

Article

Predatory Placement and Urban Vulnerability: A Geospatial Accessibility Analysis of Gambling Venue Proximity to Sensitive Community Facilities in Romania

Mihnea Cristian Popa ¹, Diana Stoica ², Daniel Constantin Diaconu ¹ and Daniel Peptenatu ^{1,*}

¹ Interdisciplinary Center for Advanced Studies, University of Bucharest, 010041 Bucharest, Romania; mihnea.cristian.popa@drd.unibuc.ro (M.C.P.); daniel.diaconu@unibuc.ro (D.C.D.)

² Romanian Government, Strada Izvor, Nr. 2-4, Sector 5, 050711 Bucharest, Romania; diana.stoica@cdep.ro

* Correspondence: daniel.peptenatu@geo.unibuc.ro

Abstract

The proliferation of gambling infrastructure within the urban environment has emerged as a significant public health concern, particularly in contexts where commercial interests intersect with the socio-economic vulnerability of resident populations. The paper investigates the spatial distribution of slot-machine gambling venues across important Romanian cities, testing the hypothesis of predatory placement. Utilizing February 2026 official licensing data from the National Office for Gambling (ONJN) and Geographic Information Systems (GIS), the research conducts a comprehensive geospatial accessibility analysis relative to sensitive community infrastructures. These include educational institutions, healthcare facilities, and religious sites, alongside socio-economically vulnerable residential zones. The methodology integrates network-based isochrone analysis, spatial density mapping, and proximity modeling to quantify effective accessibility within defined spatial ranges. These techniques identify high-exposure zones where dense gambling clusters intersect with protected institutional environments and marginalized populations. Results indicate a statistically significant spatial correlation between venue density and the immediate proximity of these sensitive community facilities. Furthermore, the findings provide a spatial evidence base for recent legislative shifts which empower local authorities to implement localized bans on physical gambling venues. Ultimately, this research illustrates how venue accessibility fosters urban risk landscapes, suggesting that local spatial autonomy is an essential pillar in mitigating gambling-related social harm.

Keywords: social vulnerability; gambling; network accessibility analysis; public health; gambling-related harm

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1. Introduction

The global landscape of gambling has undergone a profound transformation over the last century, evolving from a condemned and often illegal activity into a widely practiced and legitimate form of leisure. This process, described by sociologists as a “normalization” represents the transition of a behavior from one moral status to another, moving from deviancy to normalcy. As jurisdictions worldwide have expanded gambling options to generate state revenue and stimulate economic development, gambling has become an

established component of contemporary leisure economies and a rapidly expanding private industry [1]. However, this expansion has not been without significant social costs, presenting persistent challenges to community cohesion and civic life [2].

The normalization of gambling is inextricably linked to its recognition as a major public health concern. Research consistently demonstrates that gambling behavior is associated with a spectrum of psychiatric symptoms, including anxiety, depression, and associated features such as low self-esteem [3]. Beyond individual psychological distress, the proliferation of gambling venues is a significant predictor of severe financial instability. For instance, empirical evidence from North American markets suggests that the presence of casino-type gambling increases the rate of personal bankruptcy filings by approximately 2%. These negative consequences often extend beyond the individual gambler, affecting family members and “concerned significant others” (CSOs) through emotional distress, relationship disruption, and financial harm [4,5].

A critical dimension of contemporary gambling expansion is the phenomenon of “predatory placement” where gambling venues are strategically located to exploit urban vulnerability. Spatial accessibility plays a fundamental role in the development of gambling-related harm, as increased proximity to venues lowers the threshold for participation. In many jurisdictions, land-based gambling, particularly with electronic gambling machines (EGMs), is characterized by its high availability in convenience locations such as kiosks, grocery stores, gas stations, and restaurants. This “convenience gambling” model allows for fast and immersive play that can be initiated impulsively during daily routines. Furthermore, certain gambling formats are significantly more conducive to problem gambling than others. EGMs and casino games, which allow for rapid and continuous play, are more closely associated with problematic behavior than traditional jackpot lotteries [6].

The risk is particularly acute for vulnerable populations, including adolescents and young adults. Early onset of gambling during adolescence is a strong predictor of pathological gambling and psychiatric problems in adulthood [7]. Adolescents who engage in both smoking and gambling exhibit even more severe patterns of behavior, suggesting that smoking may serve as a clinical marker for increased gambling severity. Moreover, the transition from recreational to problematic gambling is often moderated by the gambler’s attitudes; individuals at higher risk of problem gambling tend to rationalize their experiences and maintain positive attitudes towards gambling despite incurring mounting losses [6,8–12].

Implementing effective public health interventions is often hindered by the complex network of financial stakeholders who benefit from gambling revenue. This “gambling establishment”, comprising the industry, state governments, and even non-profit organizations, often depends on gambling surplus to fund state budgets, sports, and cultural initiatives. In some European contexts, up to 60% of all gambling revenue is derived from individuals who are heavily harmed by their gambling behavior. This creates a systemic conflict of interest where governments may downplay the social costs of gambling to preserve revenue streams, often opting for responsible gambling frameworks that emphasize individual responsibility rather than structural regulations [13,14].

In Romania, the proliferation of gambling venues has reached a point of critical social tension, as reflected by public advocacy platforms such as *farapacanele.ro* [15]. These movements signal a growing community resistance against the saturation of urban spaces with betting shops and slot-machine parlors, particularly in low-socioeconomic areas and in the vicinity of schools. The legislative response to these concerns culminated in the Emergency Ordinance (Ordonanța de Urgență) no. 7 of 24 February 2026. This regulation marks a significant shift toward the decentralization of gambling control, empowering

local administrative authorities to determine the presence and density of gambling activities within their territories.

Under OUG 7/2026, a licensed operator must now obtain not only a national license and authorization from the National Office for Gambling (ONJN) but also a “local functioning authorization” from the administrative-territorial unit where they intend to operate. Crucially, the Local Council now has the authority to decide by resolution whether gambling activities are permitted at all within their jurisdiction. If permitted, the local authority is empowered to establish specific zones where these activities can occur and to set local taxes based on the square footage of the venue. These decisions must be based on criteria established by the local council’s own regulations, respecting “local development priorities” and “norms for the protection of public order, health, and safety” [16].

Despite these new powers, local authorities face the technical challenge of translating broad legislative mandates into effective spatial policies. Geospatial analysis provides a robust framework for identifying patterns of predatory placement and assessing urban vulnerability. By mapping the proximity of gambling venues to sensitive community facilities, such as educational facilities, healthcare centers, and religious or recreational sites, local authorities can develop evidence-based zoning regulations to mitigate harm.

Nevertheless, several recurring limitations can be identified. First, accessibility is frequently operationalized through administrative-level availability counts or fixed Euclidean buffers, for example, the 400 m radius employed by Wardle et al. [17], which fail to capture the morphological constraints of the pedestrian street network and conflate geometric proximity with realized behavioral access, a distinction highlighted by recent work on “daily encounters” [18]. Second, the empirical evidence is concentrated in Western European, Nordic, and Anglophone contexts (Great Britain, Australia, Finland, Quebec, Spain), while South-Eastern Europe, and Romania in particular, lacks machine-level spatial assessments. Third, existing vulnerability models such as the ecological exposure index proposed by Papineau et al. [19] rarely condition risk on the simultaneous satisfaction of proximity to machines and network-based pedestrian accessibility. The present study addresses these limitations.

This study investigates the regulatory capacity of local authorities to shape the spatial distribution of gambling venues in urban areas. It examines how the competencies introduced by recent Romanian legislation can be operationalized through geospatial analysis to mitigate urban vulnerability. By assessing zoning regulations, and proximity restrictions, the paper develops a framework through which local governments can reconcile economic activity with public health protection.

The contributions of this study are fourfold. (1) It provides the first machine-level, network-accessibility assessment of predatory gambling placement in a Central-Eastern European context. (2) It develops a transferable and replicable analytical framework integrating H3 hexagonal tessellation, network-derived pedestrian isochrones, ensemble machine learning for spatial-determinant analysis, and a multiplicative vulnerability score that formally distinguishes geometric proximity from realized behavioral accessibility. (3) It validates the predatory-placement hypothesis across three cities of contrasting scale, economic profile, and morphology, demonstrating that the pattern is structural rather than incidental. (4) It produces a spatial evidence base that directly operationalizes the local zoning competencies introduced by OUG 7/2026, enabling evidence-based exclusion-zone delineation.

2. The Socio-Economic Landscape of Gambling in Romania

To understand the spatial footprint of gambling in Romanian cities, one must first examine the industry’s massive economic consolidation over the last quarter-century. This analysis utilizes a longitudinal dataset sourced from the Romanian Ministry of Public

Finance, covering all registered legal entities from 2000 to 2024. The data is filtered by CAEN code 9200, an acronym for Clasificarea Activităților din Economia Națională (Classification of Activities in the National Economy). This system is the Romanian statutory standard for classifying economic activities and is fully harmonized with the European Union's NACE (Nomenclature des Activités Économiques dans la Communauté Européenne) framework. Specifically, code 9200 designates “Gambling and betting activities”, encompassing the operation of casinos, slot-machine parlors, bookmaking, and lottery services.

The transition of gambling from a rather small economic activity to a central pillar of the contemporary leisure economy has produced an industrial landscape characterized by a profound asymmetry between economic expansion and territorial saturation. By corroborating financial indicators across this 25-year window, this section highlights a process of accelerated market maturation where a numerical decline in independent operators has coincided with an exponential increase in aggregate revenues.

2.1. Market Consolidation: The Rise of Romania's Gambling Industry

A longitudinal analysis of the Romanian gambling sector (2000–2024) reveals a profound structural metamorphosis, transitioning from a fragmented, peripheral market into a highly consolidated and vertically integrated industrial complex. This evolution is most accurately characterized through the conceptual lens of an Extractive Economic Model. As posited by Acemoglu and Robinson, extractive institutions are architected to facilitate the systematic transfer of wealth from a broad societal base to a specialized subset, thereby stifling the incentives requisite for inclusive economic development [20,21]. In this context, the industry's capital accumulation has effectively decoupled from traditional operational requirements, specifically physical labor intensity and localized geographical presence.

This structural divergence becomes particularly visible when examining the longitudinal relationship between revenue growth, workforce dynamics, and firm concentration within the sector. Over time, the expansion of aggregate revenues has not been accompanied by proportional increases in employment or by a broader spatial diffusion of economic activity. Instead, the empirical evidence points toward a process of progressive market consolidation, in which a diminishing number of operators capture an increasing share of total sectoral value.

The financial trajectory of the Romanian gambling sector from 2000 to 2024 provides empirical evidence of a market transitioning into a highly efficient extractive apparatus. During the initial phase of the analyzed period, the industry maintained a relatively proportional relationship between fiscal growth and operational expansion. However, the subsequent two decades reveal a structural shift wherein Aggregate Net Profit (Figure 1) accelerated at a rate that fundamentally decoupled from the industry's physical and human infrastructure. By 2024, the cumulative profit growth of approximately 5972% (a 60-fold increase) underscores a transition from a service-oriented niche into a centralized financial complex. A critical observation lies in the profound divergence between capital accumulation and the scaling of traditional production factors. While sectoral profit and revenue expanded by a factor of 60, the total labor force grew by only 3.2×, and the geographical footprint measured by active Administrative-Territorial Units (UATs) increased by a mere 1.6×.

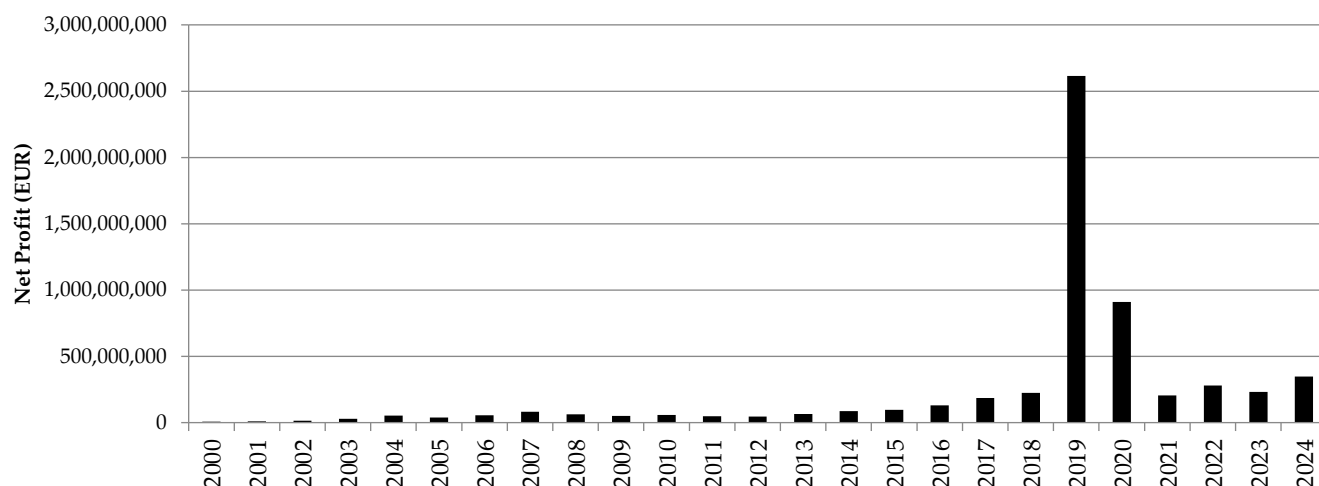


Figure 1. Longitudinal Analysis of Aggregate Net Profit (2000–2024).

This disproportionate scaling indicates that the industry has successfully optimized its “extractive efficiency,” leveraging technological and organizational consolidation to capture increasing surplus value without a corresponding expansion in its physical or operational base. In an inclusive economic model, a 60-fold increase in profit would typically necessitate a proportional commitment to human and spatial resources. In contrast, the Romanian data demonstrates an evolution toward a model where profit generation is increasingly invariant to traditional operational requirements, effectively isolating capital accumulation from the broader socio-economic dynamics of the national labor and territorial markets.

Complementing the surge in net profitability, the evolution of Aggregate Revenue provides a definitive measure of the sector’s expanding fiscal throughput and its capacity for wealth extraction (Figure 2). Between 2000 and 2024, the industry’s gross intake escalated from 49 million euros to approximately 2.9 billion euros, representing a cumulative expansion of 6118%. The near-perfect symmetry between the growth rates of revenue and net profit indicates that the industry has maintained an exceptionally high and stable conversion of societal liquidity into industrial capital. This suggests that the “extractive efficiency” of the sector is not merely a result of cost-cutting, but a consequence of the massive scaling of total capital inflow from the population.

This revenue trajectory provides further empirical weight to the argument regarding geographical and operational decoupling. The fact that aggregate revenue increased 61-fold while the number of active Administrative-Territorial Units (UATs) grew by only 1.6× points to an unprecedented intensification of spatial yield. In practice, this means the industry has transitioned from a strategy of horizontal expansion (seeking growth through new territories) to one of vertical intensification. Through the implementation of digital platforms and high-frequency gambling mechanisms, the industry has successfully multiplied the volume of capital extracted from each geographical node, effectively rendering its revenue growth independent of territorial spread.

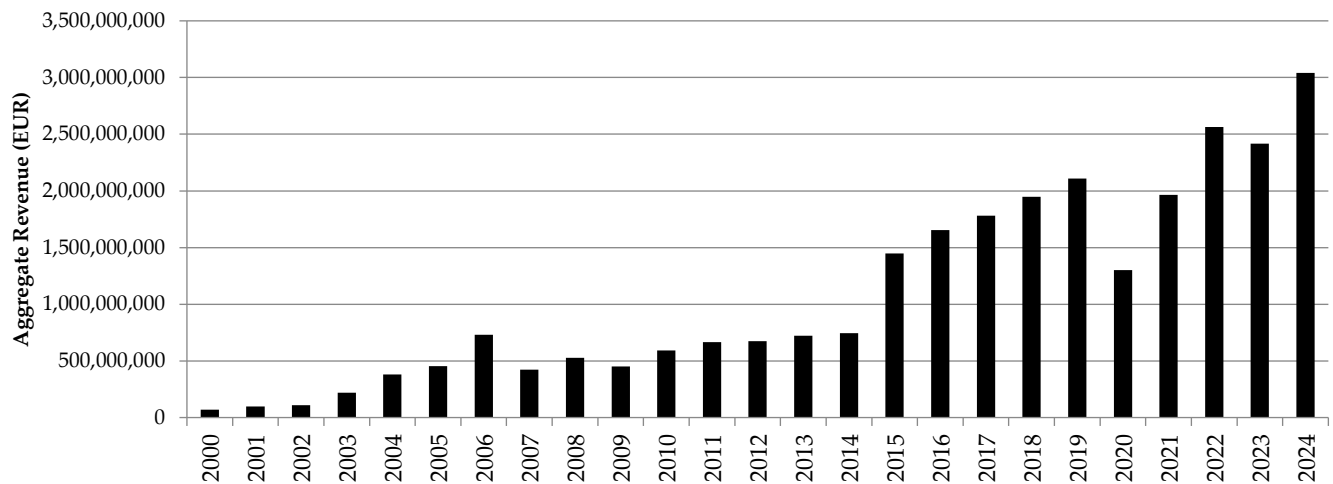


Figure 2. Longitudinal Analysis of Aggregate Revenue (2000–2024).

Furthermore, the stability of this 61-fold revenue increase across two decades indicates a highly resilient market structure that remains unaffected by the diminishing returns typically associated with traditional service industries. In an inclusive industrial framework, such explosive revenue growth would be expected to generate substantial economic “spillovers,” such as a diversified supplier base or a massive increase in sectoral employment. However, the Romanian data shows that the revenue growth is captured within an increasingly consolidated and vertically integrated system. This aligns with the defining characteristics of an Extractive Economic Institution, where the primary function of the industry is to serve as a high-capacity conduit for the systematic transfer of wealth from a broad base of users to a concentrated industrial core.

An important clarification concerns the composition of the revenue figures discussed above. These data derive from the CAEN 9200 economic activity code, which aggregates both land-based and online gambling operations and does not permit a clean separation of the two at the source. The aggregate figures are retained only as a sector-wide indicator of the extractive intensity of the gambling industry as a whole; the spatial argument of this study rests entirely on the georeferenced distribution of licensed physical premises, not on revenue data. It is precisely the physical, land-based segment that this study seeks to make visible and, through the spatial-planning instruments discussed below, to enable local authorities to regulate physical locations, while online consumption falls outside the reach of municipal zoning competencies.

The maturation of this revenue model is especially evident in the final five years of the analysis (2019–2024), where the velocity of capital accumulation reached its peak despite a stabilizing physical presence. This confirms that the industry has achieved a state of scale-invariance, where the ability to generate billions in additional revenue is no longer constrained by the need for more physical agencies or a larger workforce. Instead, the revenue growth is driven by a centralized technological infrastructure that maximizes the frequency and volume of transactions, thereby solidifying the sector’s position as a dominant extractive complex within the national economy.

The longitudinal analysis of the sector’s spatial footprint, quantified through the number of Active Administrative-Territorial Units (UATs), reveals a state of geographical stagnation that stands in stark contrast to the industry’s financial trajectory. Between 2000 and 2024, the number of UATs with an active gambling presence increased from 92 to 155, representing a total expansion of only 68% (a 1.6× increase) (Figure 3). This modest growth, characterized by a marginal Compound Annual Growth Rate (CAGR) of 2.20%, indicates that the industry has not pursued a strategy of broad horizontal expansion. In-

stead, the data suggests a process of geographical intensification, where capital is extracted with increasing density from a relatively fixed set of urban and administrative nodes.

This spatial trend provides the empirical foundation for the geographical decoupling hypothesis. In a traditional inclusive market, a 6000% increase in revenue would typically necessitate a proportional expansion into new territories to capture untapped consumer bases. However, the Romanian gambling sector has demonstrated a capacity for “geographical invariance,” where financial accumulation is no longer contingent upon a physical presence in more localities. This shift reflects the emergence of a digitally mediated spatial model in which revenue growth is no longer strictly dependent on territorial expansion into new localities. Nevertheless, physical venues have not lost their strategic relevance, rather, they appear to be increasingly concentrated within major urban centers, where higher spatial density enables operators to maximize extraction while digital platforms extend their reach nationwide.

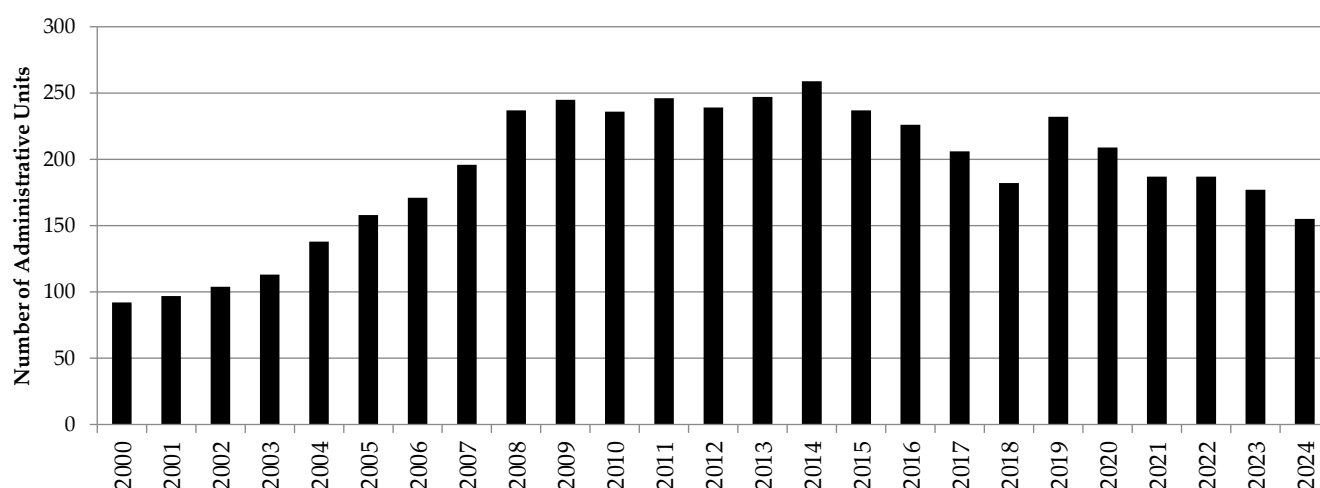


Figure 3. Territorial Footprint (2000–2024).

Furthermore, the concentration of activity within a limited number of UATs reinforces the vertical integration of the sector. The data suggests not the disappearance of the brick-and-mortar model, but its structural reconfiguration. Rather than expanding into a larger number of localities, operators increasingly intensify their presence within a stable set of urban nodes. By 2024, the industry appears to have reached a stage of structural maturity in which it maximizes its “spatial yield”, extracting substantially higher volumes of capital from the same geographical locations through a combination of high-density physical venues and digitally mediated gambling platforms. In this hybrid spatial configuration, physical locations continue to function as key urban extraction points, while online mechanisms extend the sector’s reach beyond the constraints of territorial expansion [22]. Consequently, the wealth generated from the societal base is increasingly funneled toward a centralized industrial core, rather than being redistributed through the localized economic spillovers typically associated with broader territorial expansion, such as local rents or regional infrastructure investment.

The longitudinal analysis of labor force dynamics within the Romanian gambling sector (2000–2024) reveals a notable divergence between workforce expansion and the overall financial growth of the industry (Figure 4). Over the twenty-four-year period, the number of active employees increased from 7491 to 24,381. Although this represents an absolute increase of approximately 325%, the corresponding CAGR of 5.04% indicates a comparatively moderate pace of workforce expansion when contrasted with the sector’s

substantial multi-billion-euro revenue growth. This disparity suggests that the industry's expansion has become progressively less proportional to the scaling of human capital, pointing to rising labor productivity and the increasing importance of scalable operational models within the sector.

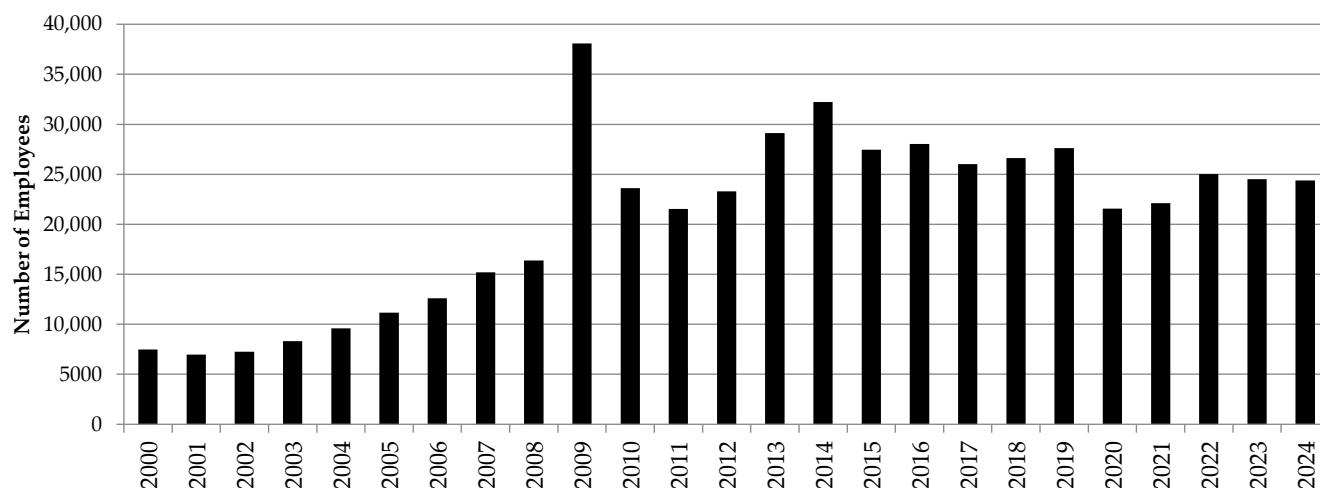


Figure 4. Labor Force Dynamics: Total Active Employees (2000–2024).

The temporal structure of the data further indicates a gradual transformation in the relationship between output and labor absorption. During the initial decade (2000–2010), workforce growth followed a pattern consistent with a traditional service-oriented structure, in which sectoral expansion required a proportional increase in personnel to manage physical operations. In contrast, in the latter phase of the analyzed period, particularly between 2015 and 2024, the growth of employment began to diverge from the sector's rapidly increasing output. This pattern suggests that the industry has progressively integrated technological and organizational efficiencies that enable substantial revenue expansion without a corresponding mobilization of the national labor market.

The limited growth of employment relative to the sector's fiscal expansion is consistent with the dynamics described by the Extractive Economic Model. Within this framework, industries capable of generating significant capital accumulation while engaging a comparatively small workforce tend to exhibit low inclusive potential. Rather than fostering broad-based economic participation through mass employment, the gambling sector appears increasingly characterized by the concentration of value within a specialized industrial core. As a result, the industry functions as a relatively enclosed economic circuit, where substantial financial flows are generated from the broader societal base while relatively limited human-capital integration occurs within the wider economy.

The structural configurations delineated in this analysis reveal that the Romanian gambling sector exhibits robust economic growth, its territorial footprint remains localized, characterized by an intensification within established urban nodes rather than a uniform national distribution.

This concentration, facilitated by the synergy between digital scalability and physical venue density, necessitates a shift in analytical focus toward the urban scale. Specifically, it remains to be determined how these establishments are spatially distributed relative to vulnerable urban receptors. To resolve this ambiguity, this study employs a granular geospatial assessment of proximity and accessibility metrics, evaluating the spatial juxtaposition of gambling venues against key community facilities.

Figure 5 provides a complementary perspective on market consolidation by capturing the evolution of labor intensity relative to revenue. The indicator “employees per 1

million EUR revenue” follows a pronounced and persistent downward trajectory over the 2000–2024 period, decreasing from levels exceeding 109 employees in 2000 to 8 in 2024. Such substantial contraction suggests a structural reconfiguration in the relationship between output and labor input, whereby revenue generation becomes progressively less contingent upon workforce expansion.

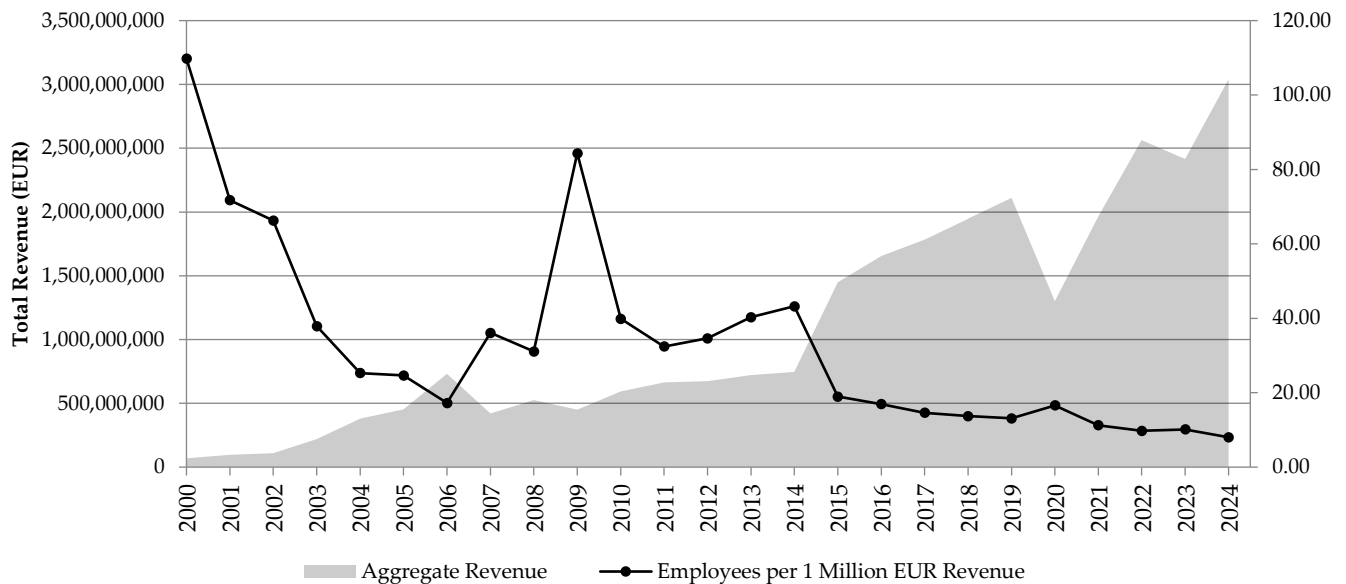


Figure 5. Employees per 1 million EUR Revenue in the gambling sector, 2000–2024.

This pattern extends the argument of sectoral decoupling by indicating that the observed financial growth is not merely disproportionate to employment, but increasingly independent of it in relative terms. While rising labor productivity is a common feature of industrial maturation, the magnitude of this decline points toward the growing relevance of scalable operational architectures, including digitalization and process automation, which enable significant output expansion without commensurate increases in personnel.

However, interpretative caution remains necessary. The aggregated nature of the indicator obscures potential intra-sectoral variation, particularly between land-based and online segments that may exhibit divergent labor requirements. Consequently, the observed decline in labor intensity should be understood as a robust empirical regularity consistent with structural decoupling, rather than as conclusive evidence of a singular causal mechanism.

2.2. Socio-Economic Determinants

The transition from macro-structural sector dynamics to a territorial dimension is fundamental to understanding how gambling is embedded within the local socio-economic fabric. Moving beyond aggregate national growth trends, this analysis explores the spatial heterogeneity of exposure, elucidating the mechanisms through which the density of industry-specific infrastructure interacts with the demographic profiles and financial resilience of communities. The objective extends beyond a mere inventory of gambling venues; it seeks to decipher the ways in which the geography of economic opportunity intersects with the geography of social risk.

The territorial distribution of gambling infrastructure at the county level, as indicated by 2021 census data, reveals a landscape characterized by extreme concentration and pronounced commercial voids. Although the national average density is approximately 4.02

units per thousand inhabitants, this value is significantly skewed by the administrative outlier of Ilfov. With a density of 58.77, Ilfov serves as a large warehouse centered in Buftea, representing gambling device storage rather than genuine local demand. Excluding this distortion, the adjusted national average is 2.68 units, which serves as a more reliable benchmark for analyzing regional pressure.

The counties with the highest infrastructure density (Figure 6) include Bucharest at 7.26, followed by major development poles such as Sibiu (5.22), Cluj (4.58), and Braşov (4.10). These figures suggest that the industry gravitates toward urban centers where high population density facilitates capital turnover. Suceava remains a significant anomaly, maintaining a density of 4.21, consistent with a pattern in which infrastructure density tracks population size even where average incomes are comparatively low. In contrast, counties like Călăraşi (1.26), Giurgiu (1.27), and Sălaj (1.27) report the lowest densities, indicating that infrastructure density remains low in regions with comparatively weaker financial flows [23].

County-Level Gambling Density

The number of gambling machines was correlated with official population data from the 2021 Population Census in order to compute density per 1,000 inhabitants

Density

- Minimal Presence
- Low Density
- Moderate Density
- High Density
- Maximum density

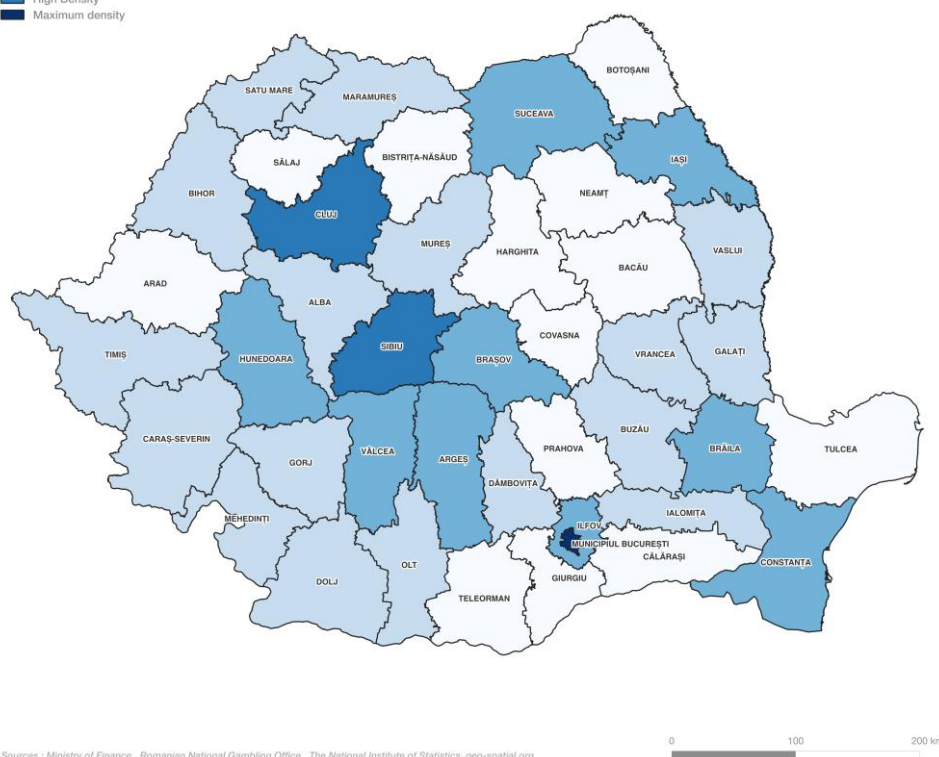


Figure 6. County-level gambling density.

Furthermore, the infrastructure distribution reveals a significant market polarization. While the adjusted average stands at 2.68 units per thousand inhabitants, nearly two-thirds of the analyzed counties (27 out of 41) fall below this threshold. This concentration highlights that the industry is not merely urban-centric but is focused on a limited number of high-intensity hubs. A critical socio-economic anomaly is observed when comparing Western resilience to Eastern exposure: Timiş, despite having the second-highest average salary in the country, maintains a density of 2.59 notably below the national average. In stark contrast, Suceava, with a significantly lower average salary, supports a density of

4.21. This discrepancy suggests that high disposable income does not inherently drive gambling density; instead, the industry appears to prioritize regions where a lack of alternative economic opportunities may increase the population's susceptibility to gambling exposure.

The micro-spatial analysis identifies ten high-exposure Administrative-Territorial Units (UATs) where infrastructure density reaches critical levels, fundamentally reshaping the local socio-economic landscape (Figure 7). Dumbrăveni (Sibiu) represents the most extreme case of saturation with a density of 168.00 units per thousand inhabitants and a total of 1048 devices, followed by Galicea (Vâlcea) with 135.56 units and Jilava (Ilfov) with 127.79 units. These extreme values are consistent with a localized pattern of predatory placement, in which the saturation of electronic gambling machines (EGMs) coincides with administrative nodes offering high capital turnover potential.

UAT-Level Gambling Density

Spatial distribution of gambling infrastructure at the UAT level indexed to the 2021 resident population, utilizing a quantile classification to represent relative consumption intensity and identify regional hubs

Density

- No physical units
- Low Density
- Moderate Density
- High Density



Sources : Ministry of Finance, Romanian National Gambling Office, The National Institute of Statistics, geo-spatial.org

Figure 7. UAT-level gambling density.

Secondary urban nodes and regional magnets also exhibit significant exposure, led by Fălticeni (Suceava) with a density of 69.24 and 1655 total units, and Târgu Frumos (Iași) with 47.41 units. This intensity is mirrored in UATs such as Răzvad (42.50) and Livezeni (39.70), where infrastructure density is highest in locations with high demographic concentration, consistent with the extractive efficiency framework discussed above. The high-exposure list concludes with Balș in Olt (32.44), Adjud (30.37), and Tileagd (28.84), highlighting a consistent structural focus on secondary urban receptors and transit-oriented locations that lack alternative leisure or economic infrastructure.

This granular evidence confirms that the industry strategically bypasses regions with anemic financial flows in favor of these high-intensity hubs. The identified “zones of con-

vergence” demonstrate that vulnerability is not a linear function of poverty alone, but a result of the convergence between exposure and constrained economic resilience.

Figure 8 advances this analysis by introducing a Composite Vulnerability Index (V_i), designed to capture territorial differences in exposure through a relational framework. Rather than expressing this relationship as a simple ratio, which would let the higher variance component dominate the composite and impose an arbitrary, scale-dependent weighting, the index relates infrastructure density to economic resilience after placing both on a common, standardized scale. Each component is converted to a z -score relative to the national mean, gambling-machine density is additionally log-transformed to attenuate its strong positive skew. The index is then defined as the difference between the standardized exposure and standardized resilience terms (Equation (1)):

$$V_i = z(\ln(D_i + 1)) - z(R_i) \quad (1)$$

where D_i is the density of gambling machines per 1000 inhabitants in county i and R_i is the average income in county i . Higher machine density thus increases vulnerability, while higher income reduces it, with both components weighted equally. Positive values identify counties where gambling exposure exceeds local economic resilience; negative values indicate the converse. Mean local income is adopted as a parsimonious, nationally available proxy for economic resilience; its single-dimension nature is addressed as a limitation in the discussion section.

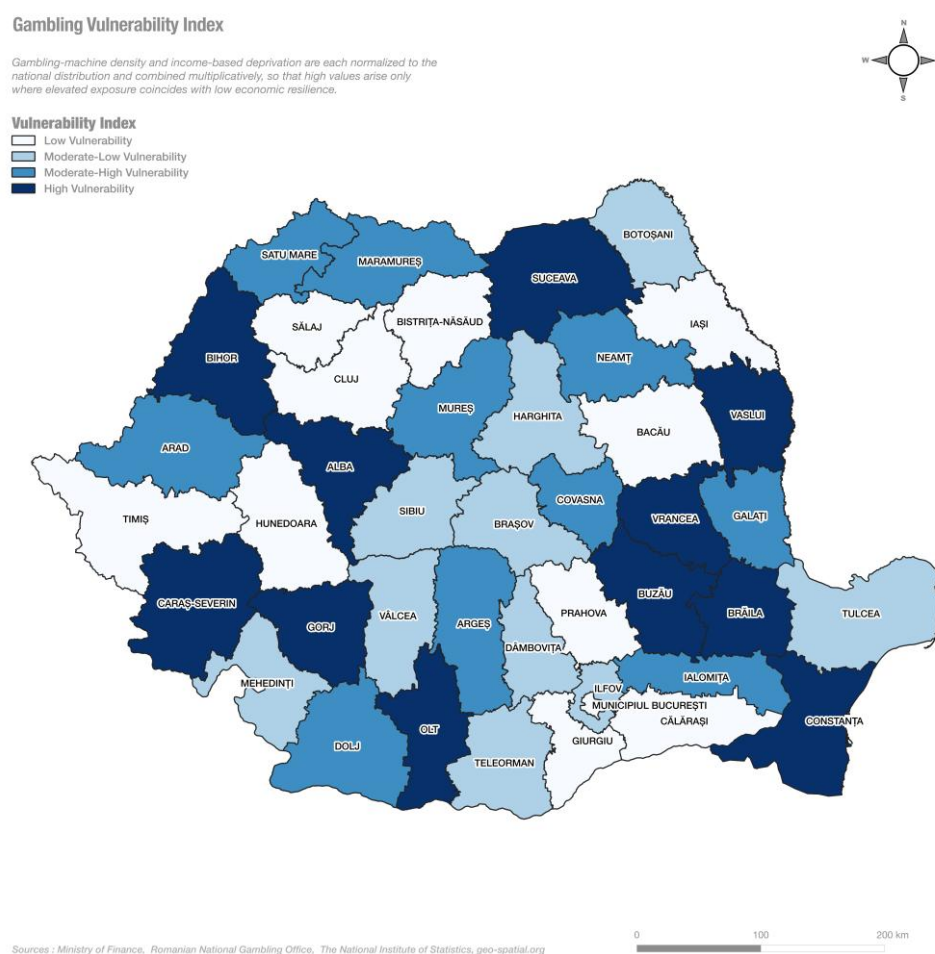


Figure 8. Gambling vulnerability index.

The resulting values are jointly determined by exposure and economic capacity because the two components enter the index additively after standardization, a county’s

score rises both with higher infrastructure D_i and with lower average income R_i . Unlike a ratio, this additive formulation does not let one dimension multiply the other; instead, each contributes an independent, comparable increment expressed in standard-deviation units. This has a direct interpretive implication: holding density constant, territorial units with below-average income receive a positive income contribution to the index $-z(R_i > 0)$ and therefore register higher scores than higher-income units with identical infrastructure availability. In this sense the metric treats exposure and economic resilience as offsetting forces comparable densities of gambling activity translate into different vulnerability scores depending on local economic conditions.

Furthermore, the empirical distribution indicates that elevated scores are not exclusively concentrated in the lowest-income territorial units. Rather, high values arise where sufficient infrastructure availability coincides with comparatively low income, so that vulnerability is not a linear function of poverty alone but the outcome of co-occurring exposure and constrained economic resilience. Both pathways are visible in the data: some counties reach the upper classes through exceptionally high density despite near-average income (e.g., Ilfov), while others do so through low income despite only moderate density (e.g., Vrancea, Vaslui).

The classification of these results further reinforces this interpretation. By employing a quantile-based approach, the upper categories capture those territorial units where this interaction effect is most pronounced. However, because the classification is relative, inclusion in the highest category reflects a specific position within the national distribution identifying “Zones of Convergence” where the regressive impact of gambling infrastructure is most acute rather than an absolute threshold of deprivation. These results support a moderated relationship: lower income levels amplify the impact of gambling availability, but do not independently determine the spatial distribution of risk.

Because the index is formulated as an additive combination of two standardized components, the source of each elevated score can be decomposed directly. Unlike a ratio, a high score does not require non-negligible density: a sufficiently low income can place a county in the upper classes even where machine density is below the national average (e.g., Vaslui, Olt, Gorj, at ≈ 2.2 – 2.4 machines per 1000). Counties that are both low-income and very low-density Călărași, Giurgiu, Sălaj (≈ 1.26 – 1.28 per 1000) remain in the lower classes, as their strongly negative density term offsets a modest income disadvantage. Elevated scores thus reflect the additive contribution of exposure and constrained resilience, with either dimension capable of driving a county upward.

3. Materials and Methods

The geospatial analysis was conducted across three Romanian urban centers selected to reflect contrasting socio-economic profiles and demographic scales. This selection was deliberate, enabling the analysis to assess whether patterns of predatory placement are consistent across urban contexts that differ substantially in terms of economic output, average income levels, population density, and urban morphology, or whether they are specific to particular socio-economic configurations. The spatial extent of each case study was defined by the administrative boundaries of the respective administrative-territorial unit.

Bucharest, as the national capital, represents the upper bound of urban scale, population density, and economic output within the Romanian system, while Pitești was selected as a mid-sized regional capital with a comparatively constrained economic profile, allowing the framework to be tested in a smaller and less affluent urban context. Iași was included as the largest urban center in the historically less-developed eastern region of the country and the principal university city of Eastern Romania, combining a large student population, a dense and morphologically constrained historic core, and a regional economic profile distinct from both the capital and from Western Romanian growth poles

such as Cluj or Timișoara. Taken together, the three cities span the principal axes of variation in the Romanian urban system national-capital status, regional economic centrality, and historically rooted East–West disparities providing a basis for assessing whether the spatial patterns identified are structural across heterogeneous urban contexts rather than contingent on the characteristics of any single city.

The primary empirical dataset consists of the georeferenced locations of licensed slot-machine gambling premises, extracted from the February 2026 licensing registry published by the National Office for Gambling (Oficiul Național pentru Jocuri de Noroc, ONJN). Critically, the unit of measurement throughout this analysis is the individual gambling machine rather than the licensed premises as a legal entity. A single venue may house anywhere from one to several dozen such devices, and it is this machine-level density that constitutes the true measure of spatial saturation and exposure intensity within a given urban area.

Five categories of sensitive community facilities were identified as spatial reference layers, reflecting both legislative protections and empirical evidence on vulnerable population exposure. These are: educational institutions, representing the primary risk receptor for adolescent exposure; healthcare facilities, including general hospitals and clinics; religious sites, which serve as community anchors; parks/children’s playgrounds, public transit stops (representing high foot-traffic nodes frequented by socio-economically diverse urban populations). All facility layers were sourced from OpenStreetMap, the Ministry of Education, and the Ministry of Health, and cross-validated against national registry data where available.

In addition to point-feature layers, two network-derived pedestrian isochrone layers were generated for the ensemble of all sensitive facilities: a 5 min walking accessibility catchment and a 10 min walking accessibility catchment. These were computed using the OpenRouteService routing engine applied to the Romanian pedestrian street network, producing polygon geometries that represent the area realistically accessible on foot within those time thresholds. Unlike Euclidean buffer zones, network-based isochrones capture the true morphological accessibility constraints of the urban street grid [24], which is particularly relevant in Romanian cities where block layouts and pedestrian permeability vary substantially between neighborhoods.

The fundamental spatial unit of the analysis is the H3 discrete global grid system, developed by Uber Technologies, at resolution level 10. Hexagonal tessellations are analytically superior to regular square grids for proximity-based spatial modeling because they minimize edge-effect artifacts: the distance from any hexagon’s centroid to the centroid of each of its six immediate neighbors is uniform, and every neighbor shares an equivalent edge length [25,26]. This isotropy is critical when computing ring-based spatial decay functions, as it ensures that directional bias is not introduced by cell geometry, a property that square grids cannot guarantee given the difference between orthogonal and diagonal neighbor distances.

The H3 grid was generated by polyfilling the administrative boundary polygon at resolution 10, producing a complete and contiguous set of hexagonal cells covering the entire study area. Each hexagon was assigned a unique H3 index, which served as the primary spatial key for all subsequent feature attribution and classification operations.

For each H3 hexagonal cell, a multi-dimensional feature vector was constructed, capturing the spatial relationship between the cell and all five categories of sensitive facilities, as well as the total count of gambling machines present within it. Three types of spatial features were computed for each facility category.

The count feature records the number of sensitive facility points whose geographic coordinates fall within the boundaries of a given hexagonal cell, as determined by H3 cell

assignment of each point's WGS84 coordinates. This measure captures the direct co-location of gambling machines with sensitive facilities at the cell level.

The minimum distance feature measures the Euclidean distance, in meters, from the centroid of each hexagonal cell to the nearest facility point of that category, computed in the projected metric coordinate system. Where no facilities of a given type are present in the dataset, the feature is assigned a sentinel value of -1, handled appropriately during the machine learning phase. This continuous proximity measure captures the gradient of spatial exposure even where direct co-location does not occur.

The neighbor count feature aggregates the count of sensitive facilities located within the six immediately adjacent H3 cells, providing a measure of the local neighborhood density of sensitive receptors surrounding each hexagon. This feature is theoretically motivated by the recognition that gambling-related harm is not confined strictly to the cell in which machines are located, but extends to the immediately surrounding urban fabric.

Two aggregate features were additionally derived: the total count of sensitive facilities of all categories within the cell itself, and the total count across all six neighboring cells. These count, distance, and neighbor-density attributes are retained in the dataset as descriptive variables; as detailed below, however, the predictive machine-learning component draws exclusively on the network-based isochrone features.

Two additional features were computed to capture the degree to which each hexagonal cell falls within the pedestrian accessibility catchment of sensitive facilities. These isochrone overlap features serve a dual analytical role within the methodology. First, they function as direct input variables to the machine learning classifier, enabling the model to learn whether the spatial co-occurrence of gambling machines with pedestrian-accessible sensitive facilities constitutes a statistically significant predictor of venue placement. Second, and more critically, they constitute the accessibility component of the final vulnerability scoring formula, operationalizing the theoretical distinction between mere geographic proximity and realized behavioral exposure: a gambling machine cluster produces concrete risk for vulnerable populations only where those populations can realistically arrive on foot from a sensitive facility during ordinary daily routines.

For each isochrone layer, two distinct sets of overlap features were derived. For the machine-learning component, the isochrones were dissolved separately for each of the five facility categories, filtered by facility type, yielding a per-type pedestrian-accessibility overlap for each cell at both the 5 min and 10 min thresholds. For the vulnerability scoring formula, the geometries of all individual isochrones across all five facility categories were additionally dissolved into a single unified polygon representing the total spatial extent of pedestrian accessibility from all sensitive facilities combined. For each hexagonal cell, the proportional area of intersection between the cell polygon and the relevant isochrone geometry was then computed (Equation (2)):

$$isochrone_{overlap} = \frac{Area(H_i \cap I)}{Area(H_i)} \quad (2)$$

where H_i denotes the geometry of hexagonal cell i and I represent the dissolved isochrone polygon. The resulting value ranges from 0 to 1, representing the fraction of the cell's area lying within realistic pedestrian reach of at least one sensitive community facility. This approach is more analytically informative than a binary intersection flag because it captures partial overlaps along the transition zone between accessibility and non-accessibility, producing a continuous gradient that reflects the probabilistic nature of pedestrian mobility in urban environments.

A composite isochrone factor was subsequently derived as a weighted average of the two overlap scores (Equation (3)):

$$isochroneFactor_i = 0.70 \times iso_{5minutes,i} + 0.30 \times iso_{10minutes,i} \quad (3)$$

where $iso5minutes,i$ denotes the proportional area of hexagonal cell i covered by the dissolved 5 min pedestrian isochrone polygon, that is, the fraction of the cell's surface that lies within a 5 min walking distance of at least one sensitive community facility as routed through the actual street network, and $iso10minutes,i$ represents the equivalent measure for the 10 min catchment. Both values range from 0, indicating no pedestrian accessibility from any sensitive facility, to 1, indicating that the cell is fully enclosed within the combined walkable catchment.

The weighting scheme assigns greater importance to the 5 min catchment on the basis of two converging lines of reasoning. First, behavioral geography and retail accessibility literature consistently demonstrate that the probability of spontaneous entry into a gambling venue decreases nonlinearly with walking distance, with the steepest decline occurring within the first five minutes of travel time. Second, the theoretical framework of convenience gambling as outlined in the paper posits that slot-machine venues are accessed primarily through impulsive, unplanned behavior triggered during ordinary daily routines rather than through deliberate travel. The 5 min isochrone precisely captures this zone of behavioral impulsivity [27], where physical proximity is sufficient to permit spontaneous entry without prior intention, whereas the 10 min catchment reflects a qualitatively different accessibility regime in which venue visits are more likely to involve at least a minimal degree of deliberate decision-making. The 70/30 ratio encodes this behavioral asymmetry, assigning dominant weight to the proximity range most strongly associated with problem gambling onset and maintenance. This composite factor enters the vulnerability scoring formula described in this chapter as a necessary multiplicative condition: a hexagonal cell with zero isochrone coverage receives a vulnerability score of zero regardless of its proximity to gambling machines, encoding the theoretical premise that predatory exposure is only realized where vulnerable populations can realistically access the gambling environment on foot during the course of their daily routines.

Prior to the machine-learning stage, the spatial structure of machine placement was formally tested using Global Moran's I , computed on the binary indicator of gambling-machine presence per cell with a first-order H3 ring-contiguity weights matrix and inference based on 999 conditional permutations. The binary presence indicator was adopted because the raw machine count is zero in the large majority of cells, a distribution that attenuates the global statistic; the presence indicator directly captures whether machine-bearing cells cluster spatially.

Two ensemble learning algorithms were trained to identify and quantify the spatial determinants of gambling machine placement: a Gradient Boosting Classifier and a Random Forest Classifier, both implemented via the scikit-learn library. The analytical purpose of this machine learning component is explicitly exploratory: rather than generating the final vulnerability classification, these models serve to establish which spatial proximity dimensions are most strongly and statistically robustly associated with the observed distribution of gambling machines across the urban fabric. This constitutes direct empirical evidence for or against the predatory placement hypothesis, independent of the scoring formula applied in the subsequent classification stage.

Both models were trained on the nineteen-dimensional feature vector described earlier, with the binary target variable indicating whether a hexagonal cell contains at least one gambling machine. To address the inherent class imbalance, that the proportion of cells containing gambling machines is substantially smaller than cells without, the Gradient Boosting model was trained with inverse-frequency sample weights, assigning a weight equal to the ratio of negative to positive instances to each positive training example. The Random Forest model was trained with the balanced class-weight parameter, achieving an equivalent reweighting internally. Both models employed 300 estimators. The Gradient Boosting configuration additionally specified a learning rate of 0.05, a max-

imum tree depth of 5, a minimum of 5 samples per leaf, and a subsample ratio of 0.8 to mitigate overfitting.

Model performance was evaluated using stratified 5-fold cross-validation. Given the severe class imbalance (positive prevalence between 2% and 4%), the area under the precision–recall curve (PR-AUC, equivalently average precision) was adopted as the primary selection and reporting metric, with the area under the ROC curve (ROC-AUC) reported alongside; both are threshold-independent and appropriate for rare-class problems. The model achieving the higher mean cross-validated PR-AUC was selected as the best estimator. The F1 score, precision, and recall at the default 0.5 threshold are reported as secondary references, together with metrics at a threshold calibrated to maximize F1 on the precision–recall curve. To quantify the stability of the headline metrics, 95% confidence intervals were obtained through 1000 stratified bootstrap resamples of the out-of-fold predictions.

Feature importance was assessed using permutation importance with 30 repetition cycles. Consistent with the use of average precision as the primary evaluation metric, the permutation procedure quantifies the decrease in average precision (PR-AUC) resulting from the random permutation of each individual feature across the held-out folds. Average precision was preferred over a fixed-threshold metric such as the F1 score for this purpose because, under severe class imbalance, threshold-dependent scores are sensitive to the choice of decision cut-off and yield unstable importance estimates, whereas average precision evaluates the full ranking of cells across all thresholds and therefore provides a more stable basis for comparing the contribution of individual features [28,29]. This method is preferred over impurity-based importance for interpretive purposes, as it is not biased by high-cardinality continuous features and directly reflects out-of-sample predictive contribution. The resulting importance ranking constitutes the primary empirical output of the machine learning stage, identifying which spatial proximity dimensions, distances to schools, healthcare facilities, transit stops, or the isochrone accessibility measures, are most strongly associated with gambling machine placement.

The spatial vulnerability classification constitutes the final analytical output of the study and is computed through a multiplicative scoring model applied to all hexagonal cells that do not themselves contain gambling machines. The model is designed to enforce two simultaneous necessary conditions for a cell to register elevated vulnerability: it must lie within a meaningful spatial proximity of an existing gambling machine cluster, and it must be located within the pedestrian accessibility catchment of sensitive community facilities. This dual-condition logic reflects the theoretical framework of predatory placement, wherein harm is realized not through geographic proximity alone but through the intersection of machine accessibility with the routine mobility patterns of vulnerable populations.

The vulnerability score for each cell is computed as (Equation (4))

$$SCORE_i = ring_decay_i \times iso_factor_i \quad (4)$$

where the ring decay component is defined as (Equation (5))

$$ring_decay_i = \max\left(0.1 - \frac{r_i}{d}\right) \quad (5)$$

with r_i denoting the minimum H3 ring distance from cell i to the nearest cell containing gambling machines, and $d = 5$ representing the decay radius in ring units, corresponding to approximately 330 m at resolution 10. This produces a linearly decreasing weight from 1.0 at immediate adjacency to 0.0 at five rings distance and beyond, encoding the empirically established principle of diminishing influence of venue proximity with increasing spatial separation. The H3 ring distance was computed using an iterative expansion algo-

rithm querying the k -ring neighborhood of all gambling machine cells from $k = 0$ to $k = 6$, assigning to each cell the minimum ring distance at which it was first reached.

The *iso_factor* is the weighted composite isochrone overlap score defined earlier. Its role as a multiplicative term rather than an additive component is methodologically deliberate: it ensures that cells outside all pedestrian catchments receive a score of exactly zero regardless of their ring distance, while cells within catchments receive a score that scales continuously with both their proximity to machines and their degree of isochrone coverage. This multiplicative structure is consistent with spatial multi-criteria evaluation frameworks in which the simultaneous absence of any one necessary condition collapses the overall score.

Three classification rules govern the final assignment of each cell to one of four vulnerability categories. First, cells for which the composite isochrone factor falls below a negligible threshold of 0.01 are unconditionally assigned to the lowest vulnerability class, regardless of their proximity to gambling machines. This formalizes the theoretical premise established earlier that predatory exposure cannot be realized in the absence of meaningful pedestrian connectivity between vulnerable populations and gambling venues.

Second, cells in immediate adjacency to a cell containing gambling machines, that is, sharing a direct H3 edge, are unconditionally classified as high vulnerability, provided their isochrone factor exceeds the negligible threshold defined above. This rule is justified by the spatial scale of the analysis: at resolution 10, immediately adjacent hexagons are separated by approximately 66 m, a distance at which the behavioral threshold for spontaneous venue entry is effectively zero. At this range, the graduated decay formula would systematically underestimate exposure, as the linear decay function is calibrated for distances at which travel cost remains a meaningful deterrent to impulsive behavior.

Third, for all remaining cells, the multiplicative score is evaluated against two empirically motivated thresholds: cells with a score of 0.50 or above are classified as High Predatory Exposure, cells with a score of 0.15 or above as Moderate Predatory Exposure, and all remaining cells as Low Predatory Exposure. Cells containing active gambling machines are assigned the distinct category of Active Gambling Presence.

To benchmark the observed proximity pattern against a null model of spatially random placement, a Monte Carlo procedure was implemented for each city. Holding constant the observed number of machine-bearing cells, cell identity was reassigned at random, without replacement, across the pool of urbanized cells (composite isochrone factor exceeding 0.01), and the proportion of reassigned cells falling within the relevant distance threshold of each sensitive facility category was recomputed over 1000 permutations, generating an empirical null distribution. Restricting the reference pool to urbanized cells ensures that the test isolates deliberate siting from the confound of general urban density, providing a conservative benchmark against random placement. This approach follows established conditional-permutation inference procedures used in spatial autocorrelation testing [30], and is consistent with comparable spatial-randomization benchmarks applied in the gambling-geography literature to distinguish deliberate venue siting from general neighborhood-level accessibility effects [31].

4. Results

The three urban centers selected for this analysis represent distinct positions within Romania's urban hierarchy and differ substantially in terms of demographic scale, economic profile, and administrative structure, yet exhibit a convergent pattern of gambling machine saturation that is inconsistent with random or market-driven spatial logic. Pitești, with a resident population of 141,275 (2021 Census), registers the highest aggregate municipal-level machine density among the three cases at 9.05 devices per thousand inhabitants, a figure that exceeds both the national adjusted average of 2.68 and the Bucharest

metropolitan average of 7.26. Iași, Romania's second-largest city by historical region with a population of 271,692, records a density of 7.31 per thousand inhabitants. Bucharest, analyzed across its six administrative sectors with a combined resident population of 1,716,983, registers an aggregate density of 7.26, though this figure conceals extreme intra-metropolitan variation: Sector 2 reaches 13.98 devices per thousand inhabitants and Sector 1 reaches 12.21, while Sectors 3, 4, 5, and 6 record densities between 4.35 and 4.87. The fact that Pitești, a mid-sized industrial city with substantially lower economic output and average income than Bucharest, sustains the highest machine density of the three cases directly corroborates the argument advanced in Section 2.2 that gambling infrastructure gravitates not toward high-income populations but toward areas where constrained economic resilience amplifies susceptibility to financial extraction.

In absolute terms, the three study areas collectively account for 15,735 licensed gambling machines: 12,472 in Bucharest, 1985 in Iași, and 1278 in Pitești. Cells with active gambling devices record an average device concentration of 22.2 machines per cell in Bucharest, 20.0 in Pitești, and 15.9 in Iași, confirming that physical premises function as high-density extraction nodes rather than dispersed convenience outlets, a spatial configuration consistent with the vertical intensification model described in this paper.

The spatial distribution of gambling machines across the three investigated urban areas was evaluated using Global Moran's I to identify underlying geographic patterns. This metric measures spatial autocorrelation, evaluating whether proximate locations exhibit similar characteristics, with a positive coefficient ($I > 0$) indicating spatial clustering, a negative value ($I < 0$) representing dispersion, and a value near the theoretical expectation ($I \approx E[I]$) signifying a completely random spatial pattern. Statistical significance was assessed through 999 random permutations, generating a pseudo p -value for each city.

Originally developed by the Australian statistician Patrick Moran as a global indicator of spatial dependence, this statistic has become a standard diagnostic tool in spatial epidemiology and urban geography for establishing whether a point process departs from complete spatial randomness before proceeding to more complex spatial or predictive modelling [30,32]. Its application here serves the same diagnostic function adopted in recent gambling-geography research [32–35], where formal autocorrelation testing has been used to confirm that machine or venue accessibility is not uniformly or randomly distributed across urban space prior to further spatial analysis [31].

All three cities exhibited statistically significant positive spatial autocorrelation: Iași ($I = 0.175$, $z = 22.4$, $p = 0.001$), Pitești ($I = 0.130$, $z = 11.5$, $p = 0.001$), and Bucharest ($I = 0.098$, $z = 20.4$, $p = 0.001$). All three pseudo p -values are significant at the 99.9% confidence level ($p = 0.001$). The consistently positive sign and large positive z -scores indicate that, across all three cities, venue placement departs strongly from spatial randomness and tends toward pronounced clustering rather than dispersion.

These results confirm that venue placement departs strongly from spatial randomness in all three cities. Because Global Moran's I is a single city-wide summary, it establishes that clustering exists but not where it is concentrated, to resolve the specific locations of clustering, a Local Indicator of Spatial Association (LISA), in the form of Local Moran's I , was additionally computed [30]. Unlike the global statistic, a LISA decomposes the overall measure into a value for each individual cell, testing whether that cell and its immediate neighbors form a statistically significant local cluster and thereby identifying discrete high–high hot-spots of elevated values surrounded by similarly elevated values. This local approach is now an established diagnostic in gambling-geography research for pinpointing the specific neighborhoods that drive city-wide concentration [31,32]. The analysis identified statistically significant high–high hot-spots ($p < 0.05$) in every city: 103 such cells in Bucharest, 55 in Iași, and 18 in Pitești. In each case these hot-spots corresponded exclusively to machine-bearing cells, with no significant low–low clusters de-

tected, indicating that the global signal is driven by concentrated local agglomerations of gambling machines rather than by diffuse city-wide structure. These local clusters provide the spatial basis for the proximity and exclusion-zone analyses presented below.

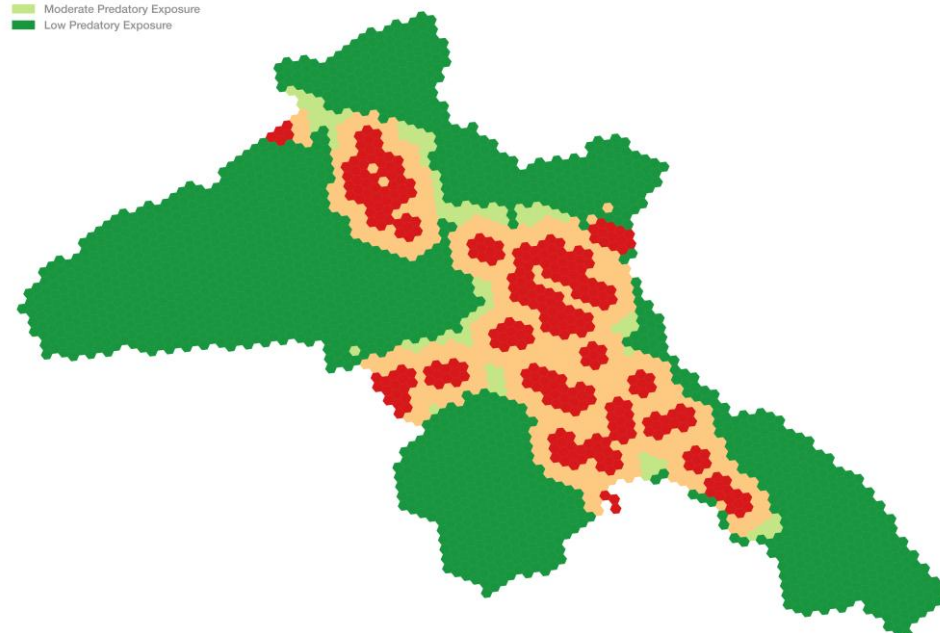
The H3 tessellation of the Pitești administrative boundary produced 2567 hexagonal cells (Figure 9). Of these, 64 contain at least one gambling machine, constituting the Active Gambling Presence core. When the ring-adjacency expansion and isochrone conditions are applied, the Active Gambling Presence zone, encompassing cells with registered gambling activity and their immediate spatial envelope, comprises 319 cells (12.4% of the urban tessellation). A further 471 cells (18.3%) are classified as High Predatory Exposure, yielding a combined high-intensity exposure zone covering 30.8% of the city's hexagonal grid. Moderate Predatory Exposure accounts for an additional 94 cells (3.7%), while 1683 cells (65.6%) fall within the Low Predatory Exposure class.

Pitești - Predatory Exposure Classification

Pitești - Spatial vulnerability classification Pitești at H3 resolution 10, indexing gambling machine proximity and pedestrian isochrone accessibility to sensitive community facilities across a multiplicative scoring framework.

Vulnerability index

- Active Gambling Presence
- High Predatory Exposure
- Moderate Predatory Exposure
- Low Predatory Exposure



Sources : Ministry of Finance, Romanian National Gambling Office, The National Institute of Statistics, geo-spatial.org

Figure 9. Pitești—Predatory exposure classification.

The proximity analysis of cells with registered gambling activity reveals a markedly non-random spatial pattern. The mean distance from gambling machine clusters to the nearest educational institution is 282.8 m, with a minimum observed distance of 21.8 m. More critically, 64.1% of all cells with registered gambling activity are located within 300 m of at least one school, and 89.1% within 500 m, thresholds corresponding respectively to the 5 min and 10 min pedestrian isochrones used in the vulnerability model. The co-location pattern with children's playgrounds is even more pronounced than with educational facilities: the mean distance from cells with registered gambling activity to the nearest playground is 264.2 m, with 64.1% within 300 m and 93.8% within 500 m. By contrast, places of worship display a weaker proximity signal, with a mean distance of 494.0 m and

only 25.0% of active gambling cells located within 300 m of a place of worship, indicating that the industry's spatial logic aligns more tightly with secular high-footfall infrastructures than with community–religious anchors. The mean distance to the nearest public transit stop is 194.0 m, with 57.8% of cells with registered gambling activity within 200 m of a stop, confirming strong co-location with high-frequency pedestrian convergence nodes. The Active Gambling Presence zone records a mean isochrone factor of 0.907, indicating that over 90% of the surface area of these cells lies within the pedestrian catchment of at least one sensitive community facility, while the High Predatory Exposure zone records a mean isochrone factor of 0.734 and a mean vulnerability score of 0.562.

The Iași tessellation comprises 5972 hexagonal cells, of which 125 contain active gambling devices (Figure 10). The Active Gambling Presence zone encompasses 564 cells (9.4%), the High Predatory Exposure class 907 cells (15.2%), and the Moderate Predatory Exposure class 297 cells (5.0%), with the combined high-intensity exposure zone covering 24.6% of the urban grid. The school proximity signal is stronger in Iași than in Pitești: 81.6% of cells with registered gambling activity are within 300 m of a school and 94.4% within 500 m, with a mean distance to the nearest educational institution of 263.3 m. The proximity pattern to children's playgrounds is the most acute of all sensitive facility categories in Iași: the mean distance from cells with registered gambling activity to the nearest playground is 176.3 m, with 85.6% located within 300 m and 93.6% within 500 m, surpassing even the school proximity signal. Places of worship, by contrast, display a weaker association, with a mean distance of 524.2 m and only 25.6% of active gambling cells within 300 m of a place of worship, a pattern consistent with that observed in Pitești. The transit co-location pattern is similarly pronounced, with 80.0% of cells with registered gambling activity within 200 m of a public transit stop and a mean distance of 136.3 m, the lowest among the three study areas, reflecting the denser and more pedestrian-oriented street network of Iași's historic urban core. The Active Gambling Presence zone records a mean isochrone factor of 0.934, marginally higher than Pitești, while High Predatory Exposure cells record a mean of 0.790.

The full six-sector tessellation of Bucharest produces 14,878 hexagonal cells, of which 563 contain active gambling devices (Figure 11). The scale of exposure in Bucharest is qualitatively distinct from the other two cases: the combined Active Gambling Presence and High Predatory Exposure zone encompasses 7463 cells, equivalent to 50.2% of the entire urban tessellation, meaning that more than half of the city's hexagonal grid falls within the high-intensity gambling exposure zone. The Moderate Predatory Exposure class adds a further 1504 cells (10.1%), leaving only 39.7% of the urban area classified as Low Predatory Exposure.

Gambling venue proximity to sensitive facilities reaches its most acute levels in Bucharest: 75.3% of cells with registered gambling activity are within 300 m of a school, 93.3% within 500 m, and 87.6% within 200 m of a public transit stop, with a mean transit distance of 106.8 m. The mean distance to healthcare facilities is 429.8 m, substantially lower than in Pitești (629.7 m) and Iași (621.5 m), reflecting the denser hospital and clinic network of the capital. The proximity to children's playgrounds is the most intense of all sensitive facility categories analyzed in Bucharest: 82.6% of cells with registered gambling activity are within 300 m of a playground and 94.7% within 500 m, with a mean distance of 198.4 m, the lowest recorded among the five categories. Places of worship show a more diffuse spatial relationship, with a mean distance of 669.2 m and only 17.4% of active gambling cells within 300 m of a place of worship, the weakest proximity signal of all sensitive facility layers, suggesting that community–religious infrastructure does not constitute a siting anchor for the gambling industry. The High Predatory Exposure zone in Bucharest records the highest mean isochrone factor of the three cases at 0.887, indicating that the

overlap between gambling machine proximity and pedestrian accessibility to sensitive facilities is more spatially pervasive in Bucharest than in either of the other study areas.

Iași - Predatory Exposure Classification

Iași - Spatial vulnerability classification of Iași at H3 resolution 10, indexing gambling machine proximity and pedestrian isochrone accessibility to sensitive community facilities across a multiplicative scoring framework.

Vulnerability index

- Active Gambling Presence
- High Predatory Exposure
- Moderate Predatory Exposure
- Low Predatory Exposure

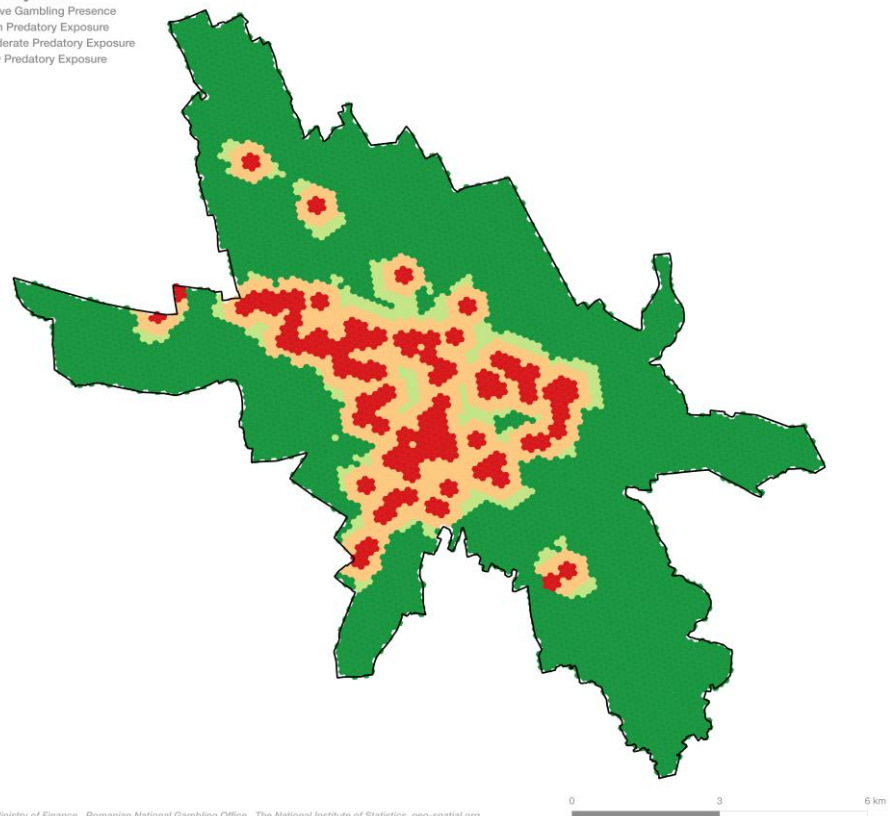


Figure 10. Iași—Predatory exposure classification.

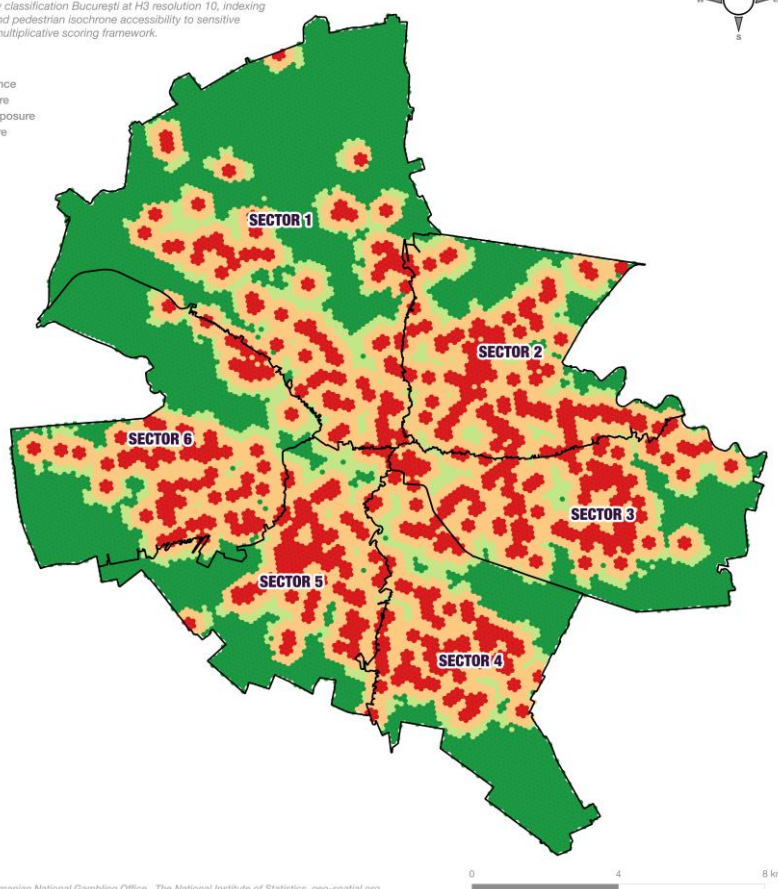
The intra-metropolitan variation across Bucharest's six sectors further reinforces the predatory placement argument. Sectors 1 and 2, which record the highest machine densities (12.21 and 13.98 per thousand inhabitants respectively), are characterized by dense transit networks, major commercial corridors, and high-foot-traffic educational clusters, precisely the spatial configuration that maximizes the intersection of gambling accessibility with vulnerable population flows. By contrast, Sectors 3, 4, 5, and 6, which include large residential peripheries with lower street-level commercial intensity, record substantially lower densities despite serving larger or equally sized populations. Sector 5, statistically the poorest sector of Bucharest, records the lowest machine density at 4.35 per thousand inhabitants, a finding that appears to contradict a simple poverty-targeting hypothesis. However, this result is consistent with the vulnerability framework established in Section 2.2: the industry does not target poverty in isolation but rather the convergence of moderate financial exposure with high pedestrian accessibility, a combination most acute in the mixed commercial–residential fabric of Sectors 1 and 2.

București - Predatory Exposure Classification

București - Spatial vulnerability classification București at H3 resolution 10, indexing gambling machine proximity and pedestrian isochrone accessibility to sensitive community facilities across a multiplicative scoring framework.

Vulnerability index

- Active Gambling Presence
- High Predatory Exposure
- Moderate Predatory Exposure
- Low Predatory Exposure



Sources : Ministry of Finance, Romanian National Gambling Office, The National Institute of Statistics, geo-spatial.org

Figure 11. București—Predatory exposure classification.

Beyond the descriptive proximity patterns, the ensemble classifiers were trained independently for each city on the twelve network-accessibility features, using stratified 5-fold cross-validation. Across all three cities, the Random Forest classifier outperformed Gradient Boosting on the primary metric and was selected as the best estimator in every case. The models achieved consistently strong discrimination between machine-bearing and machine-free cells: the cross-validated ROC-AUC was 0.837 (95% CI [0.824, 0.850]) in Bucharest, 0.897 (95% CI [0.863, 0.928]) in Iași, and 0.858 (95% CI [0.803, 0.904]) in Pitești. Because the positive class is rare (2–4% of cells), the precision–recall AUC (PR-AUC) provides a more demanding benchmark: the observed values of 0.133 (Bucharest), 0.171 (Iași), and 0.129 (Pitești) exceed the random baselines defined by class prevalence (0.038, 0.021, and 0.025 respectively) by factors of approximately 3.5 to 8.2, confirming that the accessibility features carry substantial discriminative signal beyond chance. At the default classification threshold, the F1 scores were 0.203, 0.241, and 0.208 respectively; under a threshold calibrated to maximize F1 on the precision–recall curve these rose to 0.228, 0.291, and 0.235. Consistent with the exploratory purpose of this component, these figures are interpreted as evidence of a robust statistical association between pedestrian accessibility and machine placement rather than as an operational prediction tool.

The permutation importance rankings reveal a consistent hierarchy of spatial determinants across all three cities. Pedestrian access to public transit stops and to schools emerged as the strongest discriminators of gambling-machine placement in every case: the 5 min access-to-transit feature ranked first or second in all three cities (importance of 9.8% in Bucharest, 18.0% in Iași, and 23.2% in Pitești), and access to schools ranked among the top features throughout. Access to playgrounds and the convergence features, record-

ing the number of distinct sensitive facility types reachable on foot, also contributed substantially, particularly in the larger cities. In striking contrast, pedestrian access to hospitals ranked last or near-last in every city (importance below 4% in all three cases), indicating that the proximity signal is specific to the everyday pedestrian-convergence receptors, transit nodes, schools, and play areas, rather than to healthcare facilities. This hierarchy is itself substantive evidence for the predatory-placement interpretation: machine placement tracks precisely those receptors associated with routine pedestrian footfall by vulnerable groups, and not the receptor (hospitals) least associated with impulsive, routine-driven gambling exposure.

Taken together, the three study areas present a consistent and statistically robust spatial signature of predatory placement that holds across markedly different urban scales, economic profiles, and morphological configurations. Across all three cities, between 64% and 82% of cells with registered gambling activity are located within 300 m of at least one educational institution, a pattern that a Monte Carlo benchmark formally confirms departs from random placement at $p = 0.001$ in every tested case. Holding the observed number of machine-bearing cells fixed and reallocating randomly among urbanized cells over 1000 permutations, the observed proximity share exceeded the entire empirical null distribution in every city and for every sensitive facility category tested. In Iași, the observed share of machine cells within 300 m of a school was more than double the urbanized-pool null expectation (81.6% versus a null mean of 35.9%); the same pattern held for public transit stops (80.0% versus 36.8%) and healthcare facilities (32.8% versus 19.2%). In Bucharest, observed proximity to schools (75.3% versus 44.4%), transit stops (87.6% versus 50.2%), playgrounds (82.6% versus 52.8%), and healthcare facilities (47.8% versus 27.3%) likewise exceeded random expectation by substantial margins. The pattern was consistent in Pitești for healthcare facilities (31.2% versus 15.6%), playgrounds (64.1% versus 41.3%), and transit stops (57.8% versus 31.4%). Because the benchmark itself is constructed exclusively from comparably accessible urbanized cells, these results confirm that the observed co-location reflects deliberate siting rather than an artefact of general urban density. The transit co-location signal is equally consistent, with cells with registered gambling activity in all three cities recording mean distances to the nearest stop of under 200 m, confirming that public transit infrastructure constitutes a primary spatial determinant of gambling venue siting regardless of city size.

An analogous pattern emerges for children's playgrounds, with between 64.1% and 85.6% of cells with registered gambling activity located within 300 m of at least one playground across the three cities, and with mean distances ranging from 176.3 m in Iași to 264.2 m in Pitești, in every case below the corresponding mean distance to the nearest school. Places of worship, by contrast, consistently register the weakest proximity signal across all five sensitive categories, with fewer than 26% of cells with registered gambling activity located within 300 m of a place of worship in any of the three cities, a divergence that reinforces the interpretation of predatory placement as selectively targeting infrastructures of secular pedestrian convergence rather than faith-based community anchors.

The mean isochrone factors of Active and High Predatory Exposure zones across the three cases (ranging from 0.907 to 0.979 for the active zone and 0.734 to 0.887 for the high exposure zone) demonstrate that the spatial overlap between the gambling environment and the pedestrian catchments of sensitive community facilities is not incidental but structural, and intensifies with increasing urban density and transit network complexity.

5. Discussion

The spatial analysis presented in this study provides systematic, multi-city empirical evidence in support of the predatory placement hypothesis as applied to the Romanian slot-machine gambling sector. The consistency of the observed patterns across three urban

centers differing substantially in size, economic profile, and morphological structure demonstrates that the spatial co-location of gambling infrastructure with sensitive community facilities is not a localized or incidental phenomenon but a structural feature of venue distribution at the national scale. While this pattern is consistent with the predatory placement hypothesis, market-driven dynamics linked to general pedestrian footfall and commercial demand cannot be fully excluded as a contributing mechanism on the basis of cross-sectional spatial data alone.

The school proximity findings are particularly significant. Across all three cities, between 64% and 82% of cells with active gambling devices are located within 300 m of at least one educational institution, and between 89% and 94% within 500 m. These figures are consistent with the broader international literature on gambling machine geography. Wardle et al. [17] demonstrated, using geospatial analysis of premises records across Britain, that high-density machine zones exhibit significantly younger age profiles and higher rates of economic inactivity than non-machine areas, establishing that gambling machines cluster systematically in the spatial environments frequented by the demographic groups most susceptible to harm. The present findings extend this evidence base to a Central-Eastern European regulatory context, and the magnitude of the Romanian school proximity signal, particularly in Iași, where 94.4% of machine clusters fall within 500 m of a school, suggests that the absence of mandatory exclusion zones around educational facilities has allowed a degree of spatial saturation that would be structurally impermissible in more regulated markets.

A parallel and arguably more striking pattern emerges in the proximity of gambling infrastructure to children's playgrounds. Across all three cities, the mean distance from cells with registered gambling activity to the nearest playground is systematically shorter than the corresponding distance to the nearest school, reaching 176.3 m in Iași, 198.4 m in Bucharest, and 264.2 m in Pitești. In Bucharest and Iași, more than 82% of cells with active gambling devices fall within 300 m of a playground, a figure that exceeds even the school proximity signal in the same cities. This finding carries particular interpretive weight because playgrounds, unlike schools, are unstructured spaces of informal child presence associated with adult caregivers who are themselves subject to the routine exposure effects documented in the convenience gambling literature. The spatial overlap between slot-machine premises and playground catchments therefore implicates not only the developmental environment of children, in line with the evidence on early gambling exposure and later pathological gambling trajectories, but also the daily routines of accompanying adults, extending the predatory exposure surface beyond what school-focused analyses alone would detect.

The transit co-location pattern similarly reinforces the convenience gambling framework. Mean distances from cells with registered gambling activity to the nearest public transit stop, 194.0 m in Pitești, 136.3 m in Iași, and 106.8 m in Bucharest, place gambling premises systematically within spontaneous walking distance of nodes aggregating daily pedestrian flows across socioeconomic strata. This is consistent with the argument advanced by Livingstone and Woolley [36] that the marketing and distribution of electronic gambling machines exploits the physical environments most conducive to unplanned behavioral engagement, transforming ordinary transit infrastructure into a spatial enabler of impulsive gambling participation.

A notable contrast emerges when the proximity analysis is extended to religious facilities, the fifth category of sensitive infrastructure examined in this study. Across all three cities, places of worship record the weakest proximity signal of all sensitive categories analyzed, with fewer than 26% of cells with registered gambling activity located within 300 m of a religious facility in any of the three urban areas and mean distances ranging from 494.0 m in Pitești to 669.2 m in Bucharest. This divergence is analytically

informative rather than incidental: it indicates that the siting logic of the gambling industry does not correspond to a generalized pursuit of pedestrian density or community convergence, but is selectively oriented toward secular high-footfall infrastructures, educational, recreational, and transit nodes, while exhibiting structural indifference or mild avoidance of faith-based community anchors. This selectivity reinforces the predatory placement interpretation against the competing hypothesis that gambling venue geography is a passive by-product of generic urban commerciality.

The generalizability of these findings should be assessed along two distinct axes. Methodologically, the framework is jurisdiction-agnostic: it requires only georeferenced venue locations, an open facility layer, and a pedestrian routing engine, and can therefore be transferred to any urban system, as comparable geospatial approaches in England [32], Spain [33], and the Czech Republic [18] demonstrate. Substantively, however, the magnitude of the co-location signal is partly a function of Romania's current regulatory regime, which lacks mandatory exclusion zones around sensitive facilities. In jurisdictions enforcing statutory setbacks, the same method would be expected to register attenuated proximity. The transferable contribution is thus the analytical instrument and the vulnerability logic, the specific intensities reported here are characteristic of weakly zoned markets and should not be extrapolated uncritically to differently regulated contexts.

The cross-city density comparison introduces a finding of considerable interpretive weight. Pitești, despite being the smallest and economically least dynamic of the three cases, records the highest machine density at 9.05 devices per thousand inhabitants. This is consistent with the vulnerability convergence framework and directly aligned with the findings of Rintoul et al. [37], who demonstrated that socioeconomic disadvantage predicts gambling losses at the community level, and that the relationship between machine accessibility and harm is strongest precisely where alternative economic opportunities are most constrained. The Bucharest intra-metropolitan variation reinforces this argument further: Sectors 1 and 2, which record the highest machine densities at 12.21 and 13.98 per thousand inhabitants respectively, combine high transit density, concentrated educational infrastructure, and intense pedestrian commercial activity, a spatial configuration that maximizes the intersection of machine accessibility with vulnerable daily mobility patterns. This pattern aligns with Papineau et al. [19], who proposed an ecological gambling exposure index for Quebec and demonstrated that vulnerability to gambling harm emerges not from poverty alone but from the convergence of accessibility, density, and constrained economic resilience, a logic that the present study confirms holds across geographically and institutionally distinct urban contexts.

The collective evidence from all three cities points toward a structural conclusion with direct urban planning implications. The density of gambling machines within Romanian cities, their systematic proximity to schools and transit nodes, and the high isochrone factor values of active gambling zones, averaging above 0.90 across all three cases, demonstrate that urban residential neighborhoods constitute a fundamentally inappropriate environment for high-density slot-machine placement. The international precedent of geographically restricted gambling zones, of which Las Vegas represents the most paradigmatic example, offers a conceptually relevant and empirically supported alternative model. Under this framework, high-density gambling activity is spatially segregated from residential urban fabric and concentrated in designated areas specifically planned to minimize intersection with the routine mobility of vulnerable populations, particularly children, transit users, and economically constrained residents. Evidence from jurisdictions that have implemented exclusion zone regulations consistently shows that spatial separation between gambling venues and sensitive facilities reduces both accessibility and problem gambling initiation rates, particularly among adolescent populations [38]. The spatial vulnerability maps produced in this study provide an evidence-based instrument through

which Romanian urban authorities could delineate both the zones from which gambling activity should be excluded and the types of low-sensitivity urban areas, such as peripheral commercial districts or dedicated entertainment zones physically separated from residential and educational infrastructure, in which its continued presence could be tolerated without the predatory co-location patterns documented here.

While the present study establishes a robust spatial evidence base across three demographically and economically distinct urban contexts, certain methodological boundaries define the scope of its conclusions and open productive directions for future inquiry. The cross-sectional design, grounded in a single licensing snapshot from February 2026, captures the structural geography of machine placement at a specific regulatory moment, a design choice appropriate for establishing the baseline spatial signature of predatory placement, but one that precludes causal inference about the temporal dynamics through which this configuration emerged. Three sources of bias follow from the data design and warrant explicit acknowledgement. First, the February 2026 snapshot cannot capture seasonal variation or operator churn; however, because licensing operates on slow-moving annual authorization cycles, a single registry reliably represents the structural geography of placement. Second, the ONJN registry records only licensed premises: unlicensed or informal gambling activity is necessarily excluded, which biases the exposure estimates downward and renders the reported co-location intensities conservative lower bounds rather than upper-bound artefacts. Third, the machine count reflects registered licensed devices rather than verified real-time operational status. None of these biases are capable of generating the systematic proximity signal observed; each, if corrected, would be expected to strengthen rather than attenuate it.

A further limitation concerns the operationalization of economic resilience. Vulnerability is a multidimensional construct, and the use of mean local income as the sole resilience proxy does not capture intra-area income inequality (e.g., the Gini coefficient), unemployment, or low educational attainment, each of which shapes susceptibility to gambling-related financial harm independently of mean income. While mean income is strongly correlated with composite area deprivation at the Romanian county level and therefore captures the dominant axis of variation, it may mask within-area heterogeneity. The construction of a multidimensional composite resilience index represents a priority direction for future refinement [31].

Similarly, while Euclidean distance measures are employed for proximity feature construction in the machine learning component, the network-based isochrone layers integrated into the vulnerability scoring formula substantially compensate for this constraint by conditioning exposure classifications on realistic pedestrian accessibility rather than straight-line proximity alone. Future research extending this framework longitudinally, and integrating individual-level health and financial outcome data, would allow the structural exposure patterns identified here to be linked directly to measurable harm outcomes at the population level.

6. Conclusions

This study set out to test whether the spatial distribution of slot-machine gambling devices across Romanian urban centers reflects a pattern of predatory placement, that is, a systematic tendency to locate high-density gambling infrastructure within pedestrian reach of sensitive community facilities and vulnerable population groups. The evidence produced across three cities of markedly different scale, economic profile, and urban morphology converges unambiguously in support of this hypothesis.

Across Bucharest, Iași, and Pitești, between 64% and 94% of all hexagonal cells containing gambling machines are located within 500 m of at least one educational institution, and machine clusters record mean distances to public transit stops of under 200 m in all

three cases. The proximity signal to children's playgrounds is, in every case, at least as strong as and frequently stronger than the school proximity signal, with mean playground distances ranging from 176.3 m in Iași to 264.2 m in Pitești and with between 64% and 86% of active gambling cells located within 300 m of a playground. By contrast, religious facilities consistently register the weakest spatial association with gambling infrastructure across all three cities, a divergence consistent with venue distribution being oriented toward secular high-footfall environments rather than uniformly toward pedestrian convergence in general.

Active gambling presence zones register mean isochrone factor values consistently above 0.90, indicating that over 90% of the surface area immediately surrounding gambling machine locations lies within the pedestrian catchment of sensitive community facilities. These are not marginal or ambiguous results, they describe a spatial configuration in which the co-location of gambling infrastructure with the daily mobility environments of children, transit users, and economically constrained populations is the norm rather than the exception. The density analysis reinforces this conclusion from a different angle: Pitești, the smallest and least economically dynamic of the three study areas, records the highest machine density per capita at 9.05 devices per thousand inhabitants, demonstrating that the industry gravitates not toward affluence but toward the convergence of sufficient financial flow with constrained economic alternatives and high pedestrian accessibility, precisely the vulnerability configuration identified in the international literature as most conducive to gambling-related harm.

The methodological framework developed in this study, combining H3 hexagonal tessellation at resolution 10, network-derived pedestrian isochrones, ensemble machine learning for spatial determinant analysis, and a multiplicative vulnerability scoring model, offers a transferable and replicable instrument for gambling harm geography. The dual-condition logic of the vulnerability score, which requires both proximity to gambling machines and meaningful isochrone coverage to register elevated exposure, operationalizes the theoretical distinction between geometric proximity and realized behavioral accessibility in a way that previous buffer-based approaches could not [39]. The consistency of the spatial patterns identified across three urban contexts of different size and structure suggests that this framework can be applied to the full set of Romanian municipalities with active gambling licensing without requiring case-specific recalibration, enabling a national-scale vulnerability assessment that would constitute the most comprehensive spatial evidence base on gambling harm geography in Central-Eastern Europe.

The broader implication of the findings extends beyond the Romanian regulatory context. The systematic intersection of gambling machine density with school proximity zones, transit nodes, and pedestrian-accessible community infrastructure across all three study areas demonstrates that the integration of high-density slot-machine activity into the ordinary fabric of residential urban neighborhoods is structurally incompatible with the protection of vulnerable populations. The evidence supports a fundamental reorientation of the spatial governance of gambling, away from the current model in which machines proliferate throughout residential urban tissue subject only to national licensing thresholds, and toward a model of geographic concentration in designated areas specifically planned to minimize intersection with sensitive community environments. The paradigm of spatially segregated gambling zones, in which high-density gambling activity is confined to peripheral or purpose-designated commercial areas physically separated from educational, healthcare, and residential infrastructure, represents not merely a regulatory preference but a public health necessity supported by the spatial evidence produced here. Romanian cities, as this study demonstrates, are not Las Vegas: they are dense, pedestrian-oriented urban environments in which the current geography of gambling machines constitutes a form of institutionalized predatory exposure that no responsible gambling

framework operating at the individual level can adequately address. Structural spatial intervention, grounded in the kind of evidence-based vulnerability mapping developed in this study, is the appropriate and proportionate policy response [6]. The findings carry clear planning implications, but the policy response must match the physical form of Romanian and other European cities. Their compact, functionally mixed structure makes the strict segregation of gambling venues into separate districts, or their removal beyond the city limits, both impractical and incompatible with existing land use and commercial property rights. Two more proportionate instruments are available to local authorities under OUG 7/2026. The first is density caps: limits on the number of licensed machine premises allowed per area or per thousand inhabitants within an administrative subdivision, set to prevent the saturation observed in the highest-exposure sectors. The second is minimum separation distances between gambling premises and sensitive receptors such as schools, playgrounds, and transit nodes.

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