Representation of the degree of territorial cohesion by using *travel-time maps* from transport infrastructure networks

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Abstract

From a geographical perspective, each territory is articulated according to a hierarchical network of transport infrastructures. The design and layout of this transport network depend on a number of physical and socio-economic factors. Transport infrastructures and levels of accessibility between settlements (network nodes) can determine the degree of *territorial cohesion*.

Generally, traditional mapping methods represent transport networks, and hence can estimate the actual distance between each nodes. However, *real distances* (in terms of *travel-times* and accessibility) between nodes cannot effectively estimated. Thus, these methods offer an incomplete perspective of the real degree of *territorial cohesion*.

In this conference paper, a proper method for the representation of the territory based on *travel-times mapping* is shown. For its implementation, *Geographical Information Systems* and interpolation methods are applied. Final results show a distorted representation of the perspective shown in the traditional maps. This model of representation counts with high interest both from a social and technical perspective, showing the actual degree of cohesion and accessibility within a certain territory.

Keywords

Infrastructure transport networks – territorial cohesion – transport geography – economic geography – Galician region

1. Introduction

One of the main policy objectives of local authorities is the *sustainable development* of their territories. This term is referred not only to a proper model of exploitation of the resources, but also to balanced progress and integrates principles such as *convergence* and *cohesion*, both social and economic. Pita and Pedregal (2015) refer to the perverse effects generated by societies in breaking down cohesion and increasing inequalities, especially in a context of economical crisis. For these reasons, different authorities around the world are proposing policies and initiatives, mechanisms and tools to reduce social and territorial inequalities.

From a territorial perspective, European policy is one of the most representative examples. Europe, in its process of building a *Single European Market* (*European Union*, EU), has been integrating national economies with very different levels of development and wealth. Thus, EU authorities have proposed several initiatives and mechanisms for territorial cohesion such as the "*European Territorial Strategy*" (CEC, 1999), the successive "*European Territorial Agenda(s)*" (TA-EU, 2007 and 2011) and the "*Green Paper on Territorial Cohesion*" (CEC, 2008), which describes the territory as a new dimension of the policy (Faludi, 2007).

An *infrastructure network* is a tool for articulating the territory whose design, development and management depends mainly on the predominant social and institutional project, which in the case of the EU, is the reinforcement of economic and social cohesion between different regions (Ramos, 2003). The development and expansion of terrestrial transport networks depends on the characteristics of the territory and the changes over it. Since the second half of the 20th century the transport of passengers and goods has been clearly affected by dynamics such as the high levels of urbanization, the shift of societies to the services sector, the democratization of the private car, among others. These factors as a whole led to an increase in mobility from both perspectives, quantitative and qualitative.

From a geographic point of view, transport networks are a hot topic because the spatial impact and its ability to mitigate existing imbalances. In the case of the EU, the development of a *Trans-European Transport Network* (TEN-T) has been focused on the principles of *convergence* and *cohesion* between regions. For this purpose, EU policies have implemented tools and mechanisms for redistribution, cooperation and solidarity between regions, such as the well-known investment program named *European Regional Development Fund* (ERDF) (Ross, 1998; Richardson, 1997).

There is a classical conception that considers *transport infrastructures* as a system for generating wealth (Estevan and Sanz, 1996), which has led many authors to establish a binomial relation between *transport* and *development* (Offner, 1993). Some economists argue that better

infrastructures can reduce transport costs and increase productivity and competitiveness, because of the reduction of distances between raw materials and market, the two main factors of the economic system (Vickerman, Spiekermann and Wegener, 1999). In the short term, the construction of transport infrastructures can generate new jobs, while in the medium and long term the increase of accessibility leads to improve economic competitiveness and increase employment levels (Sichelschmidt, 1999). This perspective was the adopted by the EU in the implementation of the TEN-T (CEC, 1990 and 2005).

However, there are many criticisms of these theories, which note serious deficiencies in the European strategy. Among them, the design of a transport network that favors the central regions and perpetuates the imbalances of the peripheral regions (Rodríguez Pose and Petrakos, 2004; Vickerman, Spiekermann and Wegener, 1999). Fürst *et al.* (2000) consider that the single investment in transport infrastructures cannot outweigh the own negative socio-economic dynamics in some regions. Other criticisms consider that the EU investment model is characterized by a pattern that articulates the territory from the *center* to the *periphery*, in which the interrelation of the different peripheries with each other is low. Furthermore, the design of the TEN-T is focused on the articulation of urban nodes by means of high capacity corridors, which neglects the role of secondary networks and generates important empty spaces (Ramos, 2003).

Most studies on territorial cohesion and reduction of imbalances have been carried out on a large scale, either supranational (as described for the EU policies) or national scale. At lower scales, such as the regional one, the tradition of these studies is much lower due to some difficulties such as the lack of adequate information and the definition of an optimal level of spatial disaggregation. In this sense, Pita and Pedregal (2015) developed a methodology for measuring the degree of territorial cohesion at a regional scale, which was applied to the concrete case of *Andalucía*, the second most extensive and the most populated region in Spain. Their methodology is based on three main basic components: accessibility to (a) transport means and (b) hospital care, as well as (c) the study of the degree of territorial balance between each territorial unit considered. For all of these components, a series of synthetic indexes were computed. González Laxe (2008) considers that the aims of the *European Territorial Strategy* in the region of *Galicia* (Spain) are moving in three main axes, where the second one is referred to the role of transport infrastructures. He considers as priority objectives the improvement of the connectivity between intermediate urban nodes, and the reduction of the remoteness (in terms of distance, time and costs) in regard to centers of gravity and markets.

From this point, and considering the relevant importance of transport infrastructures in terms of articulation and accessibility of territories, we propose here a proper methodology to analyze the level of territorial cohesion at intraregional scale by using *travel-time maps* or *distance*

cartograms. For this purpose, travel times and accessibility of most relevant urban nodes are estimated. Later, distorted maps of the current travel times between points are generated.

This conference paper is structured as follows. Methodology is explained in Section 2, whereas the main characteristics related to the study area are introduced in Section 3. Results obtained are shown in Section 4, and a general discussion related to the obtained results is carried out in Section 5.

2. Methodology

The study area considered here is the region of Galicia, located in the NW of Spain. As in the proposal defined by Pita and Pedregal (2015), we consider the administrative division into counties (*comarcas*) as territorial analysis unit more optimal at intraregional scale. Despite not having real political or administrative competences, these territorial units are an aggregated of municipalities with homogeneity from a perspective defined both, by the physical environment and the socio-economic use.

Galician region counts 53 counties, which present different characteristics (Figure 1.a). Within each of them, the most populated settlement is selected, leading to an initial point grid made up by 53 nodes. For computation purposes, we decide to simplify the point grid by selecting (a) the most populated nodes, and (b) the nodes which are homogeneously distributed throughout the territory. The final point grid obtained here is composed of 19 points distributed among the four provinces of this region (Figure 1.b).

Within the point grid, one concrete point is established as *central* or *main node*, from where we calculate travel times to the rest of the nodes. The point grid is articulated as a network of vectors from the main node, considering in some cases intermediate points in between. The main node considered in our network corresponds to the city of *Santiago de Compostela* (in red in Figure 1.b), which in fact is the capital of Galicia. Later, a vector from this node to a second one, which represents *Lalín*, is drawn. The values of speed for each transport mean associated to this vector (route *Santiago-Lalín*) are used as *reference values* to calculate the distortion with regard to the rest of nodes. The routes defined with higher and lower speeds are distorted in opposite directions with regard to the vector direction, whereas the reference route remains undistorted.

Once the network is designed, travel times from the central node to the rest are calculated. These times are estimated by using some applications (*Google Maps* and *Rome2rio*) for a specific time[1]. Three scenarios are considered; (a) private car, (b-c) public transport, where in the latter case we consider, the (b) *real* and (c) *effective travel time*. The *real time* refers to the current travel time required between two nodes, while the *effective time* does not consider the transfer time between the different means of transport. Public transport systems comprise bus and/or train, in addition to the combined use. In case of different travel alternatives, we consider those as valid which require less time.

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[1] Data was obtained on Wednesday, Apr.05 at 17:00h (working day).

Figure 1   (a) Division of Galician region in *provinces* and *counties* (*comarcas*). (b) Urban nodes and theoretical network (point grid) considered.

(a)   (b)
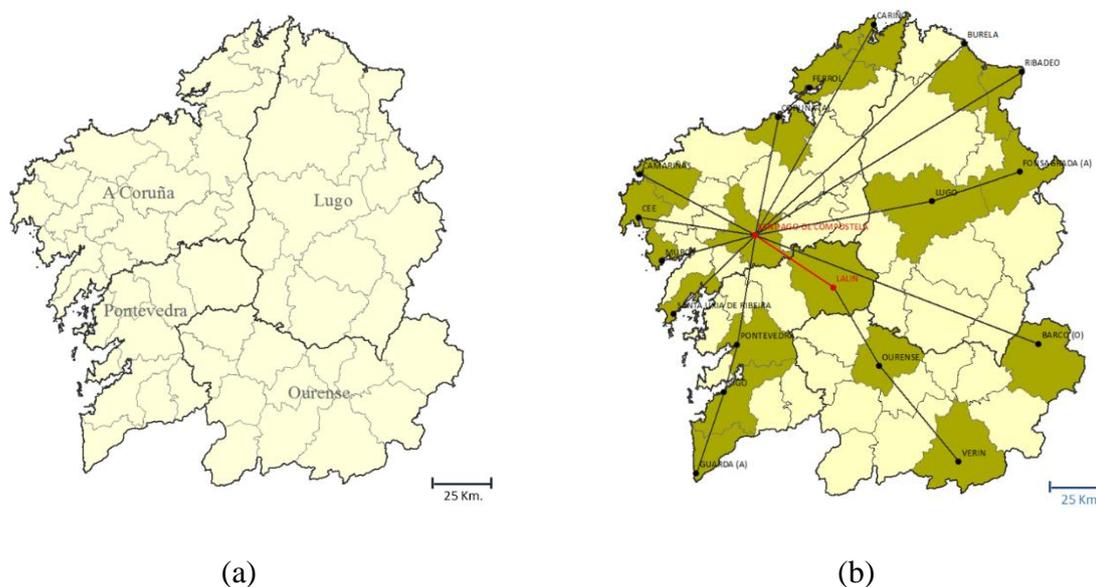
In order to calculate the displacement between nodes we use the *ESRI ArcGIS* software. For the estimation of the distortion effect for the whole region from these sample points we use the software *Darcy 2.2*, which has been developed by the *European Research Group on Spatial Simulation for the Social Sciences (S4).* The transformation model applied is based on an Euclidean interpolation with grade 2, where the values obtained for the route *Santiago-Lalín* (in red in Figure 1.b) are considered as reference - they remain undistorted in each scenario -.

3. Study area

The region of Galicia is located in the NW of Spain. Its area covers over 29,574 km² and has 2,732,347 inhabitants (INE, 2015). The relative weight of both its surface and its population with respect to the whole of Spain is about 5.8%, which implies a population density similar to the national average, which is about 92 hab/km² (INE, 2015).

However, these data hide large internal disparities. In fact, Galicia shows a proper pattern of settlement traditionally characterized by its high level of dispersion and atomization (Balsa-Barreiro, 2011), accounting for 27,312 unique populated entities, which represent almost 60% of Spain (IGE, 2014 and INE, 2015).

Economic changes suffered in the middle of the 20ᵗʰ century led to a breakdown of the traditional demographic balance between *population* and *resources*. It generated constant migratory flows from rural to urban areas. At the internal level, the cities of the *Atlantic Corridor* (*Eje Atlántico*), mainly *A Coruña* and *Vigo*, became the most important poles of demographic attraction.

The urban model of this region is based on a polycentric system of seven *main cities*, five of them located on the *Atlantic Corridor*, which concentrates most of the economic and socio-demographic dynamics of the region (Figures 2.a and 2.b). Except for the two large cities (*A Coruña* and *Vigo*), both with population levels of about 250,000 inhabitants, the rest of cities have similar demographic weights of approximately 75,000-100,000 inhabitants. Since the last quarter of the 20ᵗʰ century, surrounding settlements around the former cities have increased their population substantially. The rest of the territory is organized according to a group of *head towns*, which act as urban poles at small-scale that concentrate the economic activity of their respective areas. From a quantitative point of view, Galician settlement pattern is characterized by the quasi-generalized absence of urban nodes with population levels between 25,000 and 75,000 inhabitants.

As in the case of Spain, the low levels of population density, combined with the unique spatial pattern of settlement, requires high investments *per capita* for developing a properly structured transport infrastructure system (Figure 2.c). But there exist also other territorial constraints such as the hilly topography in the sector E-SE and the peripheral situation of this region. These constraints require even more endowment in high-quality transport infrastructure to ensure an adequate level of territorial accessibility, which enable to reach optimal levels of economic development and to avoid social exclusion (Monzón, 2017).

Figure 2   (a) Map of population density of Galicia at municipal level (in quintiles). (b) Absolute population of each urban node considered in our point grid. (c) Map of the main infrastructures of Galicia (high capacity road infrastructures –in red– and railways –in yellow–) represented on a physical map.

(a)   (b)   (c)
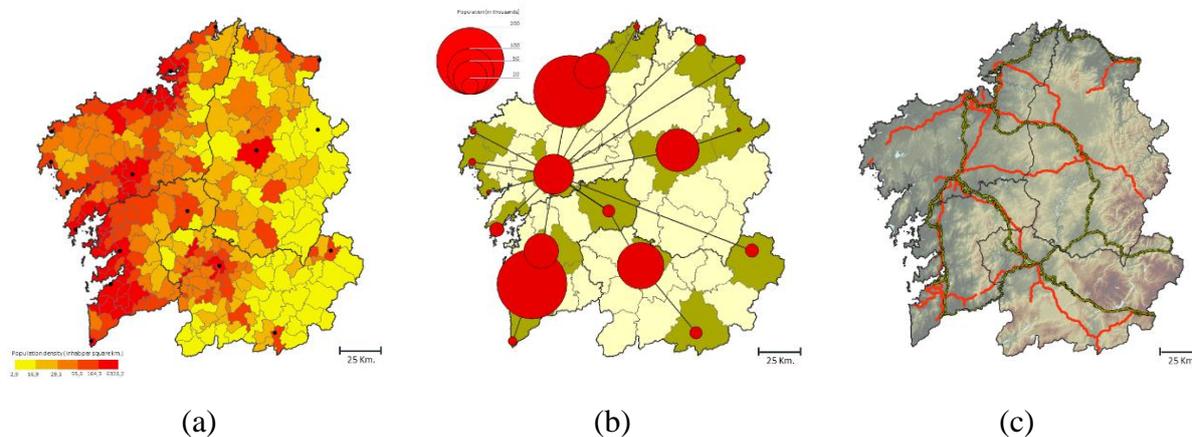
4.   Results

The results obtained for the different means of transport are shown in Figures 3 and 4, where the levels of distortion are represented both in geometric distortion maps (Figure 3), and colored raster maps (Figure 4). The first map (Figure 3) offers an intuitive view by applying an anamorphic effect to the traditional maps, which is related to the travel time required. The overlapping of the same square grid enables to compare different scenarios by using the same scale factor. In this map, displacement between points is represented by using vectors. The second map (Figure 4) represents the distortion effect by using color gradual varying from green to red tones. Green tones are related with lengths shortening while red tones with lengths extending compared to the original map. In addition, *distortion contours* (equidistant every 0.15 distortion units) are overlapped and provide a clearer representation of the distortion effects. For comparison purposes, the distorted maps obtained for each scenario are represented using the same color palette and values.

The results confirm that the axes *Ferrol-Vigo* and *Santiago-Ourense* are the best articulated, although with significant differences in each scenario. In the case of public transport systems, a better accessibility is observed within a wide sector that includes the *Santiago-Ourense* axis and the south section of the *Atlantic Corridor*. The areas with poorest levels of accessibility (highly distorted) are the inner of *Lugo*'s province, certain northern sectors and the *Costa da Morte,* in the western area of the province of *A Coruña*.

The results obtained for the public transport systems (scenarios *b* and *c*) define some relevant aspects such as the existence of a main sector between the two fundamental axes: the *Atlantic Corridor* and the *radial axis* with *Madrid*, in both cases articulated by means of the *high-speed train*, whose connection will not be completed until 2018. These scenarios show once again poor levels of communication and accessibility with regard to the northern sector of the provinces of *A Coruña* and *Lugo*, where railway line (narrow-gauge railway called *FEVE*) goes along a lower priority axis (*North Corridor*), and the sector of *Costa da Morte*, where there is not even train connection.

The map of *real times* (scenario *c*) shows clearly how the radial communications with *Madrid* have been prioritized, which can be observed in the *positive distortion* area (in green in Figure 4) shown in the axis *Santiago-Ourense*, the high levels of *negative distortion* (in red in Figure 4) in the sector which goes from *northern Galicia* to *inner Lugo*, in addition to the appearance of a new distorted area in the theoretical prolongation of the *Atlantic Corridor* towards Portugal.

Figure 3   Travel-time maps obtained for the different scenarios. The colors of the vectors indicate its direction regard to the original position. In black it approaches to the main node, while in red it goes further away.
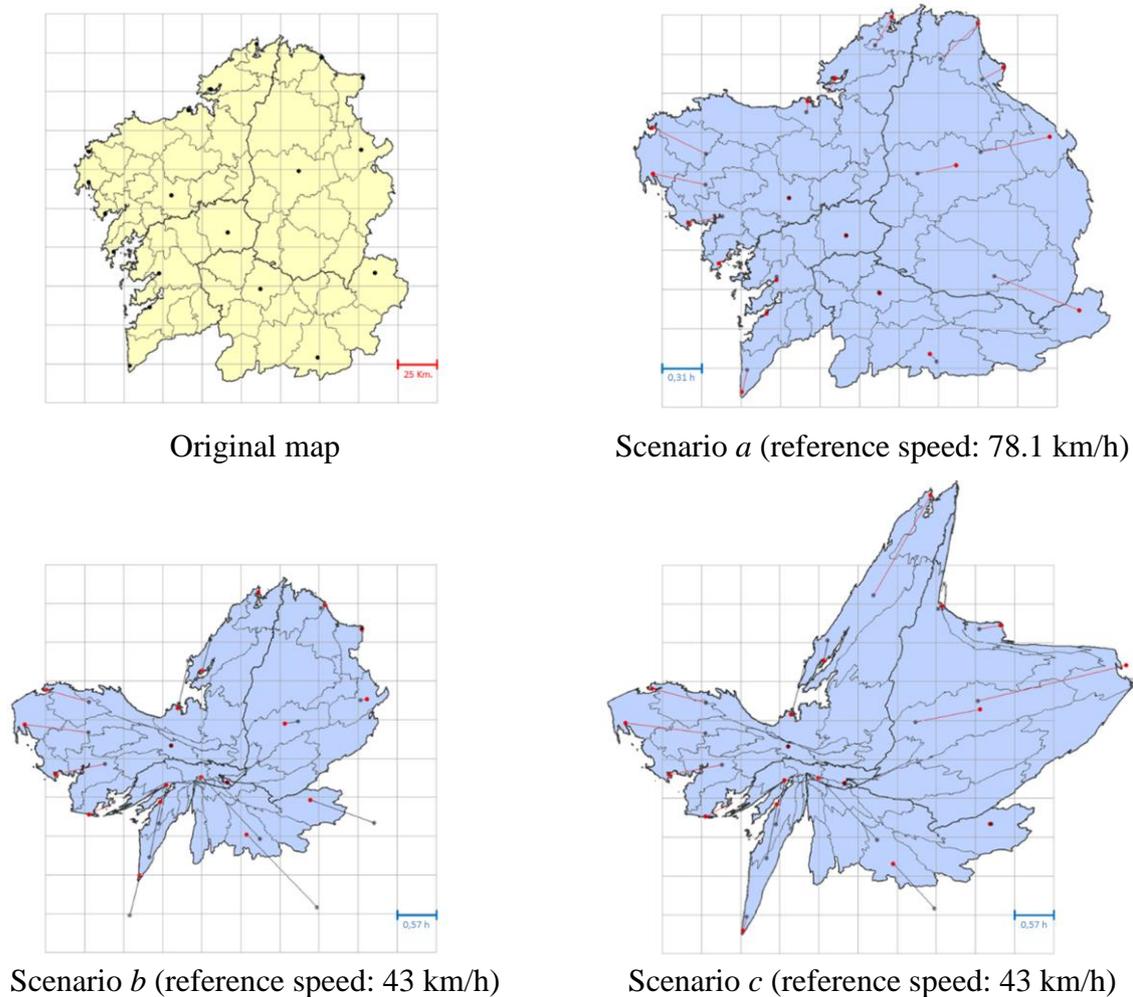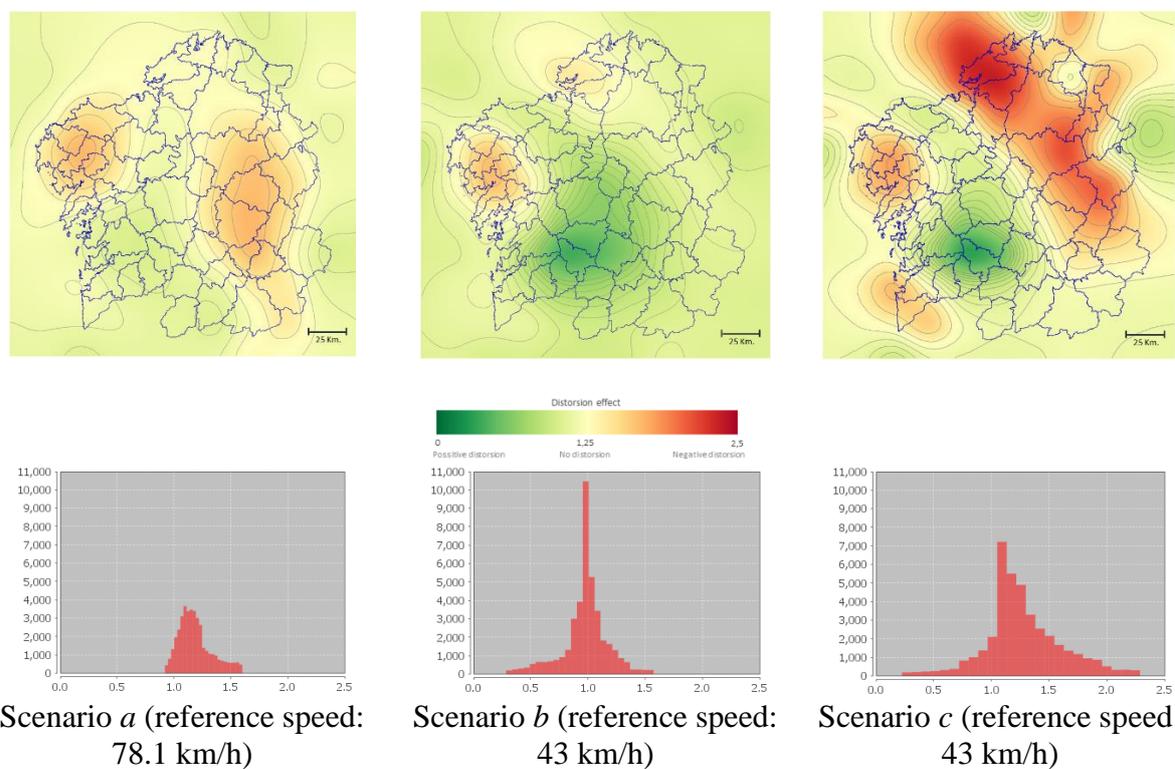

Original map

Scenario *a* (reference speed: 78.1 km/h)

Scenario *b* (reference speed: 43 km/h)

Scenario *c* (reference speed: 43 km/h)

Figure 4   Distorted maps and histograms obtained for the different scenarios. Normalized representation for all the cases.

5. Discussion

Transport infrastructures have an essential role to play in the territorial cohesion. Some aspects are relevant such as the spatial pattern of the infrastructure network, its design and characteristics. Other fundamental components are the *frequency* and *capacity* of the transport systems, which determine the degree of accessibility for the inhabitants with regard to the services, and the degree of competitiveness for the companies with regard to the economic centers.

The distortion maps obtained essentially coincide with the layout defined by the most relevant infrastructures of this region. The results obtained exhibit two fundamental axes: (a) the *Atlantic Corridor*, in direction N-S, and (b) the *Santiago-Ourense*, which is part of the radial axis with Madrid. The physical factors only show relative importance, in spite of the high costs that they originate. It can be observed how the topography does not predetermine the layout of transport infrastructures and the real accessibility in eastern area of the *Ourense*'s province.

Contrary, the isolated areas, which are poorly articulated and show low levels of accessibility, present regressive demographic and economic dynamics. The inner of *Lugo*'s province and the area called *Costa da Morte*, in the western part of the province of *A Coruña*, are clear examples. This area suffers from a traditional isolation process, despite its proximity to the most dynamic area from the region: the *Atlantic Corridor*. In fact, *A Costa da Morte* has lost around 16.6% of inhabitants since 1960, while its province has increased them around 10.7% (Balsa-Barreiro and Landsperger, 2012 and 2013). This regressive dynamic supposed reduce relative weight of more than 7% with regard to the total population of *A Coruña*'s province from year 1920 (Balsa-Barreiro, 2013).

The results obtained here show general tendencies, although several criticisms should be taken into account. In fact, our results could have been influenced by a non-dense point grid, in which uniquely relevant nodes were considered. Future studies should consider denser and more complex networks, and additionally analyze and compare the distortion effect from different reference nodes.

Finally, the methodology here presented offers an intuitive perspective about the levels of accessibility and territorial cohesion at an intraregional scale, considering the transport network and travel times required between nodes. This methodology is highly interesting for professionals, whose field of study is related with spatial information and *territory* such as architects, civil engineers, landscapers or geographers.

Acknowledgments

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