Are current road investments exacerbating spatial inequalities inside European peripheral regions?

Soledad Nogués and Esther González-González

GEURBAN Research Group. School of Civil Engineering, University of Cantabria.

ABSTRACT

The European Union has made considerable investments in transport infrastructures to reduce development gaps within and across territories and achieve a stronger regional cohesion. However, these economic efforts have not shown the expected effects, especially in peripheral regions, mainly due to the varied nature of their inner areas. This study aims to shed light on the existence of different types of areas inside peripheral regions that respond differently to the construction of new high-capacity roads, conditioning the achievement of cohesion goals. These disparities were explored through a detailed intraregional analysis of the peripheral Spanish Northwest Area over a 25-year period, through the identification of spatial categories that group homogenous areas in attention to three criteria: socio-economic development, spatial dynamics of urbanisation and accessibility improvements. The application of a hierarchical clustering technique to different time scenarios and their comparison showed the existence of dynamic, stable and regressive areas, in terms of performance. Our findings reveal that with accessibility improvements regressive areas decreased and dynamic ones increased over time, but this transformation did not translate into an improvement in socio-economic intraregional cohesion. These results highlight the importance of considering intraregional diversity when formulating and implementing policies aimed at strengthening territorial cohesion.

Keywords: peripheral areas, intraregional inequalities, transport assessment, high-capacity roads, cluster analysis.

1. INTRODUCTION

The relationship between transport and regional development is a long lasting and as yet unresolved debate (Banister and Berechman 2000; Biehl, 1991; ESPON, 2015; OECD, 2012; Vickerman, 1995). Transport is a widely accepted location factor of population and its activities, and a key element in territorial structural configuration (Hansen, 1959; Le Clerq and Bertolini, 2003). It is generally acknowledged that higher development rates are located in well-connected sites where a variety of activities are offered and a critical mass is reached within an acceptable travel time (Linneker, 1997; Bosworth and Venhorst, 2018), the quality and competitive advantage of some locations relative to others often being measured in terms of accessibility (Spiekermann and Neubauer, 2002). As such, the integration between core and peripheral areas, or rather, relative peripheral areas (Nogués and González-González, 2014), has been one of the main objectives of territorial policies at European level, investments in infrastructures being the basic tool to reduce disparities and hence to achieve territorial cohesion (EC, 1999, 2005; ESPON, 2005, 2015).

However, literature reveals that the effects of infrastructure investments on territorial cohesion and development do not follow a linear relationship or a uniform pattern, but rather, they depend on the initial conditions of the areas concerned (Banister and Berechman, 2000; ESPON, 2015; Fratesi and Wishlade, 2017, Fujita and Thisse, 2002), as well as on the spatial and temporal scale of analysis. At the less studied regional level, the effects of accessibility improvements are not evenly distributed within each region

(Gagliardi and Percoco, 2017) but there are in fact clear intraregional differences between urban, periurban and rural areas (González-González et al., 2019). These effects can be positive in periurban areas influenced by their proximity to urban centres, or negative, as a result of tunnel or pump effects, especially in deeper rural areas marked by their isolation and general decline (EC, 1999, Salas-Olmedo et al., 2009).

Thereupon, there is a need for studies which analyse the internal diversity of regions over reasonably large temporal scales (Meijers, et al., 2012; Salas-Olmedo et al., 2009; Stelder, 2014), i.e. involving a minimum of 10-15 years for high capacity infrastructures (Fariña et al., 2000), to better evaluate and understand the varied effects of road investments in the achievement of regional development and territorial cohesion. These analyses would help policy and decision makers to plan tailor-made solutions and interventions for each type of region and spatial scale, in order to obtain more efficient results (Farole et al., 2011; Fratesi and Whislade, 2017). This evaluation is particularly important in countries that are making massive investments in terms of infrastructure, such as Spain (Holl, 2007; Medeiros, 2017). The Spanish case is a clear example given the huge investments made and the limited improvements obtained in the accessibility or socio-economic status of the affected regions (Albalate et al., 2015; Rodríguez-Pose et al., 2018, Stepniak and Rosik, 2013).

In this context, the aim of our study was threefold, 1) to verify the existence of a variety of zones within the broad limits of relative peripheral areas which can be distinguished in attention to their socio-economic, territorial and accessibility conditions, 2) to determine whether the level of accessibility is indeed a key element to define them, and 3) to analyse whether accessibility changes over time, derived from transport investments, can be associated to changes in the behaviour and classification of these inner areas, or conversely, are not relevant to re-classify them and reduce territorial inequalities.

To do so, a replicable hierarchical Clustering technique, based on the use of common and available socio-economic, urbanisation, and accessibility indicators, was applied to data from peripheral Northwest Spain over the 25-year period in which most of its current road network was developed. This area, classified as a NUTS1-ES1 (Eurostat, 2016b), belongs to one of the most representative relative peripheral areas in Europe, the European Atlantic Arc. It is formed by the Autonomous Communities of Galicia, Asturias and Cantabria. Asturias and Cantabria, classified as peripheral service-oriented areas, and Galicia, included into the *'poor West European regions'* sub-group of the Heidenreich's (2003) classification of EU regions, have benefited greatly from EU funds mostly used to expand their motorway network. However, the large amount of funds received and the investments made on motorway expansions have not been mirrored in the corresponding expected regional development, making this area an ideal case study to examine and clarify the effects of transport infrastructures inside European peripheral areas.

The paper is structured in 5 sections. The following section presents transport infrastructure development as one of the main investment objectives of European territorial policy and reviews its role, along with other factors, in the development of territories. Section 3 explains the four-step classification methodology based on the delimitation of intraregional functional units, the selection of representative attributes and indicators, the hierarchical classification and its validation. Section 4 assesses the inner progress of Northwest Spain over time, summarises and interprets the results of the empirical analysis and identifies internal areas of differing performances. Finally, section 5 presents the discussion and main conclusions obtained from this research.

2. TRANSPORT INFRASTRUCTURE, TERRITORIAL DEVELOPMENT AND COHESION POLICIES IN EUROPE

2.1. Infrastructure investment in the framework of the European cohesion policy

The EU cohesion policy was introduced in 1989 with the primary goal of reducing "disparities between the various regions and the backwardness of the least-favoured regions" (Leonardi, 2005). However, this socio-economic convergence had to be accompanied by a maximization of economic growth (Farole et al., 2011). European regional policies have always believed in the potential of transport to achieve these objectives in the concerned regions (ESPON, 2015). The European Spatial Development Perspective (ESDP) itself stated that "spatial differences in the EU cannot be reduced without a fundamental improvement of transport infrastructures and services to and within the regions" (EC, 1999). As a result, investment in transport infrastructures has been a clear priority in all programming cycles of European funds over the last decades.

Since the 1990's, almost 1/3 of total EU funding has been assigned to the development of infrastructures (Gren, 2003), and especially to roads in peripheral areas outside Europe's core (Rokicki and Stepniak, 2018; Rosik et al., 2015). In the 1989-1993 period, the percentage of funding allocated to infrastructure development reached its peak at 36%, a percentage which generally fell in subsequent programming periods as transport networks were completed. In the 1994-1999 period this percentage fell to 26% but rose again between 2000 and 2006 to over 30%. Since the launching of the EU's Territorial Agenda (2007, updated in 2011), funding has continued to be concentrated in less developed regions (EC, 2014), 23% in the period 2007-2013, while European policy objectives have progressively shifted towards sustainability calling for a more sustainable transport.

However, despite these great economic efforts, there are still serious doubts regarding whether the objectives of cohesion policy have been achieved or whether the regions have continued their development pathways as if there had been no policy intervention (Farole et al., 2011; Fratesi and Whislade, 2017). Numerous studies evaluate the effectiveness and impacts of cohesion policies with very different conclusions. This is probably because, despite its relevance, regional cohesion lacks a clear and univocal conceptual or operational understanding (Abrahams, 2014; Medeiros and Rauhut, 2020; Zaucha and Böhme, 2020), its definition including ideas ranging from economic competitiveness to socio-economic convergence (Nosek, 2017).

According to several authors, although infrastructure investment has sometimes generated positive effects, on many occasions it has fostered regional polarization, increasing the marginality of those peripheral areas where the investments have been made (Barca et al., 2012; Rodríguez-Pose and Fratesi, 2004). Other studies point out that policy efficiency depends on the geographic location and starting conditions, i.e. structural inequalities, of the different territories (Dall'erba and Hewings, 2003; Gagliardi and Percoco, 2017) calling for place-based policy interventions (Barca et al., 2012). In fact, this new approach gave rise to the concept of territorial cohesion and has influenced the new 2014-2020 Cohesion program (Nosek, 2017). However, the Seventh Cohesion Report on economic, social and territorial cohesion pointed out that there are still many regions in Member States that are not connected by an efficient road network. The main source of funding for implementing EU transport policy during this period was the 'Connecting Europe Facility', which complemented European Structural and Investment Funds with a budget of 24 billion euros, of which 96.3% was mobilized between 2014 and 2016, focusing again on infrastructure investments (EC, 2017).

2.2. The role of accessibility and other factors in the development of territories

Transport infrastructure supports economic activity although it does not necessarily imply convergence and is not always enough to achieve economic development and growth. Increasing evidence shows that the relationship between transport and development is not so obvious and that the actual effect of transport infrastructure development, far from bridging the gap among regions, has sometimes been to increase the disparities between core and peripheral areas despite improvements in accessibility (Forslund and Johansson, 1995; López et al., 2008; Meijers et al., 2012; Monzón et al., 2019; Rietveld and Bruinsma, 1998; Vickerman, 1995). Several analyses indicate that although important and a pre-requisite for regional progress, infrastructure development will not guarantee a region's economic boost, unless: the area was competitive prior to the investment (ESPON, 2015); other social or institutional factors are also favourable (Dall'erba and Hewings, 2003; Hart, 1993; Holl, 2004a, b); and/or additional measures to mitigate its isolation are put into force (Baudelle and Guy, 2004).

The effects of infrastructure investment depend on the characteristics of the area or region (Halstead and Deller, 1997; Hansen, 1965). In general, areas where accessibility is low and that are only provided with new single links (very peripheral areas) often show no marked influence of the new infrastructures (Spiekermann and Neubauer, 2002), while core areas, where accessibility is already high, also show marginal influences of the new infrastructures in their socio-economic development (ESPON, 2015; Holl, 2007; Müller et al., 2010). Rather than assuring an overall increased progress, accessibility changes induced by transport infrastructures often have a stronger impact on the spatial structure of territories.

Recent contributions of the 'new economic geography' have developed a core-periphery model to explain the effects of accessibility on the spatial redistribution of economic activities (Fujita et al., 1999; Holl, 2007; Proost and Thisse, 2015). This model shows how reductions in transport cost, which are actually different in central and peripheral areas (Persyn et al., 2020), alter the balance between dispersal and agglomeration forces and can therefore have different effects depending on the regions or areas. As a result, the traditional core-periphery paradigm is being increasingly challenged, the strict definitions of core and periphery becoming dubious and overlapping. The emergence of new regional growth centres and the proliferation of opportunity locations (dynamic touristic sites, county's administrative centres, etc.) in peripheral areas, together with the decay of core industrial zones and city suburbs is rendering traditional definitions over-simplistic (Gren, 2003; Spiekermann and Neubauer, 2002), and hence the most commonly used methodologies for territorial classifications.

These classification procedures, normally based on the urban-rural dichotomy, such as the one proposed by Eurostat (2016a), are eminently based on population density and threshold criteria, which are not sufficient to analyse and understand the internal diversity of territories. Other studies included also land use and accessibility criteria, although only based on access time to urban agglomerations of at least 50,000 inhabitants (Copus et al., 2008; Jonard et al., 2009). The population and time limits set in these studies may not be representative of existing territorial structures in various countries, and may therefore hamper their replication, especially in peripheral areas. New classification methodologies that enable approaching territorial diversity holistically are thus necessary, demographic and land use variables should be considered, but also economic and more comprehensive accessibility aspects so as to better reflect the territorial dynamics of peripheral areas.

3. METHODOLOGY

Our assessment is based on a four-step replicable clustering methodology to identify homogenous groups of functional units inside peripheral areas in attention to three main criteria: socio-economic development, spatial dynamics of urbanisation and accessibility improvements. The cluster analysis is a multivariate statistical analysis that identifies non-predefined groups of similarly behaving entities (Hair et al., 2014) according to a set of certain attributes. In this study entities' attributes were represented by commonly used and available socio-economic, urbanisation and accessibility indicators. In order to evaluate which attributes are, and especially whether road development was, relevant to classify the various functional units, basic statistical values and differences of the attributes for each cluster group were analysed and tested. Also, so as to analyse whether accessibility changes imply changes in the behaviour of the different functional units' over time, several cluster analyses at different times of the study period were carried out and compared.

3.1. Step 1: Division of the study area into functional units

In order to allow a better understanding of the territorial dynamics of peripheral areas at an intra-regional level, the use of functional areas is proposed. Functional areas are defined as a group of areas with common spatial and developmental characteristics (OECD, 2002) which represent intraregional relations and flows more realistically than administrative units. Given the goals and scale of analysis of this study the delimitation of functional units covers the whole study area, as opposed to the Functional Urban Areas (FUAs) delimitation proposed by the EU-OECD (Dijkstra et al., 2019), which only focuses on urban centres with more than 50,000 inhabitants or 1,500 inhabitants per square kilometre and their hinterlands.

Functional units are usually delimited by defining a hinterland around a node or focal point, to which surrounding areas are linked through transportation and communication systems, and economic (usually labour) activities (Cörvers et al., 2009; Juillard, 1962; NCGE, 1994). Accordingly, in this study the delimitation of these units was carried out considering the aggregation of entire municipalities, since they are the smallest unit with available and harmonized data (Nogués and González-González, 2014). The proposed delimitation is based on the identification of municipal capitals that act as supramunicipal centres providing services and labour opportunities that attract daily commutes from neighbouring municipalities.

As regards our case study, Galicia and Asturias already had official functional delimitations made by their Regional Governments (DOG, 1997; BOPA, 1991). As for Cantabria, delimitation was defined from the proposal made under the development of the Regional Spatial Plan of Cantabria (PROT) (Gobierno de Cantabria, 2017), that followed the same methodology proposed here. These divisions were further amended in order to better differentiate urban and periurban processes in relation to accessibility measures. The amendment consisted in separating the major regional urban centres, i.e. A Coruña, Vigo, Gijón and Santander (population around or over 200,000 inhabitants), which resulted in a total of 96 units: 57 units in Galicia, 20 units in Asturias and 19 units in Cantabria.

3.2. Step 2: Definition of representative attributes

This step focuses on the selection, and estimation, of specific and representative attributes and their indicators, available during the whole study period. The results of these calculations were then compiled into a GIS database (ArcGIS®) to build thematic maps that represent the spatial pattern/structure of the data and their relationship with the evolution of transport infrastructures in the study area. These descriptive and visual analyses lead to a first understanding of the behaviour of homogenous areas and potential significant variables to be considered in the clustering procedure.

3.2.1. Socio-economic development

The most specific, and readily available, variables and indicators that characterize demographic dynamics attributes are Total Population, P_t and Ageing rate, Ar, i.e., the ratio between population above 64 years of age, $P_{>64}$, and P_t, which enables the characterization of trends in population loss and ageing within the study area.

As regards the economic attributes, the one which best characterizes income and welfare at intraregional level is Household Income per capita (HIC), which was thus, chosen for this study. This datum, provided by the corresponding Regional Statistic Institutes, usually needs a few amendments to ensure its homogenisation before selecting it for the analysis. Additionally, Unemployed population was also considered (Table 1). This is the only employment related datum that is available at municipal level and homogenously collected by Spanish regional unemployment offices.

3.2.2. Spatial dynamics of urbanisation

Another relevant criterion to distinguish between the various areas is the level and evolution of urbanisation, which is represented by density and spatial distribution of land use coverage attributes. The key indicators for such analysis are population density and the artificialisation rate, which represents the percentage of artificial land surface in a functional unit. Artificial land use can be estimated by analysing geographic land use databases such as the European CORINE Land Cover (CLC), which includes 39 countries, and is available at the 1/100.000 scale (EEA, 2020) for six years: 1990, 2000, 2006, 2012 and 2018.

Among the five main categories of land uses defined in the CLC, there are five classes related to Artificial surfaces: Continuous urban fabric, Discontinuous urban fabric, Industrial or commercial units, Green urban areas and Sportive and recreational areas.

3.2.3. Accessibility improvements

To guarantee that our accessibility assessment included diverse spatial effects of transport infrastructures (Gutiérrez, 2001; López et al., 2008), we selected three location-based and complementary accessibility indicators, each emphasizing one type of relationship pattern:

1) the Potential indicator (Pot), accentuates differences between urban agglomerations and rural areas, and is thus particularly suited to study the effect of high-capacity roads mainly connecting urban agglomerations. It is a gravity-based index relating the attractiveness of a destination, represented here by its population, with the travel time between nodes, t_{ij}, following a negative power function with a decay parameter value of 1 (Gutiérrez, 2001; Hansen, 1959; Spiekermann and Neubauer, 2002).

2) the Location indicator, is more related to spatial location, showing core-periphery patterns, but “does not place the emphasis on short distances” (Gutiérrez, 2001). It also relates destination population to travel time, but population is used to weight the travel time (Table 1), to account for the importance of the trip between nodes (Gutiérrez, 2001; López et al., 2008).

3) Finally, the Daily Accessibility indicator (DA), a more restrictive version of the potential indicator, stresses intraregional commuting relationships. It is a cumulative-opportunity measure that counts the number of opportunities O_j, (i.e. public services, economic activities, etc., represented here by the population), which can be reached within a fixed distance or travel time (López et al., 2008; Spiekermann and Neubauer, 2002). In order to adapt the analysis to typical intraregional daily commuting trips, a thirty-minute threshold was considered (Bertolini et al., 2005).

To calculate the three indicators, one transport network for each year of analysis was modelled into the ArcGIS programme, considering ideal average speeds in attention to the various road types. In the case of Spain, motorways and single carriageways managed by the Spanish Ministry of Public Works were modelled at 120km/h and 100 km/h respectively, while single carriageways, interurban two-line roads and local two-line roads managed by regional administrations were modelled at 90 km/h, 70 km/h, and 50km/h respectively. The capitals of the functional units and the regional capitals of the rest of the country - to consider border effects - were set as network nodes. To isolate the effects of changes in the regional network within the case study area from those associated to variations in the road network outside the region, the modelled network of the rest of the country was kept constant (2015 situation) in all created networks.

Table 1. Indicators of the criteria used in the analysis

Field	Indicator name	Formula	Variables
Socio-economic dimension	Total Population	P_t	$P_{>64}$: population above 64 years old P_t: total population
	Ageing rate	$A = \frac{P_{>64}}{P_t} \cdot 100$	
	Household income per capita	*HIC*	UnEmp: number of total registered unemployed population
	Total Unemployed population	$UnEmp$	
Spatial dimension	Population density	$D_i = \frac{P_t}{S_t}$	S_t: total surface
	Artificialisation rate	$Artif = \frac{S_{ArtLand_i}}{S_t}$	$S_{ArtLand}$: Surface of artificial land
Accessibility dimension	Potential accessibility	$Pot_i = \sum_j \frac{O_j}{t_{ij}}$	t_{ij} : travel time by the minimal-time route between each pair of entities in an area O_j : attractiveness variable of the destination δ_j : dummy variable
	Demographic Location	$LD_i = \frac{\sum O_j \cdot t_{ij}}{\sum O_j}$	
	30-minute Daily accessibility	$DA_i = \sum_j O_j \cdot \delta_{ij}$	

Source: own work from Gutiérrez (2001), López et al. (2008), OECD (2008).

3.3. Step 3: Clustering procedure

The first step consists of a correlation analysis of the attributes, using the Spearman method, to select the final set to be used for the cluster analysis after their standardization. The aim of the correlation analysis is not to avoid multicollinearity, but to reduce the number of variables that could over-represent some of the criteria (Hair et al., 2014). Standardization is highly recommended when dealing with interval-scaled variables in order to avoid the sensitiveness of cluster analyses to differences in magnitude among variables (Kaufman and Rousseeuw, 1990; Hair et al., 2014).

To perform the cluster analysis, we selected Ward's hierarchical clustering procedure, since it combines those clusters that minimize the increase in the total sum of squares across all variables in each step (Hair et al., 2014). Before carrying out the analysis, it is advisable to identify the optimal number of groups (clusters) that should result from the cluster analysis. We used the NbClust package of the R software, which allows comparing 23 different methodologies, such as Hubert or D indexes. This procedure shows the number of methods which identify the optimal number of clusters, proposing the final solution according to the majority rule (Charrad et al., 2014).

Once the classifications were obtained, the interpretation of results and identification of spatial homogenous categories relied on the assessment of the statistics of each variable, the representation of the clusters' results in maps and the comparison of the different classifications obtained. In this case, non-parametric boxplots allowed us to graphically represent several basic statistical values (such as median, maximum, minimum…) for each variable, and thus visually analyse which attributes were more dissimilar between clusters, i.e., were more relevant for the classification. All data analyses were performed using R programming language. Then, the spatial patterns shown by such classifications can be further examined using the maps compiled with the GIS software.

3.4. Step 4: Validation of the classification

3.4.1. Significance

To validate the clustering results the statistical significance of the differences in the mean values of the variables between clusters were tested using non-parametric Kruskal-Wallis and post-hoc Mann-Whitney tests (Tukey corrected) (Astel et al., 2007; Field et al., 2012).

Stability of the cluster solutions and of the spatial structures over time was assessed by comparing which functional units, and which number of them, were assigned to the same group for the different cluster solutions. Some authors have argued that clustering solutions can be considered very stable when less than 10% of the units are assigned to a cluster different from the initial one, or stable or somewhat stable when between 10-20% or 20-25% respectively (Hair et al., 2014).

3.4.2. Robustness

We considered running two additional cluster analyses and comparing them with the results of the previous classifications to ensure the robustness of the assessment. The first one included a mixture of static and dynamic values, consisting of data related to the starting year of the analysis along with changes during the analysed period. The second one considered all the relevant variables for the complete period at the same time, combined using a Principal Components Analysis (PCA). This technique reduces the number of dimensions of the data to those explaining most of the variability of the original set. Its applicability is justified when obtaining a Kaiser-Meyer-Olkin (KMO) test value over 0.7. The varimax rotation solution of the PCA was selected to clarify the relationship between factors easier (Abdi and Williams, 2010; Hair et al., 2014).

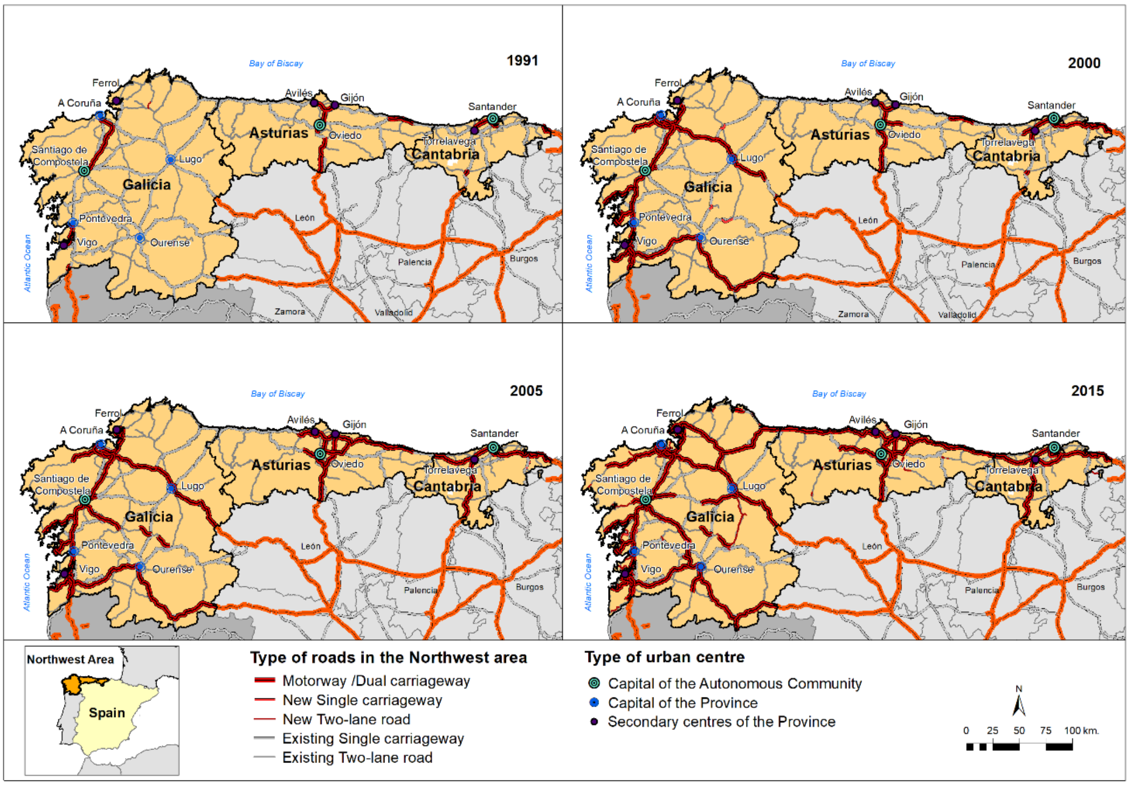
4. RESULTS

4.1. Evolution of Northwest Spain (1991-2015)

Between 1991, year in which the first section of the connecting East-West motorway (A8) was inaugurated, and 2015, when the last detour of A8 was opened in Cantabria, the motorway network of the Spanish Northwest Area increased significantly throughout the area, from 263km to 1,900km (see Figure 1). The most noteworthy actions during the 1991-2000 period, as a result of the successive national transport plans, were the

Galician Atlantic corridor and those linking Galicia and Madrid, as well as the coastal link between Santander and Bilbao. During the 2000-2015 period, the main transport investments involved the remaining sections of the Cantabrian coastal motorway to Galicia, the Santander-Madrid motorway and the new connections of the central area of Asturias with the coast (Figure 1). Galicia is now the region with the highest length of motorways in this area (1,175.3 km), followed by Asturias (467.1 km) and Cantabria (257.9 km) (MF, 2015), although in density terms (km per regional surface) the order reverses.

Figure 1. Transport network development in Northwest Spain and the rest of the Iberian Peninsula: 1991, 2000, 2005 and 2015



Source: own work compiled from Holl (2004b), IGN (2018b) and MF (2015, 2015b).

4.1.1. Socio-economic development

Demographic dynamics in the area were generally characterized by a slow population growth (0.4%) and high ageing trend (32% increase) for the whole period. The bulk of the population concentrated in the provincial capitals and main cities, such as A Coruña and Santander, which are the areas that grew the most in the period 1991-2000, coinciding with the opening of large capacity roads. Since then, the highest growth rates have occurred in periurban and coastal areas, which received population associated with the construction of low-density residential areas developed by their proximity to transportation corridors, or were revitalized by tourism. On the other hand, rural areas, particularly those in inner and more remote areas, suffered a more or less generalized population loss, more pronounced in the 2000-2015 period (Figure 2). Although Northwest Spain showed an important ageing trend as a whole, following an east-to-west increasing gradient, rural areas were the most disfavoured ones, especially the least accessible ones.

As regards economic performance, in the Northwest Area, the highest values of Household Income per capita (HIC) concentrated mainly in the large urban centres and their areas of influence (the Atlantic axis in Galicia, the central area around the Asturian Y and the eastern coastal strip of Cantabria). These are the poles of the areas connected by the main high-capacity roads. During the 1991-2000 decade, coinciding with a phase of strong expansion of the Spanish economy, unemployment decreased in general while HIC grew throughout the Northwest area (Figure 2), especially in Cantabria (96% with respect to its original situation), reaching a regional value slightly above the Spanish average (INE, 2004). From 2007 onwards, as a result of the financial crisis, HIC's growth rate slowed down, especially in rural interior areas where job losses became widespread, as happened in other regions with similar characteristics (Sánchez-Zamora and Gallardo-Cobos, 2020). By the end of the period, Asturias became the Autonomous Community with the highest regional HIC of the three analysed, 14,796 €, slightly above the Spanish average (14,431 €), while Cantabria and, especially Galicia, remained below national average (INE, 2019).

4.1.2. Spatial dynamics of urbanisation

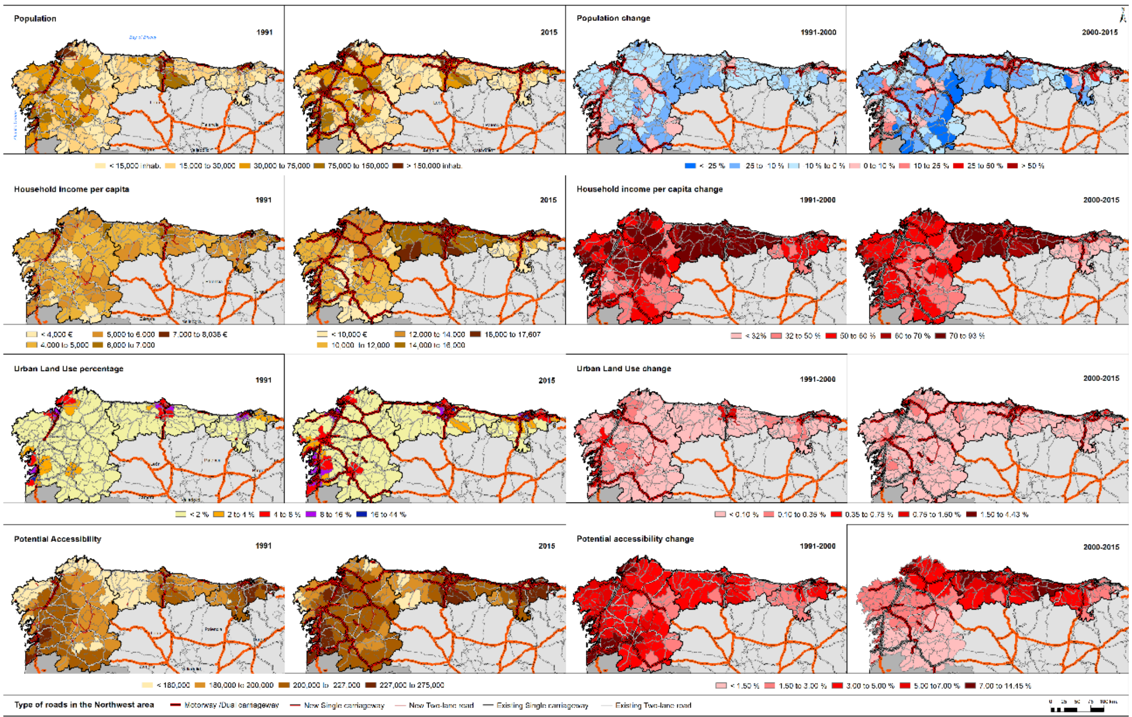
The analysis of the evolution of artificial surface propagation reveals the importance of urbanisation processes throughout the study period (49% increase), although they were more intense during the first decade, coinciding with the expansive economic cycle and the boom of the Spanish real estate sector.

More than half (51%) of the expansion of this artificialisation concentrated in the most important urban nodes (A Coruña, Vigo, Oviedo, Gijón and Santander). The urban fringe and coastal areas located along the main communication axes, such as the eastern Cantabrian coast, the central Asturian area and the southern Atlantic strip, became more dynamic, gathering 46% of the artificialisation changes and showing a significant urbanisation process. On the other hand, in the interior areas, traditional agriculture and forest uses barely gave way to new artificial surfaces, amounting to only 3% of total artificial changes in the Northwest area.

4.1.3. Accessibility improvements

In general, accessibility improved considerably in the whole Northwest Area over time, although the final accessibility level is still lower than in central and other peripheral areas of Spain. At the beginning of the study period, the main cities showed the highest accessibility values, while the interior rural areas had the lowest ones. During the 1991-2000-decade, accessibility improvements occurred in areas that started at an intermediate level, such as periurban areas and those located along the new infrastructures, adjacent or connected to the urban centres, leading to an increase in inequalities in the region. The areas of the Atlantic coastline, that had worse initial situations, stood out due to important investments in transport development during that decade. During the period 2000-2015, most improvements were concentrated in the central area of the Cantabrian coast, with the development of new links that connected the Area by slightly reducing previous disparities. At the end of the analysed period, the western Northwest Area still had the worst accessibility values, while differences between more and less accessible areas slightly decreased.

Figure 2. Initial situation (1991), Final situation (2015) and Relative changes (1991-2000 and 2000-2015) in the most representative indicators of the assessment criteria: population, household income per capita, urban land use and potential accessibility



Source: own work compiled from IGN (2018, 2018b), INE (2018), ICANE (2018), IGE (2018), SADEI (2018) and MF (2018).

4.2. Results of the cluster analysis

Several classifications were carried out using the following non-correlated variables: Total Population, Ageing Rate and HIC within the socioeconomic criteria; Surface of artificial land (Artificialisation rate) within the urbanisation criteria; and the three accessibility indicators at different times, corresponding to the 1991, 2000, 2005, and 2015 situations. Potential and Daily Accessibility were only moderately correlated and they were necessary in order to account for intraregional commuting relations.

Previously, we estimated the optimum number of clusters to be obtained by the clustering technique. The NbCluster package determined 2 (k=2) as the optimum number of clusters for the 1991 and 2005 classifications (proposed by 8 of the 23 methods analysed), k=4 (10/23 methods) for the 2000, and k=3 (9/23 methods), for the 2015 classification, respectively. The k=2 solution only differed between major urban areas and the rest. The k=3 solution, added a new category that separated second urban centres or periurban areas close to urban agglomerations from the rest of the areas, mainly due to their accessibility levels. Finally, the k=4 solution separated the rest into two groups in attention to their accessibility values.

For the sake of homogeneity, and to assess the influence of accessibility indicators in the classification, we selected 4 clusters to compare the four classifications. In view of the high similarity of the results obtained for the classifications of the four years (Figure 3) it can be concluded that Population, HIC, and Artificialisation rate were very influential in the differentiation of Cluster 2, which corresponds to some provincial capitals, from the remaining units and especially with Cluster 1 and 4 (Figure 4). Cluster 1, which groups inner southern areas[1] (Figure 3) highly differs from the rest by Ageing rate, especially in the 1991 classification. This group was also the one with the lowest Population and Artificialisation values (Table 2), representing the differentiation between the rural and, more or less, urbanized worlds. As regards Clusters 3 and 4,

[1] The classification obtained for the year 2015 switches Cluster 1 and Cluster 3.

corresponding to intermediate areas, i.e. neither urban or rural, they present the largest distances in Accessibility (Figure 4, Table 2).

Accessibility was indeed key to differentiate Cluster 3 from the rest of the rural areas. This category corresponds to areas located in the surroundings of the main urban areas and along the main road axes (Figure 3). These units present the best mean values of Potential accessibility (Table 2), as well as the second-best values in socio-economic characteristics, closer to urban areas than to the other groups, in variables such as Population and Ageing.

On the other hand, Cluster 4 groups areas mainly located in coastal zones. Cluster 4 presents the worst Accessibility values, which could seem *a priori* more representative of Cluster 1, the most rural inland areas. This is due to the peripheral situation of the region and the population weighting formulation of these indicators. While the interior areas are far from the main urban centres of their own region, they are much closer to provincial capitals of neighbouring provinces. This particularity is also revealed in the proximity of Clusters 4 and 1 as regards the Daily accessibility indicator, since there were no relevant differences when travel time limits of 30 minutes were considered (Table 2). Finally, it should be noted that Cluster 4, which initially was very similar in demographic and economic terms to Cluster 1, ended up improving significantly its economic situation, approaching the other intermediate category (Figure 4). This is due to the fact that by improving their connectivity with nearby urban centres, coastal areas benefit from their touristic appeal, thus improving their socio-economic development. Cluster 4 increased in number of units over time (from 16 to 24), especially at the expense of the reduction in Cluster 1 (from 41 to 30), indicating the improvement of some coastal rural areas, which became intermediate.

Figure 3. Spatial representation of the cluster's results

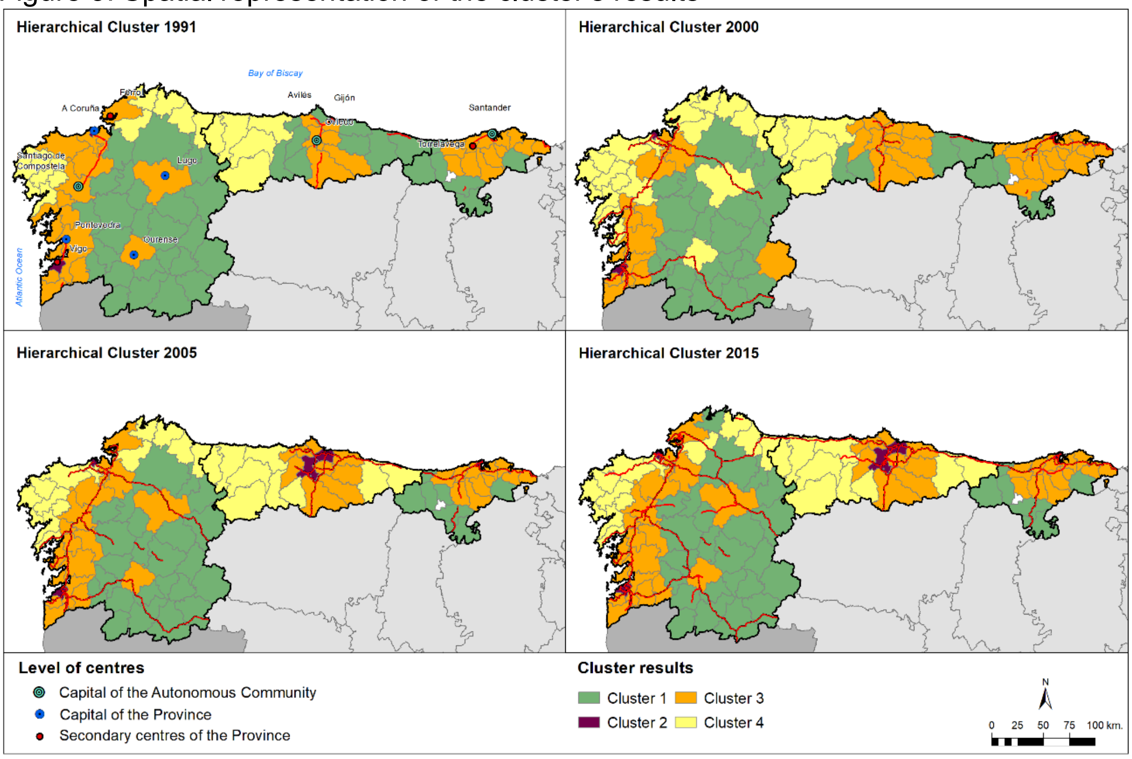
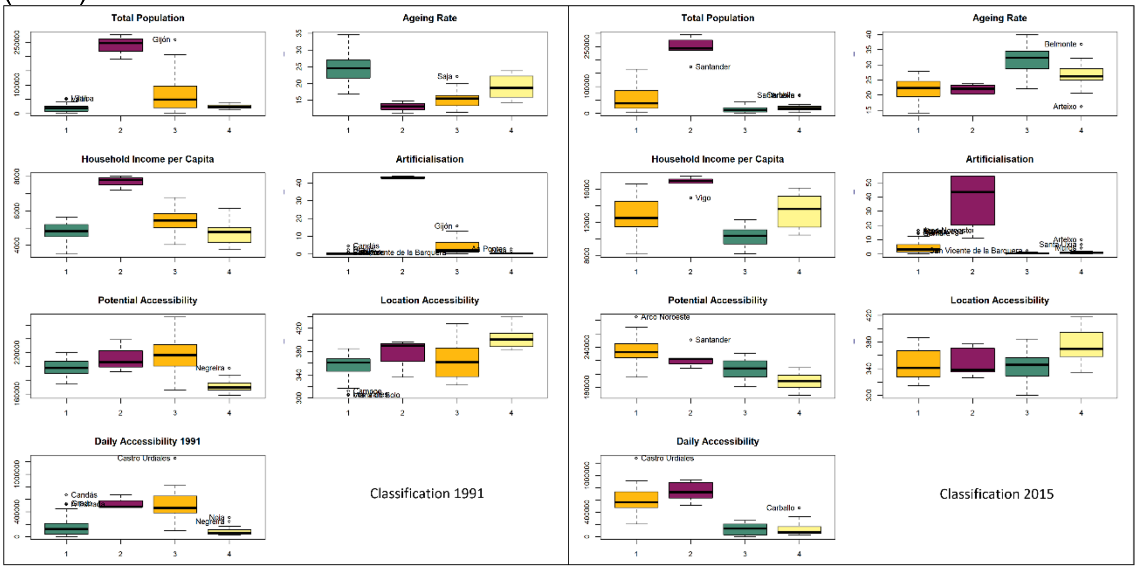


Figure 4. Boxplots of variables used in the Cluster analysis for the Initial (1991) and Final (2015) situations



Data Source: IGN (2018, 2018b), INE (2018), ICANE (2018), IGE (2018) and SADEI (2018).

4.3. Validation of classifications

4.3.1. Significance

The differences between clusters found using the previous boxplot representation were statistically evaluated by Kruskal-Wallis and post-hoc Tukey corrected Mann-Whitney tests, considering a level of significance of 0.05. Around 57% of the variables' mean comparisons between clusters were statistically significant, decreasing from 59% to 50% in the 1991-2000 period and then increasing up to 59% again in the 2015 classification (Table 2). These results indicate that homogenous groups reduced their territorial imbalances during the first period, but increased their inequalities with time. Clear statistical differences were found between Cluster 1 and 3 (rural *vs* intermediate periurban units) for 89% of the variables, Clusters 1-2 (78%) (urban *vs* rural) and Clusters 3-4 (56%) (intermediate periurban *vs* coastal units), while no statistical differences were obtained between Clusters 2-3.

The comparison of the various clustering results and their spatial distribution over time confirms the stability of the assessment and the persistent spatial structure of the region. The assignment of functional units to each cluster showed that the coincidences between groups of years were in general close to 85%, which means a very stable data structure. These differences were particularly related to the socio-economic dissimilarities between intermediate Clusters 3 and 4, and differences in urbanisation processes and economic improvement between Clusters 1 and 4 (Table 2), due both to the improvement of Cluster 4 with respect to its initial situation and the progressive increase in the number of units assigned to this cluster. This result can also be related to the assessment of the coefficient of variation, which reflects an increase in inequalities in population and income variables, variables that differentiated the urban areas (Cluster 2) from the rest, and a reduction in terms of ageing, urbanisation dynamics and accessibility terms.

Table 2. Statistical assessment of differences between variable means for each cluster

	Variables	Mean Cluster 1	Mean Cluster 2	Mean Cluster 3	Mean Cluster 4	Statistical difference between clusters (Mann-Whitney tests; p=0.05)					
						1-2	1-3	1-4	2-3	2-4	3-4
Classification 1991	Number units	41	3	36	16						
	Population	19300.66	238047	68442.28	23971.38	T	T	F	F	T	F
	AgeingRate	24.64	13.08	15.29	18.98	T	T	T	F	F	F
	Unemployed	1061.61	17572.33	4622.28	1186.44	T	T	F	F	T	T
	HIC	4778.63	7685.96	5442.84	4706.96	T	T	F	F	T	T
	Density	38.19	4733.84	234.38	56.98	T	T	F	F	T	T
	Artificialisation	0.396	42.92	4.12	0.57	T	T	F	F	T	T
	Potential Acces	198020.1	212371.7	215505.2	171760.4	F	T	T	F	T	T
	Location Acces	354.93	374.05	364.43	402.56	F	F	T	F	F	T
	Daily Access	174113.2	542628	494713.69	95572.31	T	T	F	F	T	T
Classification 2000	Number units	30	3	39	24						
	Population	17108.03	237186.33	48824.33	50444.88	T	T	T	F	F	F
	AgeingRate	28.72	17.01	20.80	20.91	T	T	T	F	F	F
	Unemployed	676.8	13565.33	2332.36	2658.33	T	T	T	F	F	F
	HIC	7266.14	11368.38	8705.68	7983.69	T	T	F	F	T	F
	Density	26.98	4654.53	196.32	108.79	T	T	T	F	F	F
	Artificialisation	0.18	46.16	3.68	1.73	T	T	T	F	F	F
	Potential Acces	203092.7	223528.4	228567.3	184996.1	F	T	T	F	T	T
	Location Acces	347.75	362.33	347.38	387.11	F	F	T	F	F	T
	Daily Access	129523.4	569673.7	565988.4	151954.5	T	T	F	F	F	T
Classification 2005	Number units	31	5	37	23						
	Population	16184.55	244083.4	56603.97	25419.87	T	T	F	F	T	F
	AgeingRate	30.26	19.27	21.12	24.42	T	T	T	F	F	F
	Unemployed	767.903	13818.2	3116.7	1264.52	T	T	F	F	T	F
	HIC	9456.28	14807.18	11665.09	11248.43	T	T	T	F	T	F
	Density	27.27	3268.41	183.25	66.42	T	T	F	F	T	T
	Artificialisation	0.33	32.98	4.03	0.85	T	T	F	F	T	T
	Potential Acces	208382.6	221960.6	232936	186076.9	F	T	T	F	T	T
	Location Acces	341.55	351.81	349.29	379.36	F	F	T	F	F	T
	Daily Access	144526.3	735544.6	605264.8	118018.7	T	T	F	F	T	T
Classification 2015	Number units	30	5	39	22						
	Population	14785.87	244397.8	55354.67	24743.55	T	T	F	F	T	F
	AgeingRate	31.78	22.02	22.09	26.70	T	T	T	F	F	T
	Unemployed	1032.6	22433	4856.97	1899.86	T	T	F	F	T	F
	HIC	10344.6	16703.18	12852.67	13400.24	T	T	T	T	F	F
	Density	24.54	3223.58	181.8	66.31	T	T	T	F	T	F
	Artificialisation	0.54	36.78	5.27	1.74	T	T	F	F	T	T
	Potential Acces	207777.2	224173.9	235065.5	190011.1	F	T	T	F	T	T
	Location Acces	341.85	349.37	346.54	375.18	F	F	T	F	F	T
	Daily Access	124776.4	735544.6	605527.4	130172.4	T	T	F	F	T	T

Data Source: IGN (2018, 2018b), INE (2018), ICANE (2018), IGE (2018) and SADEI (2018).
Note: The data from Clusters 1 and 3 for the 2015 classification have been exchanged to enable comparison with the other classifications.

4.3.2. Robustness

The Mixed dataset, composed by static (starting) and dynamic (changes) data, involved 20 variables: Total Population, Ageing rate, HIC, Artificialisation rate, Location, Potential and Daily accessibility and their changes between 1991-2015.

The PCA was performed for sets of related variables (Romano et al., 2016), in attention to the three main criteria of analysis, in order to comply with the general rule of having a 5:1 ratio between the number of observations versus the number of variables analysed (Hair et al., 2014). The socio-economic set was compiled using Population, Ageing rate, HIC and Unemployment for all years (KMO value of 0.86), i.e. 1991, 2000, 2005 and

2015, yielding 3 main components which explained 95% of the accumulated variance. The result of the varimax rotated solution was a first component RC1 which corresponds to a combination of Population and Unemployment (48% of the variance), a second component RC2 corresponding to Ageing Rate (25%), and RC3 corresponding to HIC (22%) (Table 3).

As regards the Spatial criterion, percentage of artificial land use and population density were combined for all years (KMO 0.86) into a single component which explained 96% of the variance. Finally, the Accessibility criterion (KMO 0.78) considered Potential, Location and Daily Accessibility, resulting in 2 main components which explained 93% of the variance, the first component being related to the combination of Daily and Potential Accessibility (52%) and the second mainly to Location (41%). Therefore, the PCA resulted in a dataset composed of 6 main components, 3 related to the socio-economic criterion, 1 to the spatial and 2 to the accessibility one.

Table 3. Results of the PCA

Socio-Economic				Land Use		Accessibility		
Variables	**RC1**	**RC2**	**RC3**	**Variables**	**PC1**	**Variables**	**RC1.1**	**RC2.1**
Pop_1991	0.94	-0.20	0.25	PopDen_1991	0.98	PotAcces_ 1991	0.74	-0.58
Pop_2000	0.94	-0.22	0.26	PopDen_2000	0.98	PotAcces_2000	0.79	-0.50
Pop_2005	0.93	-0.23	0.26	PopDen_2005	0.98	PotAcces_2005	0.82	-0.50
Pop_2015	0.92	-0.25	0.27	PopDen_2015	0.98	PotAcces_ 2015	0.82	-0.50
AgR_1991	-0.32	0.93	-0.12	Artificial_1991	0.98	LocAcces_1991	-0.05	0.99
AgR_2000	-0.27	0.94	-0.10	Artificial_2000	0.98	LocAcces_2000	-0.10	0.98
AgR_2005	-0.24	0.94	-0.21	Artificial_2005	0.98	LocAcces_2005	-0.10	0.97
AgR_2015	-0.14	0.89	-0.29	Artificial_2015	0.98	LocAcces_2015	-0.10	0.96
UnEmp_1991	0.95	-0.18	0.22			DailyAcces_1991	0.95	0.01
UnEmp_2000	0.95	-0.20	0.20			DailyAcces_2000	0.97	0.01
UnEmp_2005	0.95	-0.23	0.17			DailyAcces_2005	0.96	0.02
UnEmp_2015	0.93	-0.25	0.23			DailyAcces_2015	0.95	0.03
HIC_91	0.37	-0.20	0.72					
HIC_00	0.31	-0.20	0.92					
HIC_05	0.15	-0.17	0.95					
HIC_15	0.23	-0.13	0.86					
SS loadings	7.64	3.94	3.59		7.70		6.22	4.91
Proportion Var	0.48	0.25	0.22		0.96		0.52	0.41
Cumulative Var	0.48	0.72	0.95				0.52	0.93
Proportion Explained	0.50	0.26	0.24				0.56	0.44
Cumulative Proportion	0.50	0.76	1.00				0.56	1.00

To perform the cluster analysis of these two new datasets, the optimal solution determined by the NbCLust package was of 2 clusters (k=2), according to 9 methods, followed by k=5 in the case of the mixed dataset and k=6 for the PCA set. In order to compare all the clustering results together we considered the k=4 option (proposed by 2 methods).

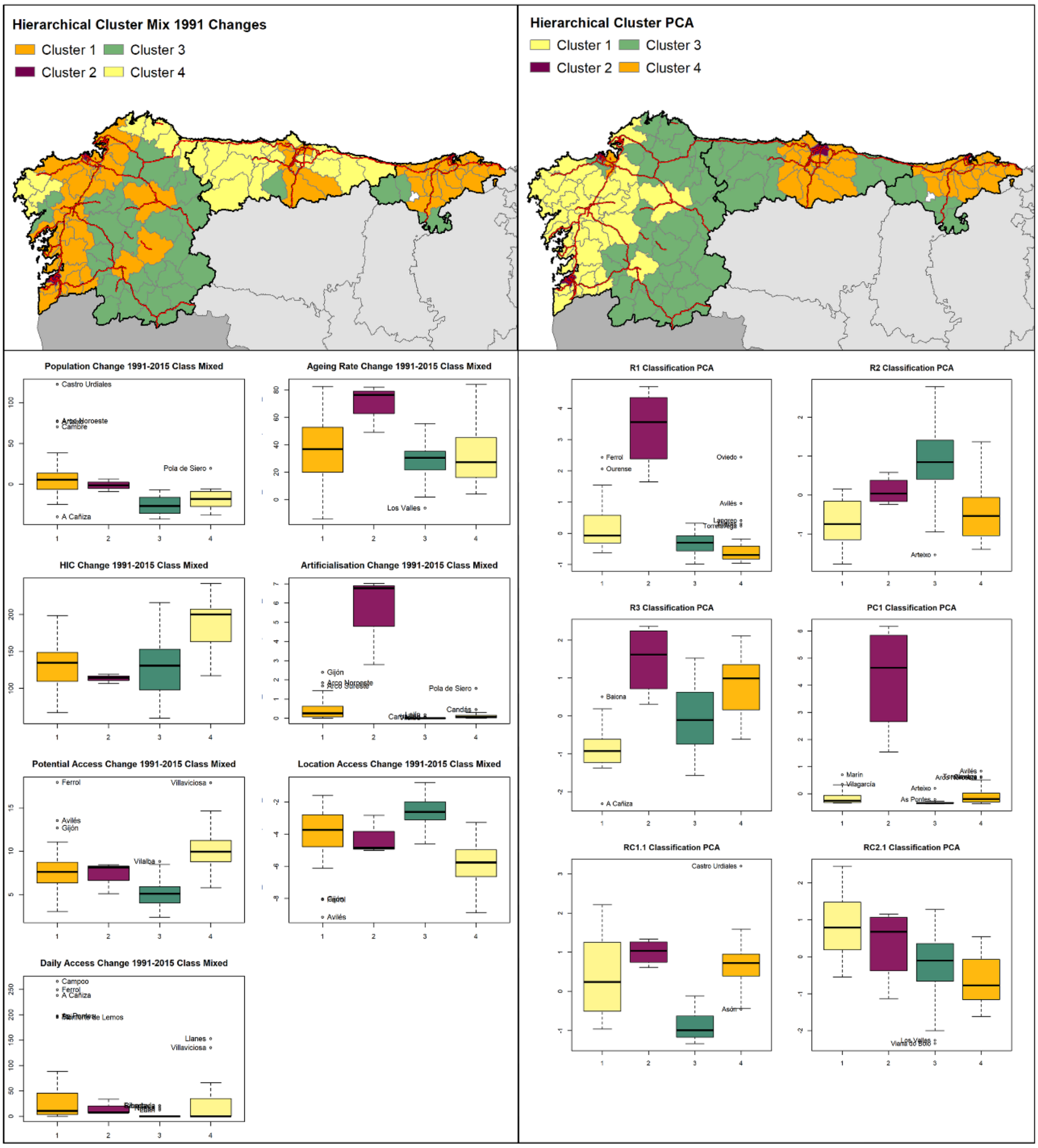
The spatial pattern derived for the k=4 solution for the Mixed set was practically the same as those obtained for each year[2] (Figure 5), except for the classification of the central urban areas of Asturias as intermediate areas, as was already the case in the 1991 and 2000 classifications. In this case dynamic coastal areas (Cluster 4) were the ones with the largest increases in Potential and Location accessibility, as well as in Economic development (HIC).

As regards the PCA results, the East-West diversity was highlighted, separating the intermediate areas of Galicia (Cluster 1) from those of Asturias and Cantabria (Cluster

[2] As happened with the 2015 classification, Cluster 1 and Cluster 3 are switched in the Mixed Classification.

4) (Figure 5). This partition was due to the Location accessibility dissimilarity (component RC2.1), which was favoured in the case of the Eastern areas by the proximity of the functional units to one of the largest Spanish metropolises, Bilbao, and impaired on Galicia's west coast by its remoteness from large urban centres outside the Northwest Area.

Figure 5. Results of the Mixed dataset and PCA classifications



4.4. Characterization of inner spatial categories

Once the performance of the functional units was analysed, four categories were identified in attention to their similar behaviour: Dynamic rural-urban fringe, Dynamic coastal areas, Stable areas and Regressive areas (Figure 6).

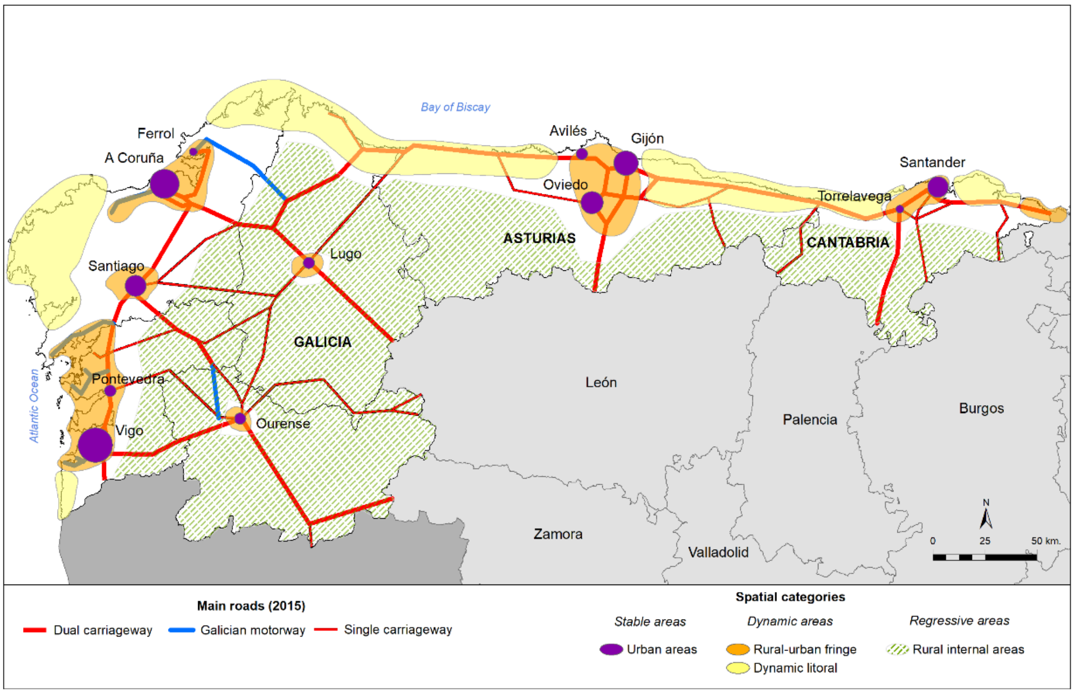
In general, *Dynamic areas* refer to those units that experienced the largest socio-economic and spatial transformations, representing the most progressive and fast-growing areas in the analysed spatial-temporal frame. On the one hand, *Dynamic rural-urban fringe areas*, starting from an intermediate level of development, experienced a large improvement in accessibility until the mid-2000s, by their proximity to the main urban areas. This vicinity facilitated a decentralization of the population and activities from central urban spaces, provoking a progressive urbanisation of near areas, which was reflected in marked artificialisation changes. This process was slowed down by the great recession of 2008. Similarly, several authors pointed to the success of these type of European urban fringe areas in the period 2000-2006, especially due to their ability to attract and maintain labour (Bosworth and Venhorst, 2018), and their difficulty to benefit from near cities after 2008, as Medeiros and Rauhut (2020) summarises.

On the other hand, we found *Dynamic coastal areas,* which correspond to small villages that have strengthened their territorial potential or attraction factor, especially through tourism and the construction of secondary residences, during the boom years. Their evolution shows the positive effects of the accessibility improvements derived from the new coastal connections on the economy and land use changes. Population, in contrast, presents negative dynamics, which are partly explained by the existence of an unaccounted floating population.

Stable areas correspond to central urban areas that already had a high level of development at the beginning of the 1990's, concentrating the highest numbers of population, income, and the highest degree of accessibility. Throughout the period, transport network improvements did not introduce significant changes to their advanced situation. These areas showed a negative demographic evolution, suffering from ageing more than any other, and were among the least dynamic in economic growth.

Finally, *regressive areas* were those with a low level of development and intraregional accessibility due to a very poor transport network. They correspond to the remotest rural interior areas, suffering from a deep depopulation process and a marked ageing trend. These areas had already a weak economic sector, which underwent a process of deagrarianization throughout the study period, and still struggle to promote a greater diversification linked to heritage and natural resources. The construction of new infrastructures had little or no impact (tunnel effects), or even favoured population and resource migration outside the area (pump effect) during the study period.

Figure 6. Spatial categories identified inside the Spanish Northwest Area



5. DISCUSSION AND CONCLUSIONS

In Europe, great transport investments have been conducted since the 1990's as key measures of European territorial and transport policy to reduce differences between core and peripheral areas and enhance territorial cohesion (EC, 1999, 2007, 2014; ESPON, 2005, 2015; Vickerman, 1995). Given their peripheral situation, countries within the Atlantic Arc have often been the focus of these policies and of large investment programs. This is the case of Spain, which has developed the longest motorway network in the European Union, mainly through the massive arrival of community funds (Albalate et al., 2015). Particularly the north-western area, has been one of the regions with the highest investment rates, far beyond the European Union's mean (Rodríguez-Pose, 2015). However, despite this enormous financial effort, these areas have not improved in cohesion terms as expected, their situation becoming even worse with respect to core areas (Meijers et al., 2012; Rietveld and Bruinsma, 1998). As hypothesized in this study, this may be due to the fact that different conditions across/inside regions could influence the result of infrastructure investments (Banister and Berechman, 2000; Fratesi and Wishlade, 2017, Fujita and Thisse, 2002).

To go deeper into this question, this paper proposes an assessment approach focused on the development of a widely applicable methodology for the identification and classification of homogenous spatial units at the intraregional level. This approach can explain whether and to what extent accessibility changes and other factors influence the inner differentiation of territories, which may exacerbate or mitigate spatial inequalities inside areas of the European peripheral regions and thus affect regional cohesion. This type of information could help policy and decision makers to obtain more effective results from cohesion policies (Fratesi and Whislade, 2017).

Our findings corroborate the existence of diverse typologies of areas in attention to their socio-economic, urbanisation and accessibility conditions, showing a strong impact of demographic and economic structures in the definition of different areas, especially in the urban-rural dichotomy. Road endowment or accessibility level was indeed relevant for the distinction of intermediate dynamic areas. As for the evolution over time, accessibility changes, i.e. transport investments, had an impact on the classification of inner areas, especially on the size of dynamic groups, since they widened the space covered by dynamic areas, i.e. Cluster 4, by reducing regressive ones, i.e. Cluster 1. However, this did not always translate into a general improvement of cohesion in socio-economic terms, pointing at a broadening of the urban-rural gap. At the same time, there was a greater differentiation between the dynamic and rural areas, and a rapprochement between dynamic fringe and urban areas, their behaviour stabilising over time.

The strongest conclusion of this paper is that analysing and considering local differences within a region are key to better establish policy strategies to reduce intraregional disparities and avoid polarization. As opposed to main urban centres that already have good accessibility, or rural areas that have significantly unfavourable initial socio-economic conditions, transport infrastructure development plays an important role in the differentiation and therefore evolution of dynamic areas. As a result, it is important to consider the characteristics and potential of intermediate areas in order to favour their development and achieve regional cohesion. These findings are in line with recent studies at other scales of analysis (Dijkstra et al., 2015; Gagliardi and Percoco, 2017, Müller et al., 2010), and highlight the need to claim that European policies, change their infrastructure investment approach, or at least complement it, by placing more focus on the intraregional scale, rather than on (only) the national or regional ones. As Harvey (2000) states it is necessary to think at different scales at the same time, given that global and local are fundamentally part of one another. Moreover, policymakers need to understand and choose which interventions are appropriate at each scale (Farole et al., 2011).

A stronger focus at regional level may be used to better justify and prioritize investments in infrastructures, encouraging those infrastructures that enable intraregional connections, from which a more positive response is expected from the cohesion point of view. A clear commitment to connections between middle-sized urban centres that promote intraregional polycentric systems, is more favourable in terms of cohesion than high-capacity infrastructures connecting peripheral areas to national core areas. This is especially relevant in a radial transport system like the Spanish one, which has historically prioritized connections between all capital regions and the capital city, Madrid.

The methodology used here, based on cluster analysis considering a combination of demographic, economic, urbanisation and accessibility data, enabled a better understanding of the spatial structure of the region under study as well as of the role that accessibility, and other drivers of development, have had on the spatial performance of inner areas. Notwithstanding, is worth to mention that other data that are highlighted as relevant for analysing the response to transport improvements by several authors, such as governance indicators (Medeiros and Rauhut, 2020; Zaucha and Böhme, 2020), and which were not used in this methodology due to lack of data, could be used in further research to improve our methodology. In the same vein, other formulations of accessibility indicators could be explored, given that different distance decay functions and parameters, such as the negative exponential function, might be appropriate for the analysis. Finally, the consideration of the complete ground transportation network, including railway networks that have changed over time, could also improve this analysis.

Methodologies such as the one presented here can be used to identify, and communicate, areas of similar performance in several countries which are subject to common development policies, for example across Europe. In this way, efforts can be joined to learn from one another and to claim and adopt policy measures to deal with the development initiatives affecting these regions. Approaches such as the one shown in this research can therefore give more support to regional policy-makers and planners in the processes of decision-making, and make a positive and significant contribution to the achievement of more comparable levels of development across areas and regions.

ACKNOWLEDGEMENTS
This research continues the work developed in the research project 'Development of a method for assessing the effects of road networks on socioeconomic, territory and mobility issues in peripheral areas. Application to the Northwest Spanish Arc', 2007-2011 (TRA2007- 66750), directed by Soledad Nogués and funded by the Ministry of Education and Science of Spain, as well as other previous projects funded by the Ministry of Public Works (2005-2008).

REFERENCES

Abdi, H. and Williams, L. J., 2010. Principal component analysis. *WIREs Interdisciplinary Reviews Computational Statistics*, 2(4), 433-459.

Abrahams, G., 2014. What "is" territorial cohesion? What does it "do"? Essentialist versus pragmatic approaches to using concepts. *European Planning Studies*, 22(10), 2134-2155. https://doi.org/10.1080/09654313.2013.819838

Albalate, D., Bel, G. and Fageda, X., 2015. When supply travels far beyond demand: Causes of oversupply in Spain's transport infrastructure. *Transport Policy*, 41, 80-89. https://doi.org/10.1016/j.tranpol.2015.03.004

Astel, A., Tsakovski, S., Barbieri, P. and Simeonov, V., 2007. Comparison of self-organizing maps classification approach with cluster and principal components analysis for large environmental data sets. *Water Research*, 41(9), 4566-4578. https://doi.org/10.1016/j.watres.2007.06.030

Banister, D., and Berechman, J., 2000. *Transportation investment and economic development*. London: University College London Press.

Barca, F., McCann, P. and Rodríguez-Pose, A., 2012. The case for regional development intervention: place-based versus place-neutral approaches. *Journal of Regional Science*, 52 (1), 134-152. https://doi.org/10.1111/j.1467-9787.2011.00756

Baudelle, G. and Guy, C., 2004. *The peripheral areas of Western Europe and EU regional policy: prospective scenarios*. Regional Studies Association Conference “Europe at the Margins: EU Regional Policy, Peripherality and Rurality”, April 15-16, Angers, 10p.

Bertolini, L., Le Clercq, F., Kapoen, L., 2005. Sustainable accessibility: a conceptual framework to integrate transport and land use plan-making. Two test-applications in the Netherlands and a reflection on the way forward. *Transport Policy,* 12 (3), 207-220. https://doi.org/10.1016/j.tranpol.2005.01.006

Biehl, D., 1991. *The role of infrastructure in regional development*. In: Vickerman, R. (Ed.), Infrastructure and Regional Development. London: Pion, pp. 9-35.

BOPA, 1991. *Decreto 11/1991, de 24 de enero, por el que se aprueban las Directrices Regionales de Ordenación del Territorio de Asturias*. Boletín Oficial del Principado de Asturias (BOPA), n. 45, p. 1169. http://www.asturias.es/bopa/1991/02/23/19910223.pdf

Bosworth, G. and Venhorst, V., 2018. Economic linkages between urban and rural regions – what’s in it for the rural? *Regional Studies*, 52(8), 1075-1085. https://doi.org/10.1080/00343404.2017.1339868

Charrad, M., Ghazzali, N., Boiteau, V. and Niknafs, A., 2014. NbClust: An R package for determining the relevant number of clusters in a data set. *Journal of Statistical Software*, 61(6), 1-36. https://doi.org/10.18637/jss.v061.i06

Copus, A., Psaltopoulos, D., Skuras, D., Terluin, I., Weingarten, P., 2008. *Approaches to rural typology in the European Union*. In: Handan Giray, F., Ratinger, T. (Eds.), JRC-Scientific and Technological Report (EUR23634EN). European Commission, IPTS. Seville – Spain, 134p.

Cörvers, F., Hensen, M. and Bongaerts, D., 2009. Delimitation and coherence of functional and administrative regions. *Regional Studies*, 43(1), 19-31. https://doi.org/10.1080/00343400701654103

Dall’erba, S. and Hewings, G.J.D., 2003. *European regional development policies: The trade-off between efficiency-equity revisited*. REAL 03-T-2, University of Illinois.

Dijkstra, L., Garcilazo, E. and McCann, P., 2015. The effects of the global financial crisis on European regions and cities. *Journal of Economic Geography*, 15(5), 935-949. https://doi.org/10.1093/jeg/lbv032

Dijkstra, L., Poelman, H. and Veneri, P., 2019. *The EU-OECD definition of a functional urban area*. OECD Regional Development Working Papers, No. 2019/11, Paris: OECD Publishing. https://doi.org/10.1787/d58cb34d-en

DOG, 1997. *Decreto 65/1997, de 20 de febrero, por el que se aprueba definitivamente el mapa comarcal de Galicia*. Diario Oficial de Galicia (DOG), n. 63, p. 3005. http://www.xunta.es/dog/Publicados/1997/19970403/Anuncio4D32_es.html

EC, 1999. ESDP – *European Spatial Development Perspective. Towards balanced and sustainable development of the territory of the European Union*. Luxembourg: European Commission - Office for Official Publications of the European Union.

EC, 2007. *Fourth report on economic and social cohesion. Growing regions, growing Europe*. Luxembourg: European Commission - Office for Official Publications of the European Comminities.

EC, 2014. *Sixth report on economic, social and territorial cohesion. Investment for jobs and growth - Promoting development and good governance in EU regions and cities*. Luxembourg: European Commission - Office for Official Publications of the European Union.

EC, 2017. *Seventh report on economic, social and territorial cohesion. My Region, my Europe, our future*. Luxembourg: European Commission - Publications Office of the European Union.

EEA, 2020. Corine Land Cover 2018. https://sdi.eea.europa.eu/catalogue/srv/api/records/53ef1493-e7a1-4216-b043-87a7c2a5a68d

ESPON, 2005. *ESPON Project 2.1.1. Territorial impacts of EU transport and TEN policies*. Final Report. European Spatial Planning Observation Network.

ESPON, 2015. *TRACC – Transport accessibility at Regional/Local scale and patterns in Europe*. Final Report.

Eurostat, 2016a. *Statistics explained: territorial typologies*. Available at: http://ec.europa.eu/eurostat/statistics-explained/index.php/Territorial_typologies

Eurostat, 2016b. *Commission Regulation (EU) 2016/2066 of 21 November 2016 amending the annexes to Regulation (EC) No 1059/2003 of the European Parliament and of the Council on the establishment of a common classification of territorial units for statistics (NUTS) C/2016/7380).*

EU, 2007. *Territorial Agenda of the European Union- Towards a more competitive and sustainable Europe of diverse regions* (Agreed on the occasion of the Informal Ministerial Meeting on Urban Development and Territorial Cohesion in Leipzig on 24/25 May 2007).

Fariña, J., Lamiquiz, F. and Pozueta, J., 2000. *Efectos territoriales de las infraestructuras de transporte de acceso controlado*. Madrid: Cuadernos de Investigación Urbanística. Escuela Técnica Superior de Arquitectura de Madrid, 97p. ISBN 84-95365-34-0

Farole, T., Rodríguez-Pose, A. and Storper, M., 2011. Cohesion policy in the European Union: Growth, geography, institutions. *Journal of Common Market Studies*, 49 (5), 1089-1111. https://doi.org/10.1111/j.1468-5965.2010.02161.x

Field, A., Miles, J. and Field, Z., 2012. *Discovering statistics using R* (1st edition.). Sage Publications Ltd.

Forslund, U. and Johansson, B., 1995. Assessing road investments – accessibility changes, cost-benefit and production effects. *Annals of Regional Science,* 29(2), 155-174.

Fratesi, U. and Wishlade, F.G., 2017. The impact of European Cohesion Policy in different contexts. *Regional Studies*, 51(6), 817-821. https://doi.org/10.1080/00343404.2017.1326673

Fujita, M., Krugman, P. and Venables, A.J., 1999. *The Spatial economy. Cities, regions and international trade*. Cambridge (USA): MIT Press.

Fujita, M. and Thisse, J., 2002. *Economics of agglomeration*. Cambridge (USA): Cambridge University Press.

Gagliardi, L. and Percoco, M., 2017. The impact of European Cohesion Policy in urban and rural regions. *Regional Studies*, 51(6), 857-868. https://doi.org/10.1080/00343404.2016.1179384

Gobierno de Cantabria, 2017. Avance del Plan Regional de Ordenación del Territorio (PROT). Gobierno de Cantabria (Cantabria Government), Santander (in Spanish).

González-González, E. and Nogués, S., 2019. Long-term differential effects of transport infrastructure investment in rural areas. *Transportation Research Part A: Policy and Practice*, 125, 234-247. https://doi.org/10.1016/j.tra.2018.01.026

Gren, J., 2003. Reaching the peripheral regional growth centres. Centre-periphery convergence through the Structural Funds' transport infrastructure actions and the evolution of the centre-periphery paradigm. *European Journal of Spatial Development*, 3(1), 2-22.

Gutiérrez, J., 2001. Location, economic potential and daily accessibility: an analysis of the accessibility impact of the high-speed line Madrid-Barcelona-French border. *Journal of Transport Geography*, 9(4), 229-242. https://doi.org/10.1016/S0966-6923(01)00017-5

Hair, J.F., Black, W.C, Babin, B.J. and Anderson, R.E., 2014. *Multivariate data analysis*, Seventh edition. Essex: Pearson New International Edition. 768p.

Halstead, J.M. and Deller, S.C., 1997. Public infrastructure in economic development and growth: Evidence from rural manufacturers. *Journal of Community Development Society*, 28(2), 149-169. https://doi.org/https://doi.org/10.1080/15575339709489780

Hansen, W. G., 1959. How accessibility shapes land use. *Journal of the American Institute of Planners*, 25, 17-35.

Hansen, N. M., 1965. Unbalanced growth and regional development. *Western Economic Journal*, 4, 3-14.

Hart, T., 1993. Transport investment and disadvantaged regions: UK and European policies since the 1950s. *Urban Studies*, 30(2), 417-436.

Harvey, D. (2000) *Spaces of hope*. Berkeley: University of California Press, 293p.

Heidenreich, M., 2003. Regional inequalities in the enlarged Europe. *Journal of European Social Policy*, 13(4), 313-333. https://doi.org/10.1177/09589287030134001

Holl, A., 2004a. Manufacturing location and impacts of road transport infrastructure: empirical evidence from Spain. *Regional Science and Urban Economics*, 34, 341-363. https://doi.org/10.1016/S0166-0462(03)00059-0

Holl, A., 2004b. Transport infrastructure, agglomeration economies and firm birth: empirical evidence from Portugal. *Journal of Regional Science*, 44(4), 693-712. https://doi.org/10.1111/j.0022-4146.2004.00354.x

Holl, A., 2007. Twenty years of accessibility improvements. The case of the Spanish motorway building programme. *Journal of Transport Geography*, 15, 286-297. https://doi.org/10.1016/j.jtrangeo.2006.09.003

ICANE, 2018. *Distribución municipal de la renta bruta estimada y per cápita estimada*. Instituto Cántabro de Estadística (ICANE) - Cantabrian Statistical Institute.

IGE, 2018. *Renda municipal dos fogares*. Instituto Galego de Estatística (IGE) - Galizian Statistical Institute.

IGN, 2018. *CORINE Land Cover 1990, 2000, 2006, 2012, 2018; CORINE Land Cover Changes 1990-2000, 2000-2006, 2006-2012, 2012-2018*, in shapefile format. Instituto Geográfico Nacional (IGN) - National Geographic Institute.

IGN, 2018b. *National Topographic Map at 1:100,000 in shapefile format*. Instituto Geográfico Nacional (IGN) - Spanish National Geographic Institute.

INE, 2004. *Contabilidad regional de España Base 1995. Cuentas de renta de los hogares. Notas de prensa*. Instituto Nacional de Estadística (INE) - National Statistical Institute. https://www.ine.es/prensa/np353.pdf

INE, 2018. *Municipal population census 1991, 2000, 2005, 2015*. Instituto Nacional de Estadística (INE) - National Statistic Institute.

INE, 2019. *Contabilidad regional de España Base 2010. Cuentas de renta de los hogares. Notas de prensa*. Instituto Nacional de Estadística (INE) - Spanish National Statistical Institute. http://econet.carm.es/inicio/-/crem/sicrem/PU39/pdf/sec26.pdf

Jonard, F., Lambotte, M., Ramos, F., Terres, J.M. and Bamps, C., 2009. *Delimitations of rural areas in Europe using criteria of population density, Remoteness and Land Cover* (JRC Scientific and Technical Reports EUR23757). Institute for Environment and Sustainability, Joint Research Center, European Commission.

Juillard, E., 1962. The region: An essay of definition. *Annales de Geographie*, 40, 429-450.

Kaufman, L. and Rousseeuw, P.J. (Eds.), 1990. *Finding groups in data: An introduction to cluster analysis*. Hoboken (USA): John Wiley & Sons, Inc., ISBN 9780471878766.

Le Clerq, F. and Bertolini, L., 2003. Achieving sustainable accessibility: An evaluation of policy measures in the Amsterdam area. *Built Environment,* 29(1), 36-47. https://doi.org/10.2148/benv.29.1.36.53949

Leonardi R. (2005) *Cohesion and regional policies in the European Union*. In: Cohesion policy in the European Union. London: Palgrave Macmillan. https://doi.org/10.1057/9780230503861_1

Linneker, B., 1997. *Transport infrastructure and regional economic development in Europe: A review of theoretical and methodological approaches*, TRP 133. Sheffield: Department of Town and Regional Planning.

López, E., Gutiérrez, J., and Gómez, G., 2008. Measuring regional cohesion effects of large-scale transport infrastructure investments: an accessibility approach. *European Planning Studies*, 16(2), 277-301. https://doi.org/10.1080/09654310701814629

Medeiros, E., 2017. European Union cohesion policy and Spain: a territorial impact assessment. *Regional Studies*, 51(8), 125-1269. https://doi.org/10.1080/00343404.2016.1187719

Medeiros, E. and Rauhut, D., 2020. Territorial cohesion cities: a policy recipe for achieving Territorial Cohesion? *Regional Studies*, 54(1), 120-128. https://doi.org/10.1080/00343404.2018.1548764

Meijers, E., Hoekstra, J., Leijten, M., Louw, E. and Spaans, M., 2012. Connecting the periphery: distributive effects of new infrastructure. *Journal of Transport Geography,* 22, 187-198. https://doi.org/10.1016/j.jtrangeo.2012.01.005

MF, 2015. *Anuario estadístico 2015. Capítulo 7 carreteras*. Madrid: Ministerio de Fomento (MF) - Ministry of Public Works.

MF, 2015b. Mapa oficial de carreteras 2015. Madrid: Ministerio de Fomento (MF) - Ministry of Public Works.

MITMA, 2020. *Informe anual 2019. Observatorio del transporte y la logística de España*. Madrid: Ministerio de Transporte, Movilidad y Agenda Urbana (MITMA) - Ministry of Transport, Mobility and Urban Agenda. https://observatoriotransporte.mitma.gob.es/recursos_otle/informe_otle_2019_1.pdf

Monzón, A., López, E. and Ortega, E., 2019. Has HSR improved territorial cohesion in Spain? An accessibility analysis of the first 25 years: 1990-2015, *European Planning Studies*, 27(3), 513-532. https://doi.org./10.1080/09654313.2018.1562656

Müller, K., Steinmeier, Ch. and Küchler, M., 2010. Urban growth along motorways in Switzerland, *Landscape and Urban Planning*, 98, 3-12. https://doi.org/10.1016/j.landurbplan.2010.07.004

NCGE, 1994. *Geography for life: National geography standards*. Second Ed. Washington D.C.: The National Council for Geographic Education (NCGE).

Nogués, S. and González-González, E., 2014. Multi-criteria impacts assessment for ranking highway projects in Northwest Spain. *Transportation Research Part A-Policy and Practice,* 65, 80-91. https://doi.org/10.1016/j.tra.2014.04.008

Nosek, S., 2017. Territorial cohesion storylines in 2014–2020 Cohesion Policy. *European Planning Studies*, 25(12), 2157-2174. https://doi.org/10.1080/09654313.2017.1349079

OECD, 2002. *Redefining territories-The functional regions*. Paris: Organization for Economic Co-operation and Development (OECD).

OECD, 2012. *Promoting growth in all regions*. Paris: Organization for Economic Co-operation and Development (OECD).

Persyn, D., Díaz-Lanchas, J. and Barbero, J., 2020. Estimating road transport costs between and within European Union regions. *Transport Policy*, in press. https://doi.org/10.1016/j.tranpol.2020.04.006

Proost, S. and Thisse, J.F., 2015. *Skilled cities, regional disparities and efficient transport: The state of the art and a research agenda*, CEPR Nº 10790.

Rietveld, P. and Bruinsma, F., 1998. *Is Transport infrastructure effective? Transport infrastructure and accessibility: Impacts on the space economy*. Berlin: Springer-Verlag.

Rodríguez-Pose, A., 2015. *Challenges for regional development and regional policies*. GRINCOH (Growth – Innovation – Competitiveness: Fostering Cohesion in Central and Eastern Europe) Final Conference, 26-27 February. Warsaw: University of Warsaw, Centre for European Regional and Local Studies (EUROREG).

Rodríguez-Pose, A., Crescenzi, R. and Di Cataldo, M., 2018. *Institutions and the thirst for 'Prestige' transport infrastructure*. In: Glückler J., Suddaby R., Lenz R. (Eds) Knowledge and Institutions. Knowledge and Space, vol 13. Cham (Germany): Springer.

Rodríguez-Pose, A. and Fratesi, U., 2004. Between development and social policies: The impact of European Structural Funds in Objective 1 regions. *Regional Studies*, 38, pp. 97-113. https://doi.org/10.1080/00343400310001632226

Rokicki, B. and Stepniak, M., 2018. Major transport infrastructure investment and regional economic development – An accessibility-based approach. *Journal of Transport Geography*, 72, 36-49. https://doi.org/10.1016/j.jtrangeo.2018.08.010

Romano, S., Cozzi, M., Viccaro, M. and Persiani, G., 2016. A geostatistical multicriteria approach to rural area classification: from the European perspective to the local implementation. *Agriculture and Agricultural Science Procedia*, 8, 499-508. https://doi.org/10.1016/j.aaspro.2016.02.055

Rosik, P., Stępniak, M. and Komornicki, T., 2015. The decade of the big push to roads in Poland: Impact on improvement in accessibility and territorial cohesion from a policy perspective. *Transport Policy*, 37, 134-146. https://doi.org/10.1016/j.tranpol.2014.10.007

SADEI, 2018. *Renta de los hogares*. *Renta familiar por habitante según concejos.* Sociedad Asturiana de Estudios Económicos e Industriales (SADEI) - Asturian Society of Economic and Industrial Studies.

Salas-Olmedo, H., Nogués, S. and González-González, E., 2009. Land use changes associated to Highways. In: Wang, D. y Li, S-M. (Eds.). *Proceedings of the 14th HKSTS International Conference. Transportation and Geography.* Vol. 2, pp. 971-980. ISBN. 978-988-98847-7-2.

Sánchez-Zamora, P. and Gallardo-Cobos, R., 2020. Territorial cohesion in rural areas: an analysis of determinants in the post-economic crisis context. *Sustainability*, 12, 3816. https://dx.doi.org/10.3390/su12093816

Spiekermann, K. and Neubauer, J., 2002. *European accessibility and peripherality: Concepts, models and indicators*. Stockholm: Nordregio Working Paper 2002:9.

Spiekermann, K. and Wegener, M., 2008. *Accessibility, competitiveness and cohesion*. In: Faludi, A. (Ed.) European spatial policy and research. Cambridge (USA): Lincoln Institute of Land Policy, pp. 115-140.

Stelder, D., 2014. Regional accessibility trends in Europe: Road infrastructure, 1957-2012. *Regional Studies*, 50(6), 983-995. https://doi.org/10.1080/00343404.2014.952721

Stepniak, M. and Rosik, P., 2013. Accessibility improvement, territorial cohesion and spillovers: a multidimensional evaluation of two motorway sections in Poland. *Journal of Transport Geography,* 31, 154-163. https://doi.org/10.1016/j.jtrangeo.2013.06.017

Vickerman, R., 1995. Location, accessibility and regional development: the appraisal of trans-European networks. *Transport Policy*, 2(4), 225-234. https://doi.org/10.1016/S0967-070X(95)00013-G

Zaucha, J. and Böhme, K., 2020. Measuring territorial cohesion is not a mission impossible. *European Planning Studies*, 28(3), 627-649. https://doi.org/10.1080/09654313.2019.1607827