7.07–9.87
Cuenca	365	135	3	0.370	0.008	0.622	37.0–37.8	3.53–3.62	2.95–4.28
Babahoyo	355	82	8	0.231	0.023	0.746	23.1–25.4	7.16–7.86	5.70–9.66
Machachi	337	105	6	0.312	0.018	0.671	31.2–32.9	16.22–17.16	13.26–20.68
Daule	320	85	6	0.266	0.019	0.716	26.6–28.4	5.77–6.18	4.61–7.59

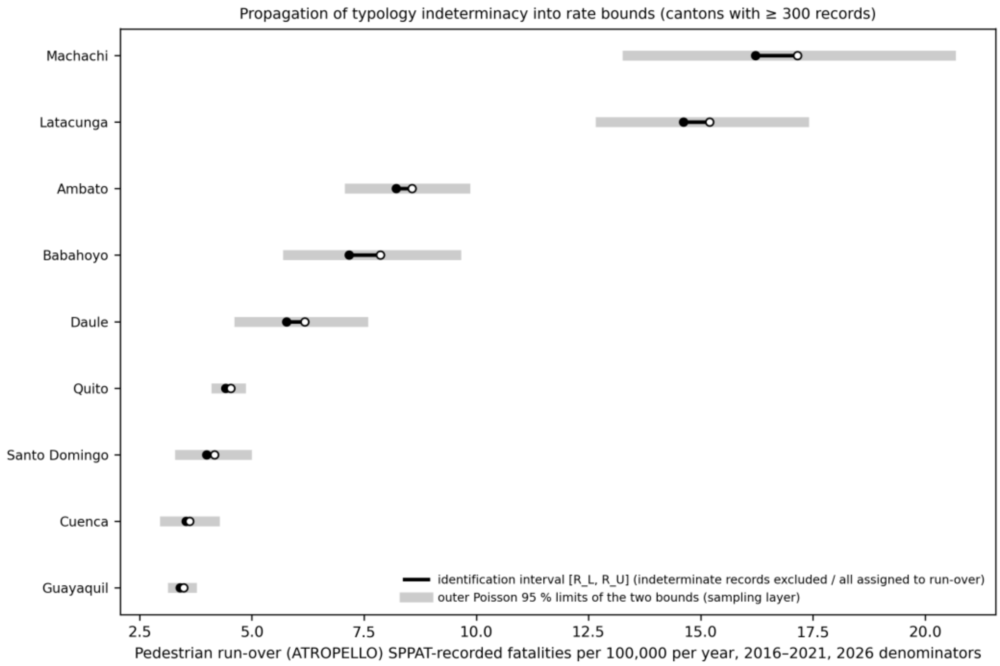

Figure 3: Propagation of typology indeterminacy into run-over rate bounds: black segment, identification interval $[R_L, R_U]$; grey band, outer exact Poisson 95 % limits of the two bounds (sampling layer). Cantons with at least 300 records.

3.6 Corridor classification

Corridor membership was checked against the published composition of the two trunk roads of the state network. The Troncal de la Sierra (E35, 781 km, nine highland provinces) runs through Tulcán, Ibarra, Otavalo, Cayambe, Quito, Sangolquí, Machachi, Latacunga, Salcedo, Ambato, Mocha, Riobamba, Cajabamba, Guamote, Alausí, Chunchi, El Tambo, Cañar, Biblián, Azogues, Cuenca, Oña, Saraguro, Loja, Catamayo, Catacocha and Macará; the Troncal de la Costa (E25, 664 km, six provinces) through San Miguel de los Bancos, Santo Domingo, Buena Fe, Quevedo, Ventanas, Puebloviejo, Juján, Milagro, Naranjal, Camilo Ponce Enríquez, El Guabo, Machala, Santa Rosa, Arenillas, Alamor, Pindal and Zapotillo. Table 7 applies this list. Four of the six cantons named as corridor cantons by the original analysis are on a trunk route (Machachi and Latacunga on the E35; Naranjal and Quevedo on the E25); Yaguachi and Babahoyo are not on either published route, and Guano, which the original analysis associated with the corridor reading, is not either, since the E35 passes through Riobamba. Three cantons that are on the E25 (Puebloviejo, Buena Fe, El Guabo) were not named as corridor cantons although they rank high. The check is documentary: it compares canton names with a published route composition and does not measure how many kilometres of trunk road each canton contains, which would require a geospatial overlay of the network on the cantonal boundaries.

Table 7: Corridor classification of the cantons discussed in the original analysis.

Label	Canton	Trunk route	Status in this study
Machachi	Mejia	E35 (Troncal de la Sierra)	on the route; asserted and confirmed
Latacunga	Latacunga	E35 (Troncal de la Sierra)	on the route; asserted and confirmed
Ambato	Ambato	E35 (Troncal de la Sierra)	on the route; not asserted by the authors
Naranjal	Naranjal	E25 (Troncal de la Costa)	on the route; asserted and confirmed

Yaguachi	Yaguachi	not on the published route of E35 or E25	asserted but NOT on the published route of either trunk road
Babahoyo	Babahoyo	not on the published route of E35 or E25	asserted but NOT on the published route of either trunk road
Balao	Balao	not on the published route of E35 or E25	not on either trunk road; not asserted
Puebloviejo	Puebloviejo	E25 (Troncal de la Costa)	on the route; not asserted by the authors
Quevedo	Quevedo	E25 (Troncal de la Costa)	on the route; asserted and confirmed
Buena Fe	Buena Fe	E25 (Troncal de la Costa)	on the route; not asserted by the authors
El Guabo	El Guabo	E25 (Troncal de la Costa)	on the route; not asserted by the authors
Guano	Guano	not on the published route of E35 or E25	not on either trunk road; not asserted
Daule	Daule	not on the published route of E35 or E25	not on either trunk road; not asserted
Santo Domingo	Santo Domingo De Los Tsachilas	E25 (Troncal de la Costa)	on the route; not asserted by the authors
Quito	Quito	E35 (Troncal de la Sierra)	on the route; not asserted by the authors
Guayaquil	Guayaquil	not on the published route of E35 or E25	not on either trunk road; not asserted
Cuenca	Cuenca	E35 (Troncal de la Sierra)	on the route; not asserted by the authors

4 Discussion

4.1 Principal finding

The original result survives in its qualitative form and not in its quantitative one. Under the corrected person-year calculation the three cantons the original analysis singled out still record SPPAT fatality rates 4.5 to 6.2 times those of Quito and Guayaquil, and the rate ratios are precise. But the period, the denominators and the set of cantons ranked were all wrong: the period corresponded to no window of the file, five denominators were rounded values, and the ranking was internal to seventeen chosen cantons. With every canton on contemporaneous person-years, Machachi is 6th of 207 and five cantons the original analysis never considered rank above it, with overlapping intervals.

4.2 Denominators and periods

A multi-year registry annualised over a single Δt and a single population is a person-year calculation with two shortcuts, and both are visible here: the shortcut on time produced a period that matched nothing in the data, and the shortcut on population produced rounded denominators. The correction is not expensive: the INEC cantonal projections for 2010–2020 are public, and accumulating them over the covered years gives every canton an exposure that no longer depends on a chosen constant. Two consequences deserve attention. The corrected rates are close to the originals in level because the two errors have opposite signs, so a reader comparing only Machachi's 56.45 and 54.94 would conclude that nothing was wrong; what changed is the ranking, and the ranking is what the original analysis used. And the mapping needed to build the denominators is itself an audit: it turned up two cantons filed under the wrong province in the source.

4.3 What the complete ranking changes

Ranking within a hand-picked set inflates the position of every member. The cantons that outrank Machachi under the corrected scenario are Loreto (79.8), Patate (69.3), Colta (43.8), Pallatanga and Las Naves, none of which appears in the original analysis and none of which lies on a trunk route; they have between 18 and 113 events and wide intervals. The honest statement is that a group of small highland and Amazon cantons and a group of corridor cantons share the top of the distribution, that the corridor group is the one whose membership is documented, and that the metropolitan cantons are far below both.

4.4 Indeterminacy is small and weakly territorial

With 251 indeterminate records in 16,526, typology indeterminacy is a 1.52 % phenomenon; its territorial association is detectable by permutation but has a Cramér's V of 0.17, and the leading cantons' intervals mostly overlap the national share. The first version's institutional narrative (delayed police reports, intake-system transitions) is not supported by anything in the file and has been removed; what remains is a description and a pointer to the cantons and the year where the share is highest.

4.5 Proposition-based coordinates versus the earlier triple

The earlier triple assigned T = completeness, $I = 1 -$ T and $F = 0$ to each field. That is one number with three names, and it fails the elementary test that a coordinate should be able to take a value other than the one implied by the others. The proposition-based coordinates of Section 2.5 pass it: for the run-over proposition in a canton, T, I and F are three observed shares, F is large (most records assert another type), and the sum to one is a statement about the partition of records, not about the coordinates' independence. Normalisation can change rank orders of triples [21], and the paper therefore ranks cantons by the identification bounds, not by any composite of T, I and F.

4.6 Two layers of uncertainty

Identification bounds and Poisson intervals answer different questions and were kept apart. The bounds are lower and upper probabilities induced by the multivalued assignment of indeterminate records [16] and are exact given the data; the Poisson intervals are sampling statements under a model. For these data the identification layer is an order of magnitude narrower than the sampling layer, which is itself a result: resolving every DESCONOCIDO would change typology rates by less than the count noise. A combination rule (for instance, Poisson intervals around each bound, reported as an outer envelope) is shown in Figure 3 as a display, not as a combined inference.

4.7 Relation to NPL and neutrosophic statistics

The coordinates borrow from NPL the separation of favourable, contrary and indeterminate evidence [18] and from neutrosophic set theory the idea that the three components are separately meaningful [19]; they do not use NPL's synthesis procedure, and I is evidential (a record that does not assert its type), not ontological. Neutrosophic statistics [17] treats data with an indeterminate part; the identification bounds of Eq. (6) are the classical counterpart of that treatment for a proportion, and they are what a neutrosophic interval rate would reduce to under the stated assignment rule.

4.8 Evidence-aware use of the dashboard

The dashboard supports descriptive review of SPPAT-recorded fatalities by province, canton, year and road-user condition, and monitoring of typology indeterminacy. It does not measure road risk, does not identify corridors, and does not support enforcement allocation, for which exposure (vehicle-kilometres, traffic flows), police records and a comparison design would be required. The original wording on guiding corridor enforcement is withdrawn.

4.9 Limitations

Rates use resident population, not exposure: person-years measure residence, not vehicle-kilometres travelled, and a canton crossed by a trunk road accumulates deaths of non-residents. The registry covers claims filed with the SPPAT and is bounded relative to police and vital records; coverage may vary by territory. The 2021 population is a linear extrapolation of the 2019–2020 increment, and the 2010–2020 series is itself a projection from the 2010 census. Corridor membership was checked documentarily against a published route composition, not geospatially, and no measure of trunk-road length per canton was computed. The typology coordinates concern one field; other fields have no indeterminacy in this file. Indeterminate records were assigned to the two extremes for the bounds; no informative assumption about their true type was made.

4.10 Future research

Trunk-road kilometres per canton and traffic flows would turn the corridor reading into an exposure model; linkage with ANT on-site records and INEC death certificates would bound under-registration; and the identification bounds could be narrowed with informative assumptions (for instance, the typology distribution of indeterminate records equal to that of the same canton's known records), reported as a separate scenario. On the neutrosophic side, the proposition-based coordinates can be extended to multi-source evidence when a second registry is linked, at which point favourable and contrary evidence from different sources would no longer partition the records and the sum-to-one design would be dropped.

5 Conclusions

Empirically, SPPAT-recorded fatality rates in corridor cantons are 4.5 to 6.2 times those of the two metropolitan cantons once exposure is measured in contemporaneous person-years, the top of the complete ranking is shared with small highland and Amazon cantons whose intervals overlap and which lie on no trunk road, and typology indeterminacy is small (1.52 %) and only weakly territorial. Methodologically, the earlier normalised field triple was replaced by proposition-based evidence coordinates whose contrary component is observed, and indeterminacy was propagated into identification bounds kept separate from Poisson sampling intervals; for these data the semantic layer is far narrower than the sampling layer. Rates from an administrative registry should be reported with their exposure assumption, their denominator source, their complete ranking and their two uncertainty layers, and they should be called what they are: recorded rates, not mortality or risk.

Declarations

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Conflicts of Interest: The authors declare no conflict of interest.

Data Availability: The open dataset is available at https://www.datosabiertos.gob.ec/dataset/fallecidos-por-accidentes-de-transito-registradas-por-el-sppat (file sppat_fallecidosaccidentestransito_2016-2021.csv, dictionary and metadata). The interactive dashboard is available at https://sppat-los-balas.ai.studio/. The INEC cantonal projections 2010–2020 used as denominators are public at https://www.ecuadorencifras.gob.ec/proyecciones-poblacionales/. The analysis script, the alias table, the results files and the figures accompany the manuscript.

Use of AI: Google Gemini and Antigravity CLI were used in the first version for code drafting, validation scripts and formatting; Claude (Anthropic) assisted with the second-round reanalysis (reproduction, denominator audit, identification bounds, chi-square audit), reference verification and manuscript editing. Data analysis, verification of every reported metric against the open file, and the final text are the responsibility of the authors.

Appendix A. Dashboard screenshots

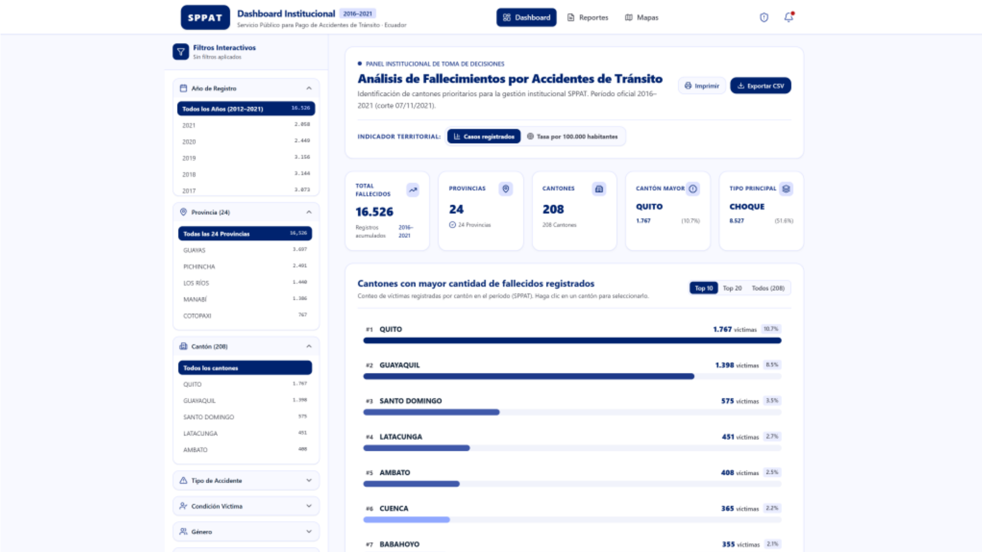

Figure A1: Institutional decision panel of the dashboard (macro indicators and cantonal ranking).

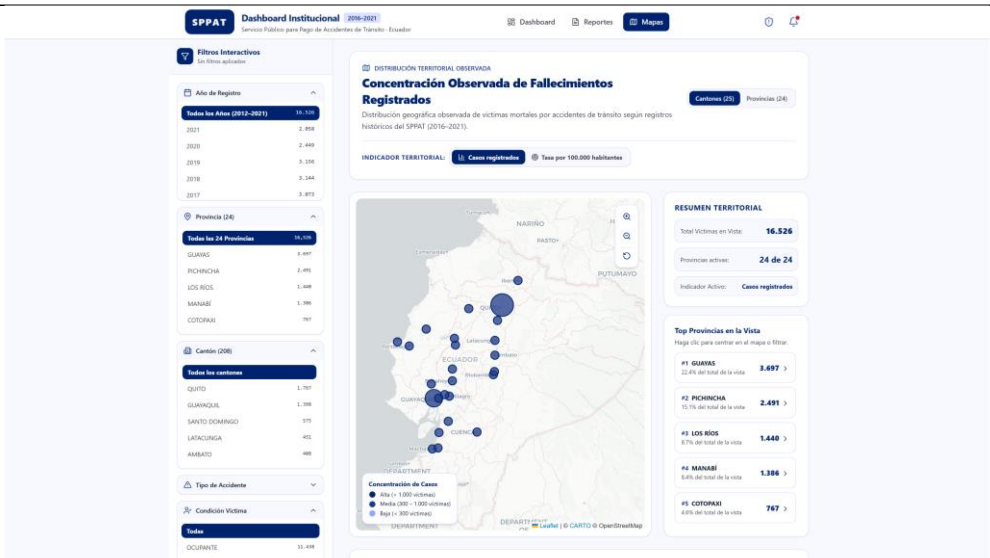

Figure A2: Geospatial module of the dashboard (territorial distribution of SPPAT records).

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