

Functional Rural Areas and Territorial Cohesion: Accessibility-Based Delimitation for Place-Based Policy in Spain

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Abstract:

Functional areas are increasingly recognised as key arenas for place-based policy intervention, particularly in contexts characterised by demographic decline, territorial inequalities and fragmented governance. In Spain, large rural territories face persistent population loss and limited access to essential services, revealing a mismatch between administrative boundaries and real functional dynamics. This paper proposes a nationwide delimitation of rural functional areas based on effective accessibility to education and healthcare services, providing a new territorial framework to support cohesion-oriented policies.

The methodology builds upon central place theory, reinterpreted through an equity-oriented perspective. Two core principles are operationalised: a 30-minute maximum travel time to essential services and the minimum population thresholds required to sustain key facilities. The analysis considers more than 36,800 population nuclei, identifying functional centres based on the presence of hospitals, secondary schools, primary schools and health centres. Using network-based travel time calculations over the national road infrastructure, areas of influence are delineated and subsequently adjusted to account for low-density gaps and polycentric configurations.

The resulting system of approximately 600 functional areas reflects actual spatial interdependencies more accurately than conventional municipal or provincial units. This approach allows for the identification of territories with structural accessibility deficits and provides an operational scale for coordinating service provision, strengthening inter-municipal cooperation and guiding territorial investment strategies.

Beyond methodological innovation, the paper discusses how accessibility-based functional delimitation can enhance the effectiveness of cohesion policy instruments in rural and peripheral contexts. By aligning policy intervention with real service areas rather than administrative fragmentation, the proposed framework supports place-based governance, improves resource allocation and contributes to more equitable territorial development in times of demographic change. The paper also critically examines the institutional, legal and administrative barriers that hinder the adoption of functional approaches in Spain, including rigid sectoral planning structures, fragmented competences across levels of government, and the persistence of funding mechanisms anchored in conventional administrative units.

Keywords:

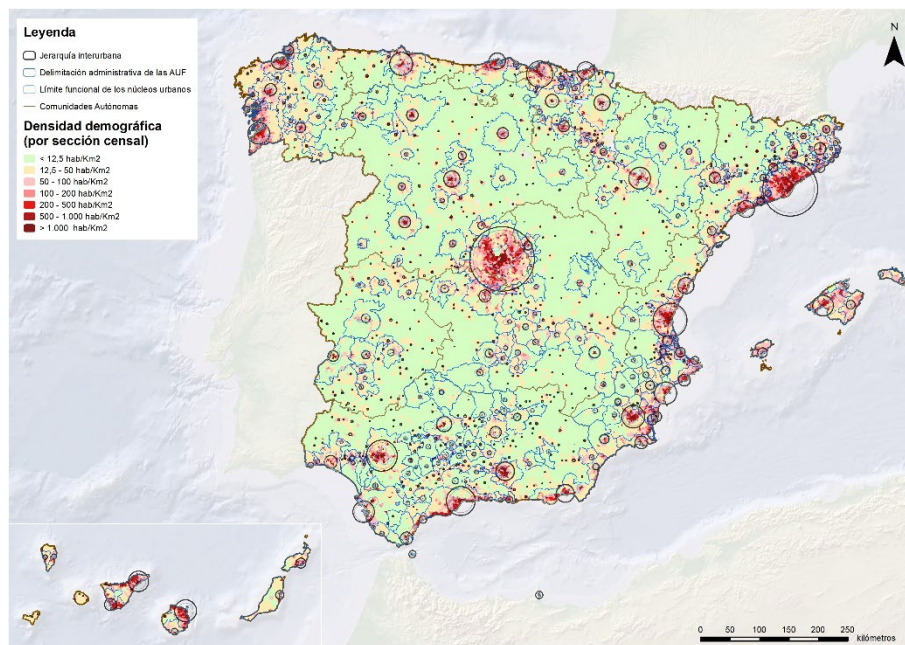
Demographic change; Functional areas; Accessibility to services; Cohesion policy; Place-based governance

1. Conceptual Framework: Functional Areas, Accessibility and Territorial Equity

The growing mismatch between administrative boundaries and real socio-economic interactions has become a central concern in regional science and territorial policy. Increasing daily mobility, network-based economic organisation and differentiated access to essential services challenge traditional urban–rural dichotomies and call for functional approaches to spatial organisation (OECD, 2012; ESPON, 2015). In this perspective, functional areas are understood as territorially coherent units structured around service provision, labour markets and everyday mobility patterns rather than formal administrative jurisdictions (Gómez Giménez, 2020, 2022).

The conceptual foundation of this research builds on Central Place Theory (Christaller, 1933; Lösch, 1940), particularly its notions of range (maximum distance consumers are willing to travel for a service) and threshold (minimum population required to sustain that service). Importantly, the threshold is closely linked to economies of scale and fixed costs: it approximates the minimum demand needed for service provision under efficiency-oriented conditions. In very low-density territories this ‘economic threshold’ is often unattainable, which means that access cannot be treated as a market outcome but must be approached as a normative commitment. While classical formulations assumed isotropic space and market rationality, contemporary reinterpretations emphasise network anisotropy, infrastructural constraints and the institutional conditions that shape spatial equity (Parr, 2002; Meijers & Burger, 2010). In such contexts, accessibility becomes a political variable linked to rights, citizenship and territorial justice, requiring compensatory public provision and governance arrangements that intentionally operate below conventional thresholds.

Figure 1. Population Density by Census Section in Spain (2021 Census). Source: National Statistics Institute (INE) and Spanish National Geographic Institute (IGN).

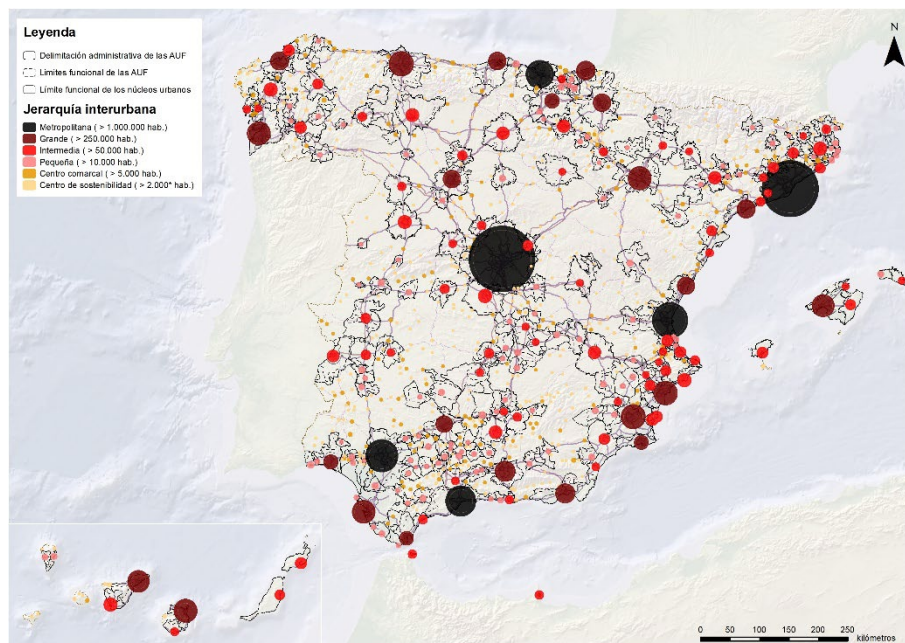


From this reconsideration of economic threshold and scale efficiency emerges a broader normative question: under what conditions should public provision deliberately operate below efficiency benchmarks to guarantee territorial equity?

From a normative standpoint, accessibility to basic services constitutes a material dimension of territorial equity. The absence of reasonable access to healthcare, education or transport infrastructure produces cumulative disadvantages that reinforce demographic decline and economic marginalisation. This aligns with the logic of place-based policy (Barca, 2009; Barca, McCann & Rodríguez-Pose, 2012), which argues that spatially differentiated challenges require territorially tailored interventions grounded in local structural conditions.

In Spain, these debates intersect with the National Strategy against the Demographic Challenge (2021), which explicitly recognises unequal access to services and opportunities as structural drivers of depopulation and territorial imbalance. The methodology presented here was developed in the framework of technical assistance to the Ministry responsible for territorial cohesion and demographic policy, with the objective of providing a consistent, evidence-based functional zoning capable of supporting monitoring, prioritisation and inter-administrative coordination.

Figure 2. Interurban Hierarchy and Functional Urban Systems in Spain. Source: Gómez Giménez (2020); INE (2021 Population Census); IGN (Geographic Reference Data).

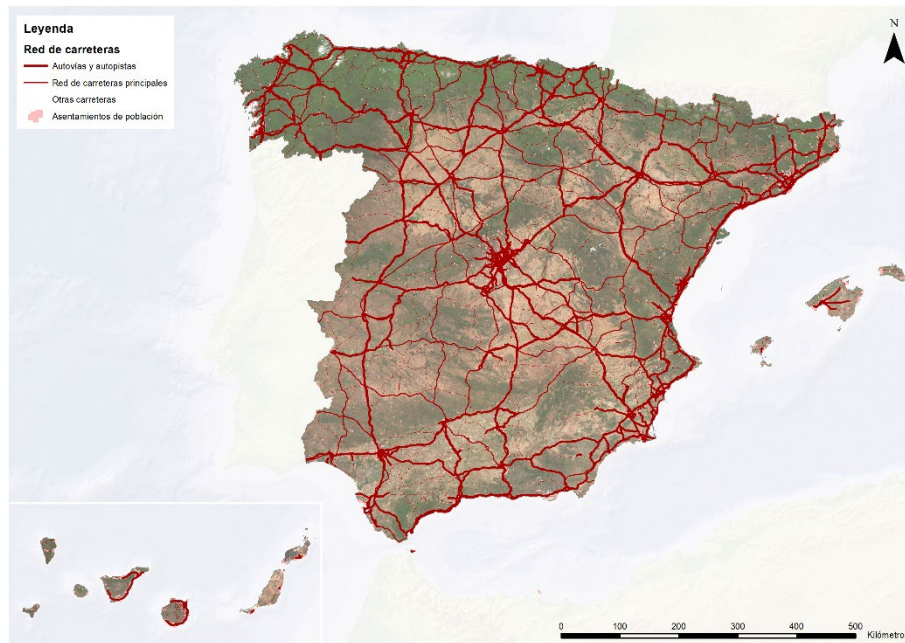


Importantly, the empirical operationalisation of accessibility in this research relies on high-resolution geospatial modelling. Travel-time calculations and network distance estimations were produced largely by technical teams of the Spanish National Geographic Institute, combining data and expertise from two of its Geographic Reference Information projects: *Redes de Transporte* (Transport Networks) and *Poblaciones* (Population Settlements). This collaboration ensures that the delimitation of functional areas is grounded in topologically consistent, three-dimensional national transport network data and geocoded settlement information covering more than 36,800 population nuclei. The methodological robustness of these calculations is therefore anchored in official geospatial infrastructures rather than simplified Euclidean approximations.

The functional approach adopted here does not seek to replace administrative frameworks. Rather, it introduces an analytical spatial layer capable of enhancing territorial governance. By identifying service-based centralities and their real areas of influence, it reframes rural disadvantage as a gradient of functional integration instead

of a categorical condition. In doing so, it contributes to cohesion-oriented policymaking by providing a common territorial reference system for evaluating inequalities and designing differentiated interventions across metropolitan, urban and rural Spain.

Figure 3. Hierarchical Classification of the National Road Network in Spain. Source: IGN (Transport Network Geographic Reference Data).



2. Methodological Design:

The delimitation of functional areas was conceived as a multistage process combining hierarchical centrality analysis, network-based accessibility modelling and administrative coherence adjustments. The methodology operationalises classical central place principles under contemporary conditions of anisotropic transport networks and differentiated service provision (Christaller, 1933; Parr, 2002), integrating geospatial modelling techniques commonly used in functional regionalisation and accessibility analysis (Hansen, 1959; Geurs & van Wee, 2004).

The empirical starting point consists of the complete national system of around 36,800 population nuclei. These settlements were first classified according to two complementary dimensions: demographic size and functional service provision.

2.1. Hierarchisation of Population Nuclei

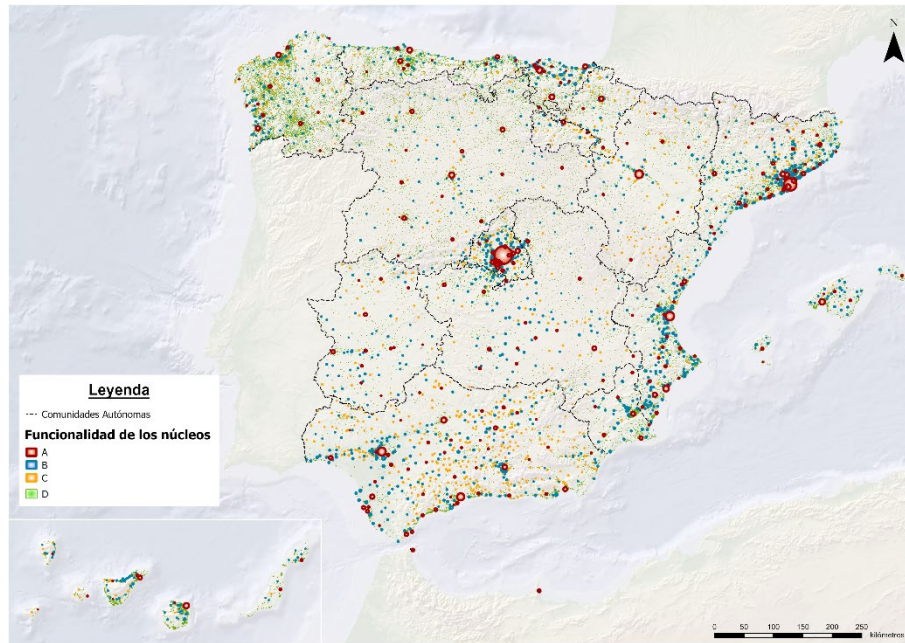
Population nuclei were organised into demographic size levels (from fewer than 100 inhabitants to more than 50,000 inhabitants) and into functional categories based on the presence of key services. Four functional centrality levels were defined:

- Level A: Presence of a general hospital.
- Level B: Presence of upper secondary education institutions and health centre.
- Level C: Presence of compulsory secondary education and health centre.
- Level D: Presence of primary education and/or health centre.

This classification translates the concept of threshold into empirical criteria of minimum service provision, linking centrality not only to population size but to effective service capacity. Unlike purely demographic hierarchies, this approach recognises that

functional relevance depends on institutional infrastructure and not solely on settlement scale.

Figure 4. Distribution of Functional Centres in Spain According to Hierarchical Classification Based on Service Centralities. Source: Ministry for the Ecological Transition and the Demographic Challenge (MITECO), SIDAMUN Integrated Municipal Data System.



2.2. Accessibility Parameters and Network Modelling Assumptions

The delimitation process was primarily structured around a maximum travel-time criterion rather than an *ex ante* fixed demographic threshold. Functional allocation initially relied on the identification of nuclei classified as A and B centralities according to service provision hierarchy. These higher-order functional centres constituted the starting nodes for network-based accessibility modelling.

A maximum travel time of 30 minutes by motorised road network to essential services was adopted as the principal operational parameter. This criterion reflects both empirical mobility patterns and a normative commitment to reasonable access standards. However, during the calibration of the model, it became evident that travel-time estimations derived from theoretical road speeds embedded in the network dataset did not always correspond to effective travel conditions.

In many segments of the national road network—particularly high-capacity or well-maintained roads—actual travel speeds tend to exceed the conservative theoretical speeds used in network modelling. As a result, some settlements appeared marginally beyond the 30-minute threshold despite being functionally integrated in practice. To correct for this distortion and avoid artificial fragmentation, the maximum range was extended *ex post* to 35 minutes in specific cases.

Conversely, in mountainous or structurally fragile territories—often those most affected by demographic decline—the opposite situation occurs: real travel speeds frequently fall below theoretical maximum speeds due to topographical constraints, road geometry, or seasonal conditions. This introduces asymmetries in accessibility modelling and highlights the limits of standardised speed assumptions in heterogeneous territorial contexts.

Importantly, no strict minimum population threshold was imposed at the outset. The delimitation began with nuclei already recognised as functional centralities (Levels A and B). However, when functional voids were detected—particularly in sparsely populated territories—the model incorporated lower-tier centralities, effectively relaxing demographic size constraints. In practice, some of these newly integrated centres correspond to settlements with populations around 100 inhabitants. Rather than representing a predefined economic threshold, this adjustment reflects an equity-oriented correction aimed at preventing territorial exclusion in areas where classical scale economies are unattainable.

Travel-time calculations were computed over the national road network using topologically consistent geospatial data produced by the Spanish National Geographic Institute (IGN). The modelling integrates the Geographic Reference Information projects *Redes de Transporte* (Transport Networks) and *Poblaciones* (Population Settlements), enabling network-based (rather than Euclidean) distance estimation and incorporating the three-dimensional structure and connectivity of the transport infrastructure.

2.3. Phase 1: Initial Delimitation through Network-Based Partitioning

The first phase consisted of assigning each population nucleus to its nearest higher-order centre (Levels A and B) within a 30-minute travel-time radius. Conceptually, this resembles a Voronoi-type partition, but instead of Euclidean distance, allocation is based on network travel time. Where equidistance occurred between centres of the same hierarchical level, boundaries were drawn along network equidistance lines. Where hierarchical differences existed, precedence was given to the higher-order centre.

This initial allocation resulted in 777 preliminary functional areas and identified 828 municipalities whose travel time to a Level A centre exceeded 30 minutes ($T > 30$), revealing functional gaps in service accessibility.

2.4. Phase 2: Gap Correction, New Centralities and Polycentric Integration

The second phase addressed territories that remained uncovered or weakly integrated after the initial allocation. Two complementary mechanisms were implemented.

First, the maximum travel-time range was extended from 30 to 35 minutes in marginal cases where settlements appeared slightly beyond the threshold due to modelling assumptions but were functionally connected to an existing centre in practice. This extension was applied selectively and aimed at preventing artificial fragmentation in territories with effective socio-spatial integration.

Second, new functional centres were introduced in areas lacking adequate coverage. Rather than relying on a predefined demographic minimum, the identification of additional centralities was based on the presence of essential public services and their effective territorial role. In many sparsely populated areas, public provision already operates below classical economies-of-scale thresholds. The methodology therefore recognises *de facto* centralities where institutional service provision sustains functional relevance despite limited population size. In some cases, these centres correspond to small settlements (even below 100 inhabitants) that perform strategic roles in their surrounding territory.

This adjustment phase thus reflects the reality that service provision in low-density regions cannot be assessed exclusively through efficiency criteria. Instead, it acknowledges that public systems frequently compensate for insufficient demand in order to guarantee territorial continuity and avoid service deserts.

A crucial component of Phase 2 was the integration of polycentric configurations. Where neighbouring nuclei exhibited more than 80% population overlap within a 30-minute catchment area, they were aggregated into a single functional area. This criterion captures situations in which multiple small towns or comarca-level settlements operate as a jointly structured service system. In such configurations, services are often distributed across adjacent nuclei—healthcare in one centre, secondary education in another, administrative functions in a third—forming a territorially interdependent network rather than a strictly hierarchical single-core structure.

These multipolar arrangements include cases of “twin towns” or closely linked small urban centres that function collectively as a local hub. Aggregating areas with high population overlap prevents artificial separation of territories that share service catchments, daily mobility patterns and institutional cooperation mechanisms. The resulting configuration therefore better reflects the functional logic of small-scale urban systems in rural and intermediate Spain.

2.5. Phase 3: Intra-Municipal Reallocation at Settlement Level

The third phase did not primarily seek administrative reconciliation. On the contrary, it introduced a finer-grained functional correction by shifting the analytical scale from municipalities to individual population nuclei.

While the initial phases of the analysis were largely conducted at municipal level—given the availability of administrative and statistical data—the final stage explicitly incorporated the full system of more than 36,800 population nuclei in Spain. This allowed for the reassessment of allocations in municipalities composed of multiple dispersed settlements.

In several cases, different nuclei within the same municipality displayed distinct accessibility patterns. Peripheral settlements located at the edge of municipal boundaries were sometimes functionally closer—in terms of network travel time—to service centres located in neighbouring functional areas. Maintaining municipal integrity in such situations would have artificially distorted the effective geography of service provision.

Phase 3 therefore involved the selective reallocation of individual nuclei across functional boundaries, even when this implied dividing a municipality between two or more functional areas. This intra-municipal differentiation ensures that each settlement is assigned to the functional area to which it is effectively connected in terms of service accessibility.

Although such fragmentation would be complex to operationalise within existing administrative frameworks, it provides a more accurate representation of territorial reality. Rather than privileging institutional boundaries, the methodology prioritises functional proximity and effective service catchments. The resulting system of 600 final functional areas thus reflects accessibility-based integration at the settlement level, revealing the limits of municipal units as proxies for functional geography.

2.6. Methodological Contribution

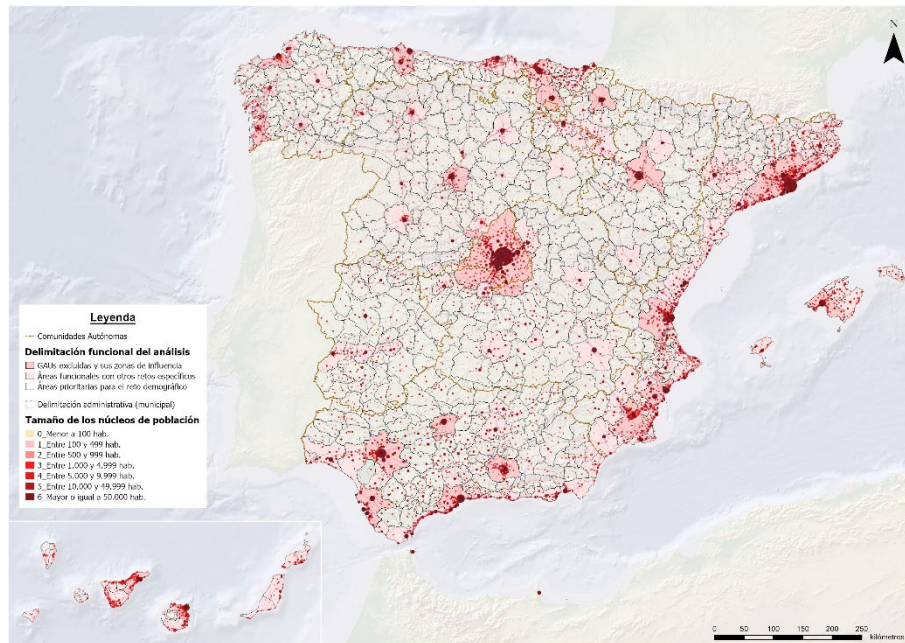
The final configuration represents a hybrid regionalisation model: it combines hierarchical service-based centrality, network-based accessibility modelling and institutional compatibility constraints. Unlike purely morphological or commuting-based delineations, this system is explicitly anchored in access to essential public services, thus linking functional geography with territorial equity objectives.

Rather than merely illustrating an iterative technical adjustment, the final configuration exposes the structural tension between scale efficiency and territorial equity. In several low-density territories, public service provision already operates below conventional

economies-of-scale thresholds, evidencing a sustained institutional effort to guarantee access where market logics would not justify it. At the same time, the persistence of functional voids in extremely sparsely populated areas highlights the material limits of accessibility under conditions of demographic contraction and geographic constraint.

In this sense, the methodology does not simply refine central place structures; it makes visible the uneven capacity of public systems to fulfil the constitutional principle of equality regardless of place of residence. Functional delimitation thus becomes not only an analytical exercise but a diagnostic instrument revealing where territorial cohesion commitments face structural challenges.

Figure 5. Delimitation of the 600 Final Functional Areas in Spain. Source: Own elaboration based on accessibility modelling and service-based centrality analysis.



3. Functional Typology and Territorial Prioritisation System

3.1. Functional Typology

Following the consolidation of 600 Functional Areas (FAs), the territorial system was structured into ten categories according to demographic scale and centrality intensity. The classification is based on the size of the central nucleus and the overall functional population, reflecting degrees of service provision and territorial integration.

The resulting distribution is as follows:

- 10 Metropolitan Areas: 5 areas (36.45% of national population; 4.96% of surface)
- 09 Proto-metropolitan Areas: 2 areas (3.83% pop.; 0.89% surface)
- 08 Large Urban Areas: 14 areas (17.33% pop.; 3.98% surface)
- 07 Intermediate Urban Areas: 45 areas (17.91% pop.; 10.37% surface)
- 06 Small Urban Areas: 60 areas (10.14% pop.; 11.17% surface)
- 05 Protourban Areas: 71 areas (6.02% pop.; 12.83% surface)
- 04 Hierarchised Rural Areas: 102 areas (3.89% pop.; 15.88% surface)
- 03 Structured Rural Areas: 226 areas (4.04% pop.; 32.11% surface)
- 02 Unstructured Rural Areas: 71 areas (0.39% pop.; 7.53% surface)
- 01 Dysfunctional Rural Areas: 4 areas (0.003% pop.; 0.28% surface)

Several structural asymmetries emerge clearly when functional areas are grouped into three major territorial blocks.

- The 21 metropolitan and large urban areas (categories 08–10) concentrate 57.6% of Spain's population while occupying only 9.8% of national surface. These areas represent the apex of functional centrality and demographic concentration within the Spanish territorial system.
- At the opposite extreme, the 403 rural functional areas (categories 01–04) account for only 8.3% of total population but cover 55.8% of national territory, revealing the vast spatial extension of low-density environments with limited demographic weight.
- Between these two poles lies an intermediate territorial layer composed of 176 protourban and small-to-intermediate urban areas (categories 05–07), which host 34.1% of the population across 34.4% of land surface. This intermediate system plays a critical structural role, articulating the national territory and mediating between metropolitan concentration and rural dispersion.

This tripartite configuration highlights a deeply polarised spatial structure: demographic and economic mass is highly concentrated in a limited urban core, while territorial extension is predominantly rural, with an intermediate layer that ensures functional continuity across scales. Such structural asymmetry underscores the necessity of differentiated territorial policies that reconcile efficiency, accessibility and constitutional principles of territorial equity, particularly in the context of demographic challenge governance.

3.2. Territorial Prioritisation Criteria

Beyond typological classification, the research develops a prioritisation framework designed to support the implementation of programmes and strategies.

The prioritisation system combines three structural demographic criteria:

1. Low population density (below 25 inhabitants per km²).
2. Long-term population decline, measured since the historical demographic peak.
3. Recent demographic trajectory, particularly population evolution during the 21st century.

Through combinatory intersection, 15 prioritisation categories are generated, distinguishing between structurally fragile territories, stabilising areas, and demographically resilient configurations.

This avoids reducing demographic vulnerability to density alone. Instead, it recognises the cumulative nature of territorial fragility:

- Low density without decline does not equal structural vulnerability.
- Historical depopulation without recent contraction may indicate stabilisation.
- Persistent decline across both historical and recent periods signals entrenched demographic stress.

The system therefore captures both structural inertia and contemporary dynamics.

3.3. Linking Functional Typology and Prioritisation

The analytical robustness of the model lies in the cross-classification between:

- Functional integration level (centrality + scale)
- Demographic vulnerability profile

This intersection allows identification of differentiated territorial situations:

- Highly rural, low-density areas with sustained demographic contraction, often coinciding with longer accessibility times and weaker service networks.

- Intermediate urban areas under demographic stress despite maintaining functional centrality.
- Territories where demographic resilience coexists with structural accessibility constraints.

The framework therefore supports calibrated, place-based intervention rather than uniform rural policy prescriptions. Intervention intensity and policy orientation can be modulated according to both functional integration and demographic trajectory.

Beyond classification and prioritisation, the model highlights the necessity of systematic territorial monitoring. The consolidation of 600 functional areas provides a stable analytical framework upon which longitudinal observation can be structured. Unlike purely administrative units, these functional territories reflect accessibility patterns, service provision logics and real socio-spatial interactions, making them particularly suitable for policy follow-up in the context of territorial cohesion and demographic challenge governance.

In this regard, an exploratory monitoring system has been developed based on a battery of 48 indicators grouped into seven analytical domains: demographic-territorial, infrastructural-accessibility, environmental, agrarian, productive, sociodemographic and socioeconomic dimensions. These indicators are not intended as static descriptors but as dynamic instruments capable of capturing structural change, vulnerability intensification or resilience processes across functional typologies.

The consolidation of a permanent statistical framework aligned with functional areas would significantly enhance policy effectiveness. Maintaining a stable database structured around these territorial units — with temporal continuity and institutional support from national statistical and geospatial agencies — would allow consistent evaluation of public interventions, improved comparability across territorial categories and better identification of emerging imbalances.

Such an approach would move beyond ad hoc evaluations and enable evidence-based territorial governance grounded in functionally coherent spatial units rather than exclusively administrative boundaries. In this sense, the functional delimitation not only serves as a diagnostic instrument but also as a potential long-term monitoring infrastructure for cohesion-oriented public policy.

4. Governance Implications and Cohesion Policy Relevance

The functional zoning proposed in this research has direct implications for multi-level governance and the design of cohesion-oriented policies. At its core lies a classical problem in regional science: scalar mismatch, understood as the misalignment between the spatial scale of socio-economic processes and the scale at which governance competences and policy instruments are defined (Hooghe & Marks, 2003; Brenner, 2004).

In Spain, as in many European countries, administrative boundaries reflect historical compromises rather than contemporary functional realities. Municipalities vary enormously in size, demographic structure and institutional capacity. Provinces and autonomous communities display highly heterogeneous territorial configurations. This institutional architecture generates what can be termed *path-dependent territorial governance*: fiscal allocation systems, sectoral planning instruments and statistical monitoring frameworks are anchored in historically sedimented administrative units, reinforcing their persistence even when they no longer correspond to functional dynamics.

From a cohesion policy perspective, this creates two structural distortions:

- First, resource allocation mechanisms—particularly those based on per capita formulas or administrative eligibility criteria—may not correspond to real service areas. Functional dependencies frequently cross municipal or even provincial borders, yet funding instruments often remain territorially bounded. This fragmentation weakens policy effectiveness in areas where service provision relies on inter-municipal cooperation or polycentric configurations.
- Second, monitoring and evaluation systems struggle to capture territorial inequalities at the appropriate scale. Indicators aggregated at municipal or provincial level obscure intra-provincial disparities and mask the functional interdependence of settlements. The functional areas developed in this research provide an intermediate analytical scale capable of improving comparability across territories and aligning evaluation frameworks with actual service catchments.

The proposed model therefore operates as an *analytical governance layer*. It does not alter formal competences, but it introduces a consistent territorial reference system through which sectoral policies (healthcare, education, transport, digital infrastructure) can be coordinated. In this sense, it contributes to the operationalisation of place-based policy principles (Barca, 2009), translating normative commitments to territorial equity into spatially explicit governance tools.

Moreover, the integration of accessibility indicators into the typology-prioritisation matrix enhances the strategic orientation of cohesion policy instruments. By identifying territories where demographic vulnerability and accessibility deficits overlap, the framework supports differentiated intervention intensity rather than uniform rural policy schemes. Functional areas thus become operational arenas for coordinating multi-sectoral investment, particularly in the context of demographic challenge and service sustainability.

In theoretical terms, the research demonstrates how classical central place logic can be embedded within contemporary multi-level governance systems, transforming a descriptive spatial model into a prescriptive policy instrument.

5. Institutional and Operational Barriers to Functional Approaches in Spain

Despite their analytical robustness, functional approaches encounter significant institutional and operational barriers in the Spanish context.

5.1. Sectoral Rigidity and Administrative Inertia

Public policies in Spain remain strongly sectoralised. Health, education, transport and social services are governed through distinct legal frameworks, budget lines and administrative hierarchies. Planning instruments are typically aligned with administrative jurisdictions rather than functional service areas. This sectoral rigidity limits the capacity to adopt integrated territorial approaches, even when functional evidence demonstrates spatial interdependencies.

Furthermore, fiscal allocation systems are predominantly linked to municipal or regional administrative units. Funding formulas rarely incorporate functional catchment areas, which reduces incentives for cross-boundary cooperation and reinforces institutional inertia.

5.2. Fragmented Competences in a Decentralised State

Spain's highly decentralised political system distributes competences across municipalities, provinces and autonomous communities. While decentralisation

enhances territorial autonomy, it also produces coordination challenges in functional territories that span multiple jurisdictions.

Functional areas frequently extend beyond a single municipality and, in some cases, cross provincial or regional boundaries. However, existing inter-municipal cooperation mechanisms (e.g., *mancomunidades*) are unevenly developed and often lack sufficient fiscal or strategic capacity. This fragmentation complicates the implementation of service-based territorial planning.

5.3. Data and Statistical Constraints

Operationalising functional approaches requires high-resolution geospatial and demographic data. While the collaboration with the National Geographic Institute ensured methodological rigour in this project, routine policy implementation would require sustained updating of network data, service registries and population distributions.

Moreover, statistical systems are primarily structured around administrative units, creating challenges for consistent monitoring at functional scales. The absence of institutionalised statistical reporting for functional areas represents a barrier to long-term integration of this framework into policy evaluation processes.

5.4. Political Economy Constraints

Finally, redefining territorial reference units may encounter political resistance. Administrative boundaries are not neutral technical artefacts; they embody representation, fiscal entitlements and political identity. Functional zoning, even when conceived as analytical rather than institutional reform, can be perceived as challenging established territorial arrangements.

This political economy dimension reinforces path dependency and may limit the speed at which functional evidence translates into governance reform.

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