



Research Article

# DYNAMICS OF VIOLENCE AND FIREARMS IN ECUADOR: SPATIAL PATTERNS AND CHALLENGES IN BALLISTIC TRACEABILITY FOR INVESTIGATIVE PURPOSES

*English translation with AI assistance (DeepL)*

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## **DYNAMICS OF VIOLENCE AND FIREARMS IN ECUADOR: SPATIAL PATTERNS AND CHALLENGES IN BALLISTIC TRACEABILITY FOR INVESTIGATIVE PURPOSES**

**Summary:** 1. INTRODUCTION. 2. DYNAMICS OF VIOLENCE IN URBAN AND SUBURBAN CONTEXTS IN ECUADOR. 2.1. METHODOLOGIES FOR THE GEOGRAPHICAL TARGETING OF VIOLENCE AND THE CONTEXTUALISATION OF HIGHLY TARGETED AREAS OF VIOLENCE. 2.1.1. Methodologies for the geographical localisation of violence. 2.1.1.1. Sources of information and data collection procedures. 2.1.2. Contextualisation of hyper-localised areas of violence. 2.1.3. Cartographic representation and spatial analysis of critical zones. 2.2. TRENDS AND DETERMINANTS OF VIOLENCE IN ECUADOR: SOCIO-STRUCTURAL IMPACT AND THE CENTRAL ROLE OF FIREARMS IN LETHAL VIOLENCE. 3. TRACEABILITY AND IDENTIFICATION OF FIREARMS: CHALLENGES IN THEIR TRACKING, CLASSIFICATION AND BALLISTIC ANALYSIS 3.1. Unmarked privately manufactured firearms: challenges in their tracing, classification and criminal investigation. 3.1.1. Ballistic tracing tools and systems: implementation and limitations of the IBIS system. 3.2. Limitations of the study. 3.3. Implications for criminal investigation. 4. CONCLUSIONS.

**Abstract:** Analysis of the dynamics of lethal violence in Ecuador reveals a radical shift in the profile of public safety, characterised by an exponential rise in homicides, reaching a historic rate of 51 per 100,000 inhabitants by 2025. The temporal stability of crime concentration was demonstrated through the use of spatial autocorrelation tools and the Local Morán Index, revealing the existence of micro-territories with high crime concentrations, such as the Durán Canton. The recurrence of violent incidents demonstrates that crime is consistently concentrated in the same locations, as is the case in certain micro-areas that continue to exhibit high levels of violence over a prolonged period. Similarly, the central role of firearms as a means of committing homicides is highlighted, creating fundamental technical challenges for forensic science. The development of 'ghost' weapons using 3D printing or CNC machines complicates traditional techniques for the control and tracing of weapons. A comparison of genuine weapons and suspect weapons shows that the existence of highly sophisticated copies or technical modifications makes it quite difficult today to identify serial numbers and the clear origin of the weapons.

**Resumen:** El análisis de las dinámicas de violencia letal en el Ecuador revela un cambio radical en el perfil de la seguridad ciudadana, que se caracteriza por un crecimiento exponencial de los homicidios hasta alcanzar una tasa histórica de 51 por cada 100,000 habitantes en 2025. Se evidenció la estabilidad temporal de la concentración delictiva mediante el uso de herramientas de autocorrelación espacial y el Índice Local de Morán, al mostrar la existencia de microterritorios de alta concentración delictiva, por ejemplo, el Cantón Durán. La repetición de hechos violentos evidencia que el delito se concentra siempre en los mismos lugares tal y como sucede en algunas microzonas que continúan mostrándose con niveles elevados de violencia durante mucho tiempo. De la misma manera, se pone en evidencia el papel central de las armas de fuego como medio para cometer homicidios, lo que crea desafíos técnicos fundamentales para la criminalística. El desarrollo de armas fantasma que utilizan impresión 3D o máquinas CNC dificulta las técnicas tradicionales para el control y la localización de armas. La comparación de armas auténticas y armas sospechosas muestra que la existencia de copias o

modificaciones técnicas muy desarrolladas hacen que hoy en día resulte bastante difícil la identificación de los números de serie y del origen claro de las armas.

**Keywords:** intentional homicide, ghost guns, organised crime, ballistics analysis

**Palabras clave:** homicidio intencional, armas fantasma, crimen organizado, análisis balístico

## **ABBREVIATIONS**

ABIS: Automated Ballistic Identification Systems.

Cartridge: A unit comprising a bullet, a cartridge case, gunpowder and a primer.

CNC: Computer Numerical Control.

DMG: Guayaquil Metropolitan District.

DGIN: General Directorate of Investigations of the Ecuadorian National Police

H.I.: Intentional Homicides

IBIS: Integrated Ballistic Identification System. A commercial ballistic identification system originally developed by Forensic Technology, now owned by LeadsOnline.

PAHO: Pan American Health Organisation

WHO: World Health Organisation

GDP: Gross Domestic Product

p-value: Level of statistical significance.

Projectile: Part of the cartridge expelled from the barrel when fired and which is in motion.

UNODC: United Nations Office on Drugs and Crime

UNRECPOL: National Crime Information Reception Unit of the Ecuadorian National Police

Cartridge case: The metal component of the cartridge that contains the other elements of the ammunition.

z-score: High and low values suggest that the locations of the homicides are not random



## **1. INTRODUCTION**

Urban violence in Ecuador has risen significantly in recent years, reaching levels that have posed a challenge to public safety and the country's social development. This phenomenon is evident from an analysis of intentional homicides, specifically those committed with firearms, which shows that the homicide rate reached a record high in 2025 of 51 incidents per 100,000 inhabitants. Based on the data, it can be shown that the spatial and temporal concentration of these violent incidents is not random, but is focused on micro-territories, such as the Durán Canton, where lethal violence has remained stable over time, revealing patterns of recurrence and persistence.

From a methodological perspective, the analysis of these dynamics has relied on advanced spatial autocorrelation tools and the Local Morán Index, which enable the identification of hyper-focalised areas of violence to generate risk maps; this facilitates an understanding of the geographical distribution of crime and the identification of critical zones, which is essential for the design of targeted and effective public policies. Furthermore, the incorporation of traceability for firearms-related offences, as well as the integration of ballistic data and the evaluation of the IBIS (Integrated Ballistic Identification System), have provided valuable information on the use and circulation of firearms in urban contexts, although they have also revealed technical and operational limitations, particularly in the face of the proliferation of privately manufactured weapons and 'ghost' weapons produced using technologies such as 3D printing and CNC machines.

These technological advances in firearms manufacturing pose a challenge to security, as they make it difficult to identify serial numbers and trace the origin of firearms, thereby complicating the work of the authorities in preventing, controlling and detecting crime; furthermore, the existence of sophisticated replicas and advanced technical modifications requires the constant updating of ballistic analysis methods and the implementation of new control and regulatory strategies. In this regard, the illicit economy linked to the trafficking and use of firearms is a key factor in the perpetuation of urban violence, interacting with structural socio-economic factors such as poverty, inequality and social exclusion, which create conditions conducive to the expansion of organised crime.

Against this background, this article aims to analyse the dynamics of homicidal violence in Ecuador, its spatial distribution and the challenges associated with the traceability and ballistic identification of firearms used in contexts of criminal violence. To this end, the canton of Durán was selected as a case study due to its high levels of lethal violence and the persistence over time of areas of hyperconcentration. The study seeks to provide empirical evidence that contributes to an understanding of the spatial patterns of violence and the existing technical limitations on the identification and tracing of firearms used by criminal organisations.

## **2. DYNAMICS OF VIOLENCE IN URBAN AND SUBURBAN CONTEXTS IN ECUADOR**

### **2.1. METHODOLOGIES FOR THE GEOGRAPHICAL TARGETING OF VIOLENCE AND THE CONTEXTUALISATION OF AREAS OF EXTREMELY HIGH VIOLENCE CONCENTRATION.**

#### **2.1.1. Methodologies for the geographical targeting of violence.**

Homicidal violence is a deep-rooted problem that impacts the quality of democracy, institutions, the family and society. In general, it constitutes a social problem that affects the quality of life of citizens, households and the social and economic development of a locality. It is a multi-causal phenomenon that must be understood holistically; therefore, based on the existing academic literature, it can be analysed from various angles. One such angle is the crime triangle, derived from one of the main theories of environmental criminology (Cohen and Felson, 1979). In this model—the crime triangle—the victim and the offender coincide in time and space in the absence of a capable guardian. In light of the above, it is essential to identify and geographically locate the areas where problems of homicidal violence are concentrated.

##### *2.1.1.1. Source of information and data collection procedure*

The information used in this study is drawn from administrative records consolidated by the Special Commission on Statistics for Security, Justice, Crime and Transparency, a technical body coordinated by the National Institute of Statistics and Censuses (INEC), established to strengthen the production, validation and standardisation of official statistics relating to public safety, justice, crime and transparency in Ecuador.

The database used corresponds to the national register of intentional homicides, comprising the offences of homicide, murder, contract killing and femicide. Access to the information was obtained through institutional mechanisms, as the National Directorate for Information Analysis forms part of the Special Commission on Statistics, which allows authorised access to consolidated information for analytical and statistical purposes.

The period analysed covered the years 2022, 2023, 2024 and 2025. The database comprised 9,175 records relating to intentional homicides that occurred between 2022 and 2025.

The main variables used were: province code, canton code, sub-zone, district, circuit, sub-circuit code, revised geographical coordinates (X and Y), date of the offence, type of weapon and type of violence.

Prior to the spatial analysis, the records underwent validation, cleansing, georeferencing and quality control processes, ensuring the consistency of the information used for spatial autocorrelation analyses and the identification of hyper-focalised areas of violence.

**Table 1**  
*Descriptive statistics of the analysed database*

<b>Variable</b>	<b>Value</b>
Records analysed	9,175 intentional homicides
Period analysed	2022–2025
Canton analysed spatially	Durán
Tiles generated	9,291
Identified hotspots	343
Areas of high concentration	19

Source: Special Commission on Security, Justice, Crime and Transparency Statistics. Compiled by the authors

Over the last 40 years, the identification of small areas with high concentrations of crime has become a fundamental requirement for the efficient management of security (Weisburd et al., 2016). In this regard, Professor Sherman demonstrated empirically in the late 1980s that crimes are not randomly distributed in space (Sherman et al., 1989); on the contrary, he identified strong concentrations of crime at a micro-geographical level, known as ‘*hot spots*’;<sup>1</sup> Specifically, he found that 50 per cent of all emergency calls to the police over a two-year period originated from just 3 per cent of the city’s addresses. Similar studies have shown that 5 per cent of *hot spots* accounted for 50 per cent of all crimes (Weisburd et al., 2004).

Within this empirical context, a series of further studies confirmed that crime tends to be concentrated in very small areas. Thus, Weisburd (2015) formulated the ‘law of crime concentration’, arguing that, regardless of variability, there is a narrow range in the proportion of crimes concentrated in certain locations, suggesting a consistent pattern across cities of different sizes and characteristics. For a 50 per cent concentration of crime, the range was approximately 4 per cent of street segments — between 2.1 and 6 per cent — whilst, for a 25 per cent concentration, the range was less than 1.5 per cent — between 0.4 and 1.6 per cent.

The law of crime concentration has been confirmed in Europe, Asia, North America, Latin America and several countries in the Global South; all empirical studies show that there are micro-territorial units which account for a very significant proportion of crimes and, consequently, a high presence of situational factors that facilitate their commission in those specific locations. Furthermore, various studies have demonstrated the existence of temporal stability in crime concentration (Weisburd, 2015). In one specific case, in Seattle, it was found that, over a seven-year period, the bandwidths for the cumulative proportions of 50 per cent and 25 per cent of crime ranged between 4.6 and 5.8 per cent and between 0.9 and 1.2 per cent of street segments, respectively. From this perspective, the stability of crime concentration does not necessarily imply that specific hotspots remain constant over time.

<sup>1</sup> An area with a high concentration of crime compared with the distribution of crime across the entire study area. In other words, a geographical area in which the number of criminal incidents or disturbances is above average, or an area where people face a higher-than-average risk of victimisation.

In conclusion, the methodology proposed for the geographical targeting of violence in Ecuador—through the integration and complementarity of qualitative analyses and multidimensional territorial assessments—enables an understanding of the social, economic, institutional and criminal mechanisms underlying the persistence of these hyperconcentrations of homicides.

### 2.1.2. Contextualisation of hyper-focalised areas of violence

In Ecuador, to identify hyper-focalised areas of violence, a tessellation process was used to identify statistically significant areas of crime concentration and to examine the persistence of these hotspots over the last three years.<sup>2</sup>

Firstly, to statistically identify critical points of violence in Ecuador, the ‘Morán Local Index’ was applied to the tessellation units established across the entire territory. This index is obtained through spatial autocorrelation, which compares the value of a given geographical unit — hexagonal tiles — with that of adjacent geographical units (Buzai and Montes, 2021). This type of calculation is based on a fundamental law of geography: everything is related to everything else in space, but nearby things are more closely related than distant ones (Tobler, 1970); in this regard, it is found that areas of high crime surrounded by similar areas exhibit positive spatial autocorrelation, whilst areas of high crime adjacent to areas of low crime exhibit negative spatial autocorrelation.

*ArcGIS Pro* was used to calculate the Morán’s Index, which enabled the generation of an automated statistical report containing *z-scores* —high or low values suggest that the spatial distribution of homicides is not random— and *p-values* — indicating the level of statistical significance; a value below 0.05 indicates significance—and the index itself—which ranges from –1 to 1 and indicates the degree of autocorrelation.

Secondly, the temporal variation of the micro-territories or tiles within each territory was analysed. We identified statistically significant *hotspots* for each year, from 2022 to 2024. Subsequently, the levels of homicide concentration were classified within each tessera according to the following parameters: *high-high*, for areas which, in a given year, had high levels of criminal violence and were adjacent to territories also with high concentrations; *high-low*, for territories with high levels of criminal violence adjacent to areas of low concentration; *low-high*, for territorial units with low levels of criminal violence and adjacent to high-concentration territories; *low-low*, for territories with low levels of criminal violence bordering on low-concentration zones; *non-significant concentration*, for areas with a very low probability of intentional homicides; and finally, *areas of hyper-concentration*, which correspond to the micro-cells that maintained the high-high category for three consecutive years.

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<sup>2</sup> The entire district was divided into tiles represented by hexagons measuring 200 metres on each side. These tiles became our spatial units of analysis. Ignoring traditional territorial boundaries — as defined by the Secretariat for Planning — and instead using territorial units created by the analysts is a very common practice within the scientific community. This is because a set of regular units provides temporally stable cells, allows for the selection of cell size, ensures uniform coverage and enables the visualisation of absolute values, as all cells are the same size.

To determine whether the persistence of homicides in certain cells over a three-year period was not due to chance, the *p-value* and *z-score* were verified. Consequently, only those cells with *p-values* below 0.05 and classified as ‘High-High’ over the three-year period were identified as indicating that criminal violence in certain micro-territories is recurrent over time.

In summary, a concrete methodological framework is proposed for contextualising hyper-focalised areas of homicidal violence in Ecuador, aligned with government evidence on the concentration of crime in micro-locations and spatial analysis using the Morán’s Index. The combination of hexagonal tessellation, local spatial autocorrelation and a three-year temporal persistence criterion to define areas of hyperconcentration constitutes a technically suitable tool for determining and substantiating, through a comprehensive assessment, the dynamics of the phenomenon of violence affecting the national territory.

### **2.1.3. Cartographic representation and spatial analysis of critical zones**

In this analysis, tesserae — micro-territories — were identified with a statistically significant spatial concentration of intentional homicides in the Durán canton<sup>3</sup> and temporal stability, represented on the map in yellow. The Local Morán Index was calculated for each year to obtain the *z-score*, *p-value* and *index* values, as well as to generate the thematic layer of micro-territories with their different levels of concentration. In this way, the spatial representation made it possible to distinguish various levels of statistical concentration of intentional homicides in the Durán canton.

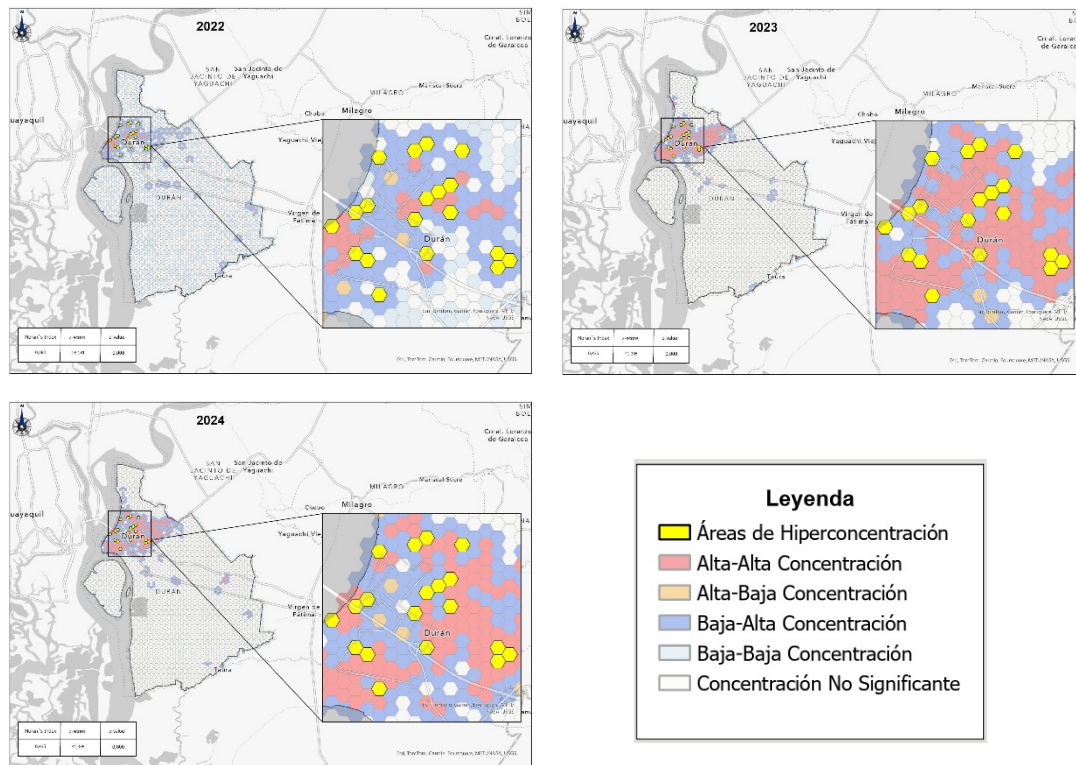
Among the micro-cells showing statistically significant values, the ‘*high-high* concentration’ category — shown in red — indicates units with high levels of homicides surrounded by other micro-cells also exhibiting high concentration. The ‘*high-low* concentration’ category describes areas with high levels of criminal violence bordering on zones of low concentration. The ‘*low-high* concentration’ category refers to units with low levels of criminal violence adjacent to areas of high concentration. The ‘*low-low* concentration’ category corresponds to areas with low levels of criminal violence bordering micro-cells of low concentration. Finally, the *areas of hyperconcentration* identify the micro-cells that maintained the ‘*high-high*’ status for three consecutive years.

Given this temporal persistence and the high density of criminal violence in the Durán canton, these micro-territories constitute areas of hyper-concentration and are therefore of particular relevance for the prevention of intentional homicides.

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<sup>3</sup> The canton of Durán belongs to the province of Guayas in Ecuador and is situated on the banks of the River Guayas, opposite the city of Guayaquil.

**Figure 1**  
 Areas of concentrated criminal violence in the Durán canton



Source: Special Commission on Justice Statistics. Note: The figure shows the identification of micro-territories with a statistically significant spatial concentration of intentional homicides in the Durán canton, as well as their temporal stability

Figure 1 shows that spatial autocorrelation—the Morán Local Index—identified 19 clusters<sup>4</sup> of hyperconcentration in the Divino Niño, Recreo, Liga Cantonal, Arbolito, Centro de Durán and Albert Gilbert, all within the Durán canton. These represent the micro-territories which, over three consecutive years—from 2022 to 2024—exhibited high levels of criminal violence and were surrounded by areas with a high incidence of intentional homicides. Furthermore, over the three-year period, clusters classified as ‘high-high concentration’ were identified in the Divino Niño, Recreo, Liga Cantonal, Arbolito, Centro de Durán and Albert Gilbert sectors, where rates of criminal violence significantly exceed the average and are surrounded by areas with equally high rates. These patterns of spatial autocorrelation are significant because they have annual p-values below 0.05 and favourable z-scores, suggesting that the observed clusters are not the result of chance.<sup>5</sup>

<sup>4</sup> A cluster is a group of incidents, places, people or cases that share similar characteristics and form a pattern relevant to the research.

<sup>5</sup> The Durán canton comprises 8 districts

**Table 2**  
Description of persistent violence hotspots over time.

Type of micro-territories	Year 2022	Year 2023	Year 2024
<b>Hyperconcentration</b>			19
<b>High-High concentration</b>	41	160	142
<b>High-Low concentration</b>	28	21	18
<b>Low-High concentration</b>	238	181	230
<b>Low-Low concentration</b>	1290	87	113
<b>Trace Concentration</b>	1500	2648	2594

Source: Special Commission on Justice Statistics

Table 2 shows the colour-coded classification of micro-territories based on the concentration of violence from 2022 to 2024. Of particular note is the temporal stability of certain micro-territories which, for three consecutive years, were classified as *having* a 'high-high' concentration; given this persistent condition, they came to be classified as areas of *hyper-concentration*. In total, there are 19 micro-territories which, over the last three years, have experienced significantly high levels of criminal violence and bordered on other territories also characterised by high levels of violence.

In conclusion, the cartographic representation and spatial analysis in the Durán canton demonstrate that homicidal violence is not a diffuse phenomenon, but is anchored in specific territorial micro-units. Using hexagonal tessellation and the Local Moran's I — applied annually from 2022 to 2024 — 19 micro-territories were identified that classify as areas of hyperconcentration, mainly in the Divino Niño, Recreo, Liga Cantonal, Arbolito, Centro de Durán and Albert Gilbert sectors. The persistence of these 'high-high' *clusters* over three consecutive years confirms the temporal stability of crime concentration and suggests the presence of structural factors that sustain the high level of violence in these areas.

## 2.2. TRENDS AND DETERMINANTS OF VIOLENCE IN ECUADOR: SOCIO-STRUCTURAL IMPACT AND THE CENTRAL ROLE OF FIREARMS IN LETHAL VIOLENCE

In 2010, Ecuador recorded an intentional homicide rate of 17.5 per 100,000 inhabitants, remaining in double figures until 2013, when the rate stood at 10.9. The Pan American Health Organisation (PAHO) and the World Health Organisation (WHO) have indicated that homicide rates exceeding 10 per 100,000 inhabitants constitute an indicator of epidemic-level violence. According to this criterion, Ecuador recorded levels of homicidal violence considered epidemic between 2010 and 2013, subsequently reducing its figures to fall below that threshold in 2014, when it recorded a rate of 8.2 homicides per 100,000 inhabitants. In 2016, Ecuador recorded a rate of 5.8 homicides per 100,000 inhabitants, one of the lowest levels observed in the country in recent decades.

The rate remained at 5.8 in 2017 and 2018, rising to 6.9 in 2019 and 7.8 in 2020; in 2021, the rate exceeded 14, at which point Ecuador once again faced an epidemic of violence, and since that year an exponential rise has been observed; in 2022 the rate stood at 27.58, rising to 46.25 in 2023 before recording a slight decrease in 2024 to 39.31, but rising again in 2025 to 51, making it the most violent year in Ecuador since 1980.

It has been found that six provinces in Ecuador (Guayas, El Oro, Santa Elena, Los Ríos, Manabí and Esmeraldas) account for 86 per cent of all violence occurring in the country; in other words, approximately nine out of every ten intentional homicides recorded in the country are concentrated in these six provinces. According to Alvarado and Muggah (2018), the patterns of homicidal violence differ from one country to another and even within the same country, from one city to another and between neighbourhoods within the same city. Therefore, understanding the nature of the phenomenon of violence and identifying the structural factors influencing its exponential rise is essential to grasping the origins of the problem.

Various studies have highlighted that processes of social exclusion, institutional weakness, the presence of illicit economies and the state's limited capacity to exercise territorial control can foster the emergence of contexts conducive to criminal violence. These factors often interact with highly profitable illegal markets, creating incentives for the consolidation of criminal organisations and an increase in violent conflicts.

Sen (2020) noted that development cannot be measured solely on the basis of economic growth, but must also take human development into account; in other words, 'the expansion of freedom is both the primary end of development and its principal means' (p. 16). Thus, development is not merely about observing an increase in economic indicators such as GDP, but also involves the elimination of certain forms of deprivation of liberty that leave individuals with few options and limited opportunities in life; and one such factor relating to personal freedom is the freedom to live in a safe environment, where their rights are respected and, above all, their life – the primary legal right that the State is called upon to protect.

A global perspective, as outlined by the United Nations Office on Drugs and Crime (UNODC, 2019), indicates that increases in homicide rates are frequently associated with social and economic indicators that change slowly. However, when rapid changes occur, the explanation is usually linked to organised crime. Sudden spikes in homicide rates are linked to shifts in power dynamics between competing criminal groups. These changes can be triggered by various factors, such as the emergence of a lucrative smuggling route that causes the groups involved to come into conflict. Globally, men and male adolescents aged 15 to 29 are at the highest risk of homicide, both as victims and as perpetrators; this is largely due to the situation in Latin America, where the causes of homicidal violence are frequently linked to gangs and organised crime.

Saborío (2019) conducted a study on the influence of drug-related violence in Costa Rica and found that the rise in homicides is linked to small-scale drug dealing and drug trafficking. Local organisations that begin by selling drugs in vulnerable communities can evolve and become part of the international drug trade network.

The approaches developed in the specialist literature allow for a partial interpretation of the recent evolution of criminal structures in Ecuador. From this perspective, it can be argued that certain local criminal organisations gradually evolved until they became integrated into transnational drug trafficking networks, thereby gaining greater financial resources and operational capacity. This process is thought to have facilitated the consolidation of criminal alliances and the expansion of complementary illicit activities that strengthened their territorial presence.

Competition between criminal organisations is thought to have encouraged the systematic use of violence as a means of territorial control and positioning within illicit markets. In this context, firearms became the primary physical enabler, as shown below:

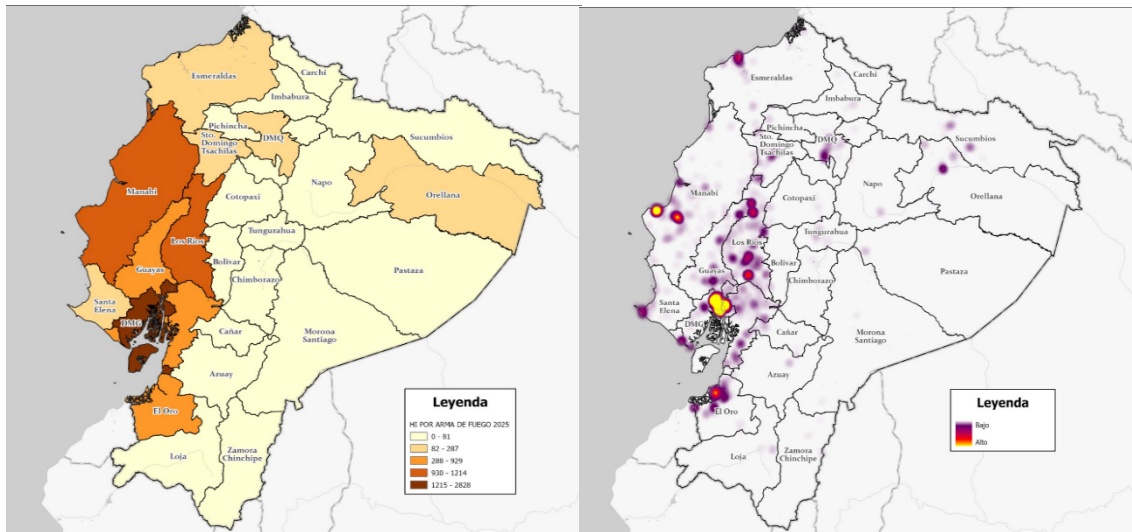
**Table 3**  
*Intentional homicides committed with firearms in 2025, by sub-zone*

<b>Sub-zone</b>	<b>H.I. Firearm</b>
DMG	2828
Manabí	1214
Los Ríos	1199
Guayas	903
El Oro	667
Esmeraldas	287
Santa Elena	214
DMQ	163
San Diego de los Tsáchilas	121
Orellana	120
Sucumbíos	81
Cañar	57
Tungurahua	39
Bolívar	32
Pichincha	29
Cotopaxi	25
Azuay	20
Loja	20
Imbabura	19
Napo	17
Zamora Chinchipe	15
Pastaza	15
Morona Santiago	14
Chimborazo	10
Carchi	6
<b>Grand total</b>	<b>8,115</b>

Source: Special Commission on Justice Statistics.

In 2025, a total of 9,234 intentional homicides were recorded in Ecuador, of which 8,115 – that is, 88 per cent – were committed with a firearm. This means that of every 10 intentional homicides occurring in Ecuador, 9 were committed with firearms during that year. The zones and sub-zones where these incidents are concentrated are: Zone 8 DMG with 2,828 intentional homicides, Manabí with 1,214, Los Ríos with 1,199, Guayas with 903, El Oro with 667, Esmeraldas with 287 and Santa Elena with 214.

**Figure 2**  
*6 e choropleth map showing the concentration of H.I. by firearm in 2025*



Source: Special Commission on Justice Statistics and author's own analysis

The maps show the distribution of homicides committed with firearms in Ecuador during 2025, broken down by province. It can be seen that the province of Guayas has the highest levels of violence, followed by Manabí and Los Ríos, which also show significant levels of violence. In contrast, the Amazon region and most of the south-central highlands have the lowest rates.

In summary, over the past decade, homicide rates in Ecuador have shifted from a 'island of peace' scenario—with rates below the epidemic threshold set by PAHO and the WHO—towards a criminal epidemic, characterised by exponential spikes that place the country among the deadliest in the world. The transition from single-digit rates to figures exceeding 40 homicides per 100,000 inhabitants in just a few years reflects a structural breakdown in security, consistent with regional evidence linking these figures to the reconfiguration of criminal markets and disputes between organisations involved in drug trafficking and related illegal economies.

### 3. TRACEABILITY AND IDENTIFICATION OF FIREARMS: CHALLENGES IN THEIR TRACKING, CLASSIFICATION AND BALLISTIC ANALYSIS

#### 3.1. UNMARKED PRIVATELY MANUFACTURED FIREARMS: CHALLENGES IN THEIR TRACING, CLASSIFICATION AND CRIMINAL INVESTIGATION

As part of the operational and tactical interventions carried out in Ecuador by the Armed Forces and the National Police, firearms that have been the subject of illicit trafficking, as well as those used in intentional homicides, have been seized. Such findings are of particular relevance in judicial proceedings and criminal investigations, where the aim is to obtain as much information as possible: the perpetrators, the methods employed,

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<sup>6</sup> A choropleth map is a type of thematic map that represents the spatial distribution of a quantitative variable by using different shades or colours within predefined geographical areas, enabling patterns to be identified and comparisons to be made between regions.

the resources obtained and the links between members of criminal groups. For this reason, conducting an investigation into arms trafficking requires precise information on the firearms, such as their origins, manufacturer details and the routes taken, all with the aim of establishing traceability.

In the past, the acquisition of firearms might have been associated with traditional concepts linked to the arms industry, but this notion has changed and today we face new dynamics (Fletcher et al., 2026, p. 3), at present, the illicit trafficking of firearms is driven by new dynamics associated with black markets, transnational criminal networks and decentralised manufacturing processes. In the Ecuadorian market, the cost of firearms varies significantly depending on their origin, being considerably higher in the case of industrially manufactured weapons, whilst artisanal or locally produced versions are sold at notably lower prices.

Firearms manufacturing processes have undergone a revolution in recent times, as production has been liberalised in terms of design, manufacture and marketing. The United States has been one of the pioneering countries in driving this transformation, from the first 3D printers used by Cody Wilson to the present day, with manufacturing using aluminium blocks or metal powder printers (Armament Research Services [ARES], 2015). This development has been driven by collaborative manufacturing communities linked to the *maker* movement, whose principles promote the open sharing of designs, knowledge and tools for the independent production of various objects, including firearms. The digital dissemination of design files and manufacturing processes has facilitated access to technologies that previously required specialised industrial capabilities. As a result, criminal organisations can exploit these resources to manufacture, modify or assemble firearms outside traditional state control mechanisms, creating new challenges for criminal investigation and ballistic traceability (Gavilán, n.d.).

In Ecuador, specifically in the city of Manta, a clandestine workshop was discovered in 2023 that possessed 3D printers and CNC machines — originally known as computer numerical control machines — which were being used to manufacture the FGNE submachine gun — Sig Sauer MCX Rattler model; during the investigations, it was established that the organisation had a specialist in manufacturing and design, and .CAD, .CN, .STL and GCODE design files were found in their possession, all of which are used in printing and machining equipment (Teleamazonas, 2023); A key point is that this suggests the scope of such manufacturing poses a challenge to the investigation itself, since if the designs are accessible to anyone, it is possible to manufacture parts and components and modify weapons in terms of calibre or lethality—aspects that are essential when launching an investigation. So-called ‘ghost guns’ are so named because they lack conventional identification features, such as serial numbers, manufacturing records or formal traceability mechanisms. They are generally composed of parts and components acquired separately, assembled using private manufacturing processes or 3D printing technologies. In the United States in particular, a regulation issued by the *Bureau of Alcohol, Tobacco, Firearms and Explosives* (ATF) – part of the Department of Justice – permits the sale of firearm parts and components, but prohibits the sale of the basic structure, such as the receiver in long guns and the frame in handguns. It is in this context that, invoking the Second Amendment, certain sectors of society have manufactured their own action blocks and frames, and using parts purchased online have managed to assemble functional firearms (Policing Institute, 2026).

Alongside members of the public, there are private companies which, as part of this community, have specialised in the sale of parts and components for long and short firearms, including frames that are not fully manufactured but are 70 per cent complete, selling them alongside the accessories and tools required to complete their assembly. For example, mechanism frames for long guns are offered, made of aluminium and shaped to accommodate the component holes, but without the holes for the fasteners (Europol, 2025). One might think that, if the law permits the possession of a firearm, it would not allow it to be outside the legal framework; however, these ‘maker’ movements have set up clubs where people can use their replica firearms and fire them, as evidenced in written and audiovisual publications or on social media (Throwing Copper CRA, 2024).

The security agencies responsible for controlling and monitoring the use of firearms in various countries base their work on databases compiled from import and sales records, as well as applications for firearms licences. This entire chain generates records and traceability that can be used in criminal investigations. However, when it comes to ‘ghost’ or privately manufactured firearms, in most cases they do not have a serial number; although on some occasions the manufacturer under whose name they are sold can be identified, this poses difficulties for criminal investigations, as their true origin cannot be ascertained, which benefits criminal organisations by preventing traceability (Fletcher et al., 2026, p. 5).

According to data gathered from the media, it has been established that firearms trafficking originates in the south, from Peru, and enters the country via seaports. However, these are not the only sources; there are also light aircraft arriving from Central America or shipments via international post, meaning that establishing a clear line of inquiry is only possible within the context of a specific investigation. For example, in the *Casador* case in Peru, a company was involved that sold firearms to front men, who then reported them as stolen; these were subsequently trafficked to Ecuador, and one of these weapons was identified as having been used in the murder of presidential candidate Fernando Villavicencio; another significant case is the seizure of firearms off the coast of the Galápagos Islands, where it was established that some of the weapons lacked identification as they were privately manufactured (Insight Crime, 2023).

The situation is further complicated when weapons are manufactured using 3D printers, as the models are available for free download, making identification even more difficult, given that both the designs and the manufacturing processes are open-source (ARES, 2015).

### **3.1.1. Ballistic tracing tools and systems: implementation and limitations of the IBIS system**

IBIS is one of the most important technological tools in the forensic analysis of firearms; this system enables the digital capture and comparison of the microscopic markings that the weapon’s mechanical components—such as the firing pin, extractor and chamber—leave on bullets and cartridge cases at the moment of firing.<sup>7</sup> It should

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<sup>7</sup> In forensic ballistics, the term ‘projectile’ is used to refer to the element of the cartridge which, upon firing, is propelled through the barrel and travels towards its target. Once this element has lost its momentum and is recovered as physical evidence, it is usually referred to as a bullet in certain technical and operational contexts and in certain forensic fields. Microscopic markings produced by the individual

be noted that the IBIS system is one of several Automated Ballistic Identification Systems (ABIS) available internationally. There are other technological solutions with similar functionalities, including Evofinder, BalScan and Sensofar, which are used by various law enforcement agencies and forensic laboratories.

As these markings possess unique characteristics resulting from wear and tear and the specific features of the firearm, IBIS facilitates the identification of matches between ballistic evidence recovered from different crime scenes, enabling links to be established between violent incidents that might, at first glance, appear unrelated.

In investigations into intentional homicides, ballistic cartridge cases recovered from the crime scene constitute a source of evidence of high probative value. During the firing process, the firearm imprints a series of micro-markings on the cartridge case that reflect the internal characteristics of the mechanism that fired the shot. Comparative analysis of these marks enables ballistics experts to determine whether different cartridge cases originate from the same firearm, helping to reconstruct the sequence of events and establish possible links between different criminal incidents (Houck & Siegel, 2015).

Various studies have indicated that, in the context of organised crime, it is relatively common for the same firearm to be used in multiple violent incidents over time; this reuse is due, amongst other factors, to the limited availability of illegal weapons and the need to maintain operational resources within criminal organisations. Consequently, ballistic analysis makes it possible to identify patterns of repeated use of specific firearms, facilitating the linking of intentional homicides involving the same weapon (Braga & Cook, 2018).

From a criminal analysis perspective, the information derived from ballistic analysis is of significant strategic value; identifying matches between cartridge cases recovered at different crime scenes reveals hidden connections between violent incidents, contributing to an understanding of the territorial dynamics of homicidal violence. This type of analysis also facilitates the identification of potential repeat offenders, patterns of weapon movement, and geographical areas where certain criminal phenomena are concentrated (Ratcliffe, 2016).

The analytical potential of the IBIS system is considerably enhanced when ballistic information is integrated with other sources of criminal data, such as police records, territorial intelligence and analyses of patterns of violence; this integration enables a more comprehensive understanding of the role played by firearms in shaping homicidal violence and in the dynamics of criminal conflicts. In this way, ballistic analysis not only contributes to the forensic investigation of individual cases, but also becomes a key tool for developing strategies to prevent and control armed violence (Wellford, Pepper & Petrie, 2005).

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characteristics of the firearm can be observed on this element; these form the basis of ballistic identification processes. The cartridge case is the metal component of the cartridge that contains the other elements of the ammunition and which, after the shot is fired, remains in the chamber before being ejected during the firearm's firing cycle. For the sake of clarity, this study will primarily use the technical terminology specific to forensic ballistics.

The implementation of the system has made it possible to link cases and identify firearms across different investigations; to ensure the system remains technologically up to date, it was upgraded with the latest IBIS technology from the Canadian company Forensic Technology —now part of LeadsOnline— and a key feature of this system is that it allows connection to an international network of IBIS systems, facilitating the exchange of information between countries in the region (IBIN Manual, n.d.).

Correlation takes place in two areas: the first links cases involving violent incidents based on ballistic evidence — bullets and cartridge cases — which, depending on the timing, can be linked across different dates when an unidentified firearm has been fired in multiple incidents; the second area links ballistic evidence collected at different crime scenes with ballistic records registered by firearms control authorities or obtained through forensic analysis, thereby establishing their origin (ISUPOL Research Journal, 2023). This approach has been extremely useful in solving cases, particularly those involving homicides; however, the system’s effectiveness depends largely on the number of cases recorded: the greater the volume and variety, the higher the probability of correlation. The identification of firearms and their origin will depend on whether they are registered in the system, thereby establishing traceability (IBIN Manual, n.d.).

Computer systems and databases constitute another strength in the fight against arms trafficking and in criminal investigations; one aspect to consider is the tracing of firearms via the ATF’s *eTrace* system, which has made it possible to trace firearms sold from the United States and distributed internationally, facilitating the tracing of those used in illegal acts (Policing Institute, 2026). At the local level, the first generation of IBIS was implemented approximately ten years ago, with the creation of databases integrating records of firearms control managed by the Ecuadorian Armed Forces, police firearms, and bullets and cartridge cases recovered from crime scenes or obtained through ballistic analysis (ISUPOL Research Journal, 2023); furthermore, the Ecuadorian Armed Forces manage the 5ARM system database, which is responsible for the control and issuance of certificates for firearms possession licences, maintaining information on legally held firearms belonging to individuals and legal entities. According to legal regulations, the Ecuadorian National Police has the authority to trace firearms in criminal cases.

The limitation of these computerised tracing systems arises when seized firearms lack serial numbers or markings; whilst it is true that some may undergo restoration processes, this only applies to a small number of weapons; consequently, in other cases, as they lack serial numbers, it is not possible to determine their origin or place of manufacture unless a private-sector brand or company can be identified (Small Arms Survey, 2023)

### 3.2. LIMITATIONS OF THE STUDY

This research has limitations arising from the nature of the administrative records used. The database on intentional homicides contains both public variables and variables that are restricted for reasons of security and the protection of sensitive information. Furthermore, the spatial accuracy of the analyses depends on the quality of the georeferencing processes and the institutional validation of the records. Finally, the results reflect only officially recorded events; therefore, future updates or statistical reclassifications could partially alter some of the findings.

Furthermore, due to the observational nature of the study, the results allow for the identification of spatial associations and patterns of concentration, but do not establish direct causal relationships between the variables analysed.

### 3.3. IMPLICATIONS FOR CRIMINAL INVESTIGATION

The findings highlight several operational challenges for criminal investigations and the traceability of firearms used by criminal organisations. In particular, the growing prevalence of privately manufactured firearms necessitates strengthening the technical capabilities of forensic laboratories and expanding institutional and international cooperation mechanisms to improve identification and tracing processes.

To improve the effectiveness of methods for tracing privately manufactured or 'ghost' firearms, it is necessary to recognise that forensic ballistics studies can gather information which, when analysed collectively, enables the tracing of manufacturers, the identification of points of sale, potential routes and the ways in which criminal organisations use them. At present, information derived from expert reports and the records contained in the IBIS system constitutes a key source for criminal analysis, the identification of criminal patterns and the ballistic tracing of firearms used in violent incidents.

One of the main challenges for contemporary ballistic investigation is determining whether the weapons analysed are industrially manufactured or privately manufactured. In this context, ballistics experts must possess specialist knowledge that goes beyond the analysis of a weapon's operating mechanisms, incorporating skills aimed at determining its origin through the examination of markings and serial numbers; the detection of attempts to remove, alter or falsify identifying features; identification of modifications relating to calibre, firing capacity or lethality; and distinguishing between original firearms, replicas and privately manufactured firearms.

This last aspect constitutes an emerging phenomenon of particular relevance to criminal investigations, as the processes involved in the manufacture of privately made and industrially produced firearms may employ similar technologies, materials and equipment. However, differences tend to manifest themselves in the quality of the finish, the assembly mechanisms, functional modifications and the adaptation of components intended to alter the calibre, operational capacity or ballistic performance of the firearm.

## 4. CONCLUSIONS

The findings suggest that homicidal violence in Ecuador has undergone a structural transformation in recent years, as evidenced by the sustained increase in intentional homicides, which reached a historic rate of 51 per 100,000 inhabitants in 2025. The spatial analysis carried out identified persistent patterns of territorial concentration of violence, particularly in the canton of Durán, where the existence of areas of hyperconcentration confirms the temporal stability of certain criminal risk scenarios.

Firearms remain the primary means of committing homicides in Ecuador, which poses technical and operational challenges for forensic science and public safety. Ballistic analysis, supported by systems such as IBIS, has proved to be an effective tool for identifying weapons and linking violent incidents, thereby enabling the reconstruction of criminal sequences and the establishment of connections between

different cases that may occur in Ecuador or, through international judicial assistance mechanisms, in other countries in the region or around the world.

However, the emergence and proliferation of privately manufactured firearms, particularly those produced using three-dimensional (3D) printing and computer numerical control (CNC) machining technologies, poses a growing challenge to traditional systems of control, tracing and criminal investigation. The absence of serial numbers, the ease with which essential components can be modified, and the ongoing refinement of manufacturing processes significantly hinder the identification, classification and traceability of these weapons, thereby reducing the capacity of conventional mechanisms to determine their origin, routes of circulation and possible links to criminal activities. Consequently, this phenomenon calls for the strengthening of the technical capabilities of forensic laboratories, the ongoing updating of ballistic identification systems, and the development of national and international cooperation mechanisms to tackle new forms of trafficking and the illicit use of firearms more effectively.

The findings of the research lead to the conclusion that homicidal violence in Ecuador exhibits patterns of spatial concentration that are highly consistent with international evidence derived from environmental criminology and place criminology. The identification of persistent areas of hyperconcentration over several consecutive years confirms that lethal violence is not distributed randomly across the territory, but rather responds to structural dynamics associated with specific social, economic and criminal factors. In this regard, the findings support the need to implement prevention strategies targeted at high-risk micro-territories, optimising the allocation of institutional resources and strengthening local security governance.

Similarly, the growing presence of privately manufactured firearms and the expansion of decentralised production technologies represent an emerging challenge for traditional systems of control, tracing and criminal investigation. The evolution of these methods requires the strengthening of forensic capabilities, the ongoing updating of automated ballistic identification systems and greater international cooperation to trace weapons used by organised crime networks.

Finally, future research should explore in greater depth the relationship between the spatial concentration of homicides, criminal markets and the circulation of firearms, incorporating longitudinal analyses and predictive models that enable a more precise understanding of the factors underlying the persistence of lethal violence in certain areas of Ecuador.

The findings reinforce the need to integrate spatial analysis tools, criminal intelligence and ballistic traceability as complementary components in the design of public policies aimed at reducing lethal violence in Ecuador.

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