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ESTIMATION OF SOCIAL COHESION IN THE SPANISH MUNICIPALITIES AFTER THE IMPLANTATION OF THE HIGH SPEED RAILWAY

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I. INTRODUCTION

The adopted transport policies pay particular attention to social cohesion through different models of use and development (Frank et al., 2014; Marti-Henneberg, 2013), since the transport networks are crucial for the socioeconomic structure in the modern world (Miralles-Guasch, 2011), and are an important tool for social cohesion and territorial integration because they act as catalysts in unifying spaces (Vickerman 1992) or providing structure to the territory, also reflecting the existing imbalance between urban systems and socioeconomic activities (Givoni, 2006). While the economic profitability and the environmental impact of transport infrastructure were traditionally taken into account, social cohesion has now become an integral part of the deployment of new infrastructures or the improvement of existing ones, especially high-speed railways connecting major cities and economic centres, where these benefits are most obvious. However, these benefits are not as clear in cities with smaller populations located along their layouts because their access to the major motorways is limited, and in most cases, they do not have railway stations. Moreover, these cities are usually located in regions with geographic and demographic disadvantages and limited access to the major centres of economic activity.

In this regard, the strategic objectives of the Infrastructure, Transport and Housing Plan (PITVI) consider infrastructure essential to boosting economic development and social and territorial cohesion. Additionally, this plan supports high-capacity motorways and high-speed railway as strategic infrastructures to improve mainland Spain's social cohesion. Specifically, the fundamental objective of PITVI by the year 2024 is to create a motorway network ensuring connections among the Autonomous Communities, international connections, ports and airports, and major border crossings. Similarly, this plan seeks to form a railway network connecting all the provincial capitals through high-speed lines, with networks exclusively for passenger traffic.

However, the deployment of a new High-Speed Rail (HSR) line usually generates great expectations of socioeconomic revitalisation. However, many of these expectations are never realised, or if they are, the changes occur more slowly and less dramatically than expected (Biehl, 1986; Plassard, 1992; Bellet, 2013) because these high-quality infrastructures are actually embedded in a complex system of territorial relations and must be treated as such. The impact analysis must therefore take into account the space characteristics and organisation where they occur before and after their deployment, as well as the strategies developed by the different actors during the decision-making and infrastructure evaluation (Garmendia et al., 2010) because infrastructures allow the economic development of the territory that they do not directly cause (Plassard, 1992; Miralles, 2002). Nevertheless, high-speed rail corridors do in fact provide important comparative advantages over other places that do not have them. Therefore, while not alone sufficient for economic growth and wealth creation, these infrastructures can boost substantial aspects of social and economic structures (Plassard, 1997; Martens et al., 2012).

The overall objective of this paper is to assess how accessibility improvement effected by the deployment of new high-speed railway corridors affects social and territorial cohesion of the Peninsular Spanish municipalities.

Regarding the area of study, only mainland Spain is considered for analysis; a joint analysis of road and rail infrastructures is presented, and the scope of action of PITVI in terms of high-speed railway is taken into account. As for the scale of work, work at the municipal level was chosen because local connections prevail over the transport network (Pueyo et al., 2012). Therefore, although the scale analysis regarding railways could be regional, when considering available HSR stops or services, the use of the local scale is deemed more appropriate because it takes into account specific stations and their locations in this mode of transportation and the particular connection between motorways and secondary roads.

The specific objectives are socioeconomically characterising the municipalities of mainland Spain and determining their potential accessibility, assessing the degree of improvement in accessibility with the development of new infrastructures (HSR lines) and defining an indicator of social cohesion.

The starting hypothesis of this paper is as follows: *The new railway infrastructures specified in PITVI will improve the existing social cohesion among all non-insular Spanish municipalities*.

This paper synthetically presents the research results, focusing on the methodological aspects.

II. METHODOLOGY

An important part of the initial tasks in designing and creating base mapping is the modelling of the transport system under study, which makes use of vector-based mapping. Thus, the lines represent all the roads allowing access to HSR stations on one hand and the conventional rail infrastructure itself and that corresponding to the HSR service on the other. This linear mapping evokes a multimodal transport network, the railway stations being the only connection points between both infrastructures (road and rail), whether high-speed or conventional train. All the linear mapping is divided into sections (understood as the line segments that are limited by two intersections with other line segments) and nodes (which are the points in which three or more line segments converge). In this linear mapping, each network section is associated with (non-geographic) alphanumeric information, a unique numeric identifier, its maximum allowable speed according to the type of track (e.g., fast, national, regional, provincial), the section length and the impedance (defined as the resistance of a rail section to being crossed by a user of the system) in minutes. The second type is the mapping that represents the set of geo-referenced points symbolising railway stations, regardless of whether they are high-speed, because they are the only intermodal points. The third type of mapping shows the main urban centre of each municipality represented as a point. Finally, the fourth type of mapping is polygonal graphic entities that form the municipalities.

The data belonging to the municipality and the districts within it were added to the polygonal graphic entities mentioned above (Table 1). The variables were selected after consulting a wide literature on the determination of socioeconomic conditions characterising the dynamics of various municipalities under study (Fischer and Nijkamp, 2014; Rose and Harrison, 2014; Serra et al., 2014).

Table 1
VARIABLES USED FOR THE SOCIOECONOMIC CHARACTERISATION OF THE PENINSULAR SPANISH MUNICIPALITIES

Variables used for the socioeconomic characterisation of the Peninsular Spanish municipalities.		
Variable	Identifier	Source
Resident population	V1	2012 Municipal Census of Inhabitants, National Institute of Statistics (INE, in Spanish)
Market share per capita	V2	La Caixa 2012 Economic Yearbook
Motor vehicles registered per capita	V3	La Caixa 2012 Economic Yearbook
Industrial average per capita	V4	La Caixa 2012 Economic Yearbook
Unemployment rate	V5	2012 Labour Force Survey by the State Public Employment Service (Servicio Estatal Público de Empleo - SEPE)
Dependence index	V6	2012 Municipal Census of Inhabitants, National Institute of Statistics - INE
Percentage of second homes	V7	2011 Census of Population and Housing, National Institute of Statistics - INE
Population employed in the primary sector	V8	2011 Census of Population and Housing, National Institute of Statistics - INE
Population employed in the secondary sector	V9	2011 Census of Population and Housing, National Institute of Statistics - INE
Population employed in the tertiary sector	V10	2011 Census of Population and Housing, National Institute of Statistics - INE
Population used in the construction industry	V11	2011 Census of Population and Housing, National Institute of Statistics - INE

Source: Prepared by the authors.

The normalisation of these 11 variables was subsequently performed so that all have similar weights in the socioeconomic classification of municipalities. Then, the relationship or dependence between the variables was analysed by using the Spearman correlation coefficient. Next, a principal component analysis (PCA) was performed, and it was found that by using seven components, it was possible to collect 85% of the original variance. This statistical synthesis technique is used to reduce the size, that is, the number of variables, losing the least amount of data possible. Thus, the new major derived components are a linear combination of the original variables and are also independent of each other. After the reduction to seven components, an independent component analysis (ICA) was conducted. This statistical technique enables finding a linear representation of the non-Gaussian data so that the components are statistically independent or as independent as possible. Once the PCA was completed, the correlation between the main components was verified to test their independence. Then, all the municipalities were classified using the seven independent components grouped through the method of self-organising maps (SOM).

Once the four classes were obtained, depending on the values representing the original variables in them, they were reclassified into three classes according to social cohesion as follows: backward, potentially backward and non-backward. Once the municipalities were classified, they were characterised on the basis of statistics, such as the arithmetic mean and standard deviation of the 11 original variables

Then the indicator of potential accessibility is calculated. This indicator applies to each Spanish municipality and assesses accessibility with the new network HSR. Specifically, the potential accessibility measures the degree of connection between the main centre of the municipality and the remaining peninsular towns. The mathematical expression of the potential accessibility indicator (PPr) is adopted as follows:

$$PP_r = \sum_j \frac{P_j}{I_j}$$

Where P_j is the population of the main destination centre (to which those of the other towns of the municipality have been added if existing) and I_j is the impedance of the travel distance between the origin and destination town.

As with socioeconomic variables, after calculating the indicator of potential accessibility, municipalities are classified into four categories according to their accessibility deficiencies: municipalities with no, not very significant, significant or very significant deficiency of accessibility, if the value of accessibility is between the maximum and minimum obtained value is greater than 50%, is between 50% and 25%, if it is between 25% and 10% or if it less than 10%, respectively.

However, the great difference between the maximum and minimum values of potential accessibility obtained impedes correct classification of municipalities. To solve this problem, the natural logarithm of each value of accessibility obtained is calculated. Thus, the difference between the maximum and minimum values is much smaller and therefore allows classifying municipalities into the above four categories.

Once the municipalities are classified according to their socioeconomic structure and potential accessibility, the next step is to calculate the weighting factor to apply to each category (Φ_r). This factor depends on the weighting factor varies from 0 to 4, as shown in Table 2. The table shows how the most favourable cases occur in municipalities without backwardness or accessibility deficiencies and whose weighting factor is 0. Similarly weighting factors are assigned to other the table cells using the above-mentioned German Plan for Infrastructure and Transport (BMVBW, 2003) and the work of López (2007) as guidelines.

Table 2
MATRIX AVERAGED FACTORS FOR COHESION CRITERIA

Matrix of averaged factors for cohesion criteria				
	Accessibility deficiencies			
CATEGORY OF STRUCTURAL BACKWARDNESS	*None*	*Not very significant*	*Significant*	*Very significant*
Non-backward regions	*0*	*1*	*1*	*2*
Potentially backward regions	*1*	*1*	*2*	*3*
Backward regions	*1*	*2*	*3*	*4*

Source: López, 2007.

Finally, the indicator of social cohesion is calculated as the ratio expressed in percentage terms and considers the difference between future accessibility after the implementation of PITVI (PP_{rs}) and the current accessibility (PP_{ro}), weighted by the factor expressed in the above table, and the current value of accessibility.

$$CS_s = \frac{\Phi_r \cdot \left(PP_{rs} - PP_{ro}\right)}{PP_{ro}} \cdot 100$$

With this indicator, municipalities that will experience an improvement in or deterioration of their social cohesion after new high-speed rail corridor construction can already be classified and identified. According to this expression (CS_s), in the less developed regions, the value of the indicator of social cohesion is high because the weighting factor may also be high, while the opposite may occur in the more developed regions, where the weighting factor will be the lowest.

III. RESULTS

The results emerge from the analysis of social cohesion in a period before the expansion of new road HSR infrastructures and from the analysis performed after the full deployment of this infrastructure.

IV. CURRENT SITUATION OF RAIL INFRASTRUCTURES

The analysis of the current situation of rail infrastructures starts from the study of the peninsular Spanish municipalities' classification based on their structural backwardness. The analysis shows how the different municipalities are grouped in the following distribution pattern according to their structural backwardness: In the northern half, there are more non-backward municipalities, while the southern half is characterised by the existence of potentially backward municipalities. Non-backward municipalities seem to correspond to provincial capitals and cities with greater populations in the different regions, such as the municipalities forming the major metropolitan areas of the country: Madrid, Barcelona, Valencia, Seville, Zaragoza, Bilbao, and others.

The results shows that there is no accessibility deficiency in the municipalities forming the metropolitan areas of Madrid, Barcelona or Valencia because they account for the greatest population sizes and have the greatest provision of transport infrastructure. Similarly, there are three models of centre-periphery distribution, fed by the existence of a national radial infrastructure network, whose centre is in the main core of the above-mentioned metropolis. In particular, it can be observed how municipalities that are already provided with motorways or HSR lines are areas where accessibility deficiencies are not significant.

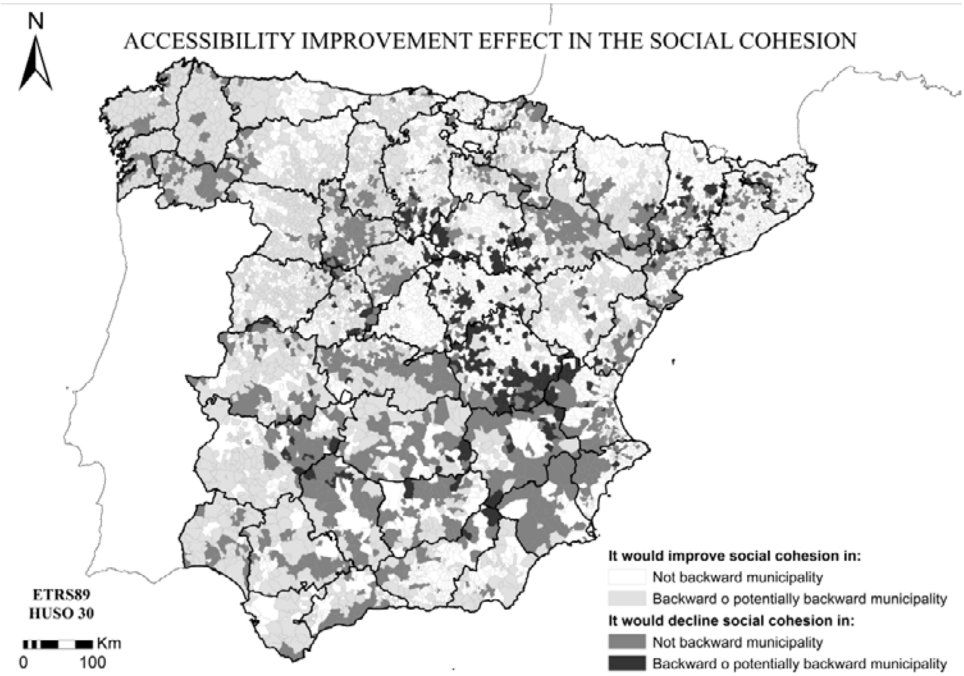
V. FUTURE SITUATION WITH NEW RAIL INFRASTRUCTURES

When analysing the future situation with the deployment of new infrastructures set by PITVI, the results obtained enable assessment of the degree of improvement that they effect in the area under study. Below are presented the most relevant findings.

Regarding the accessibility deficiency level of the Spanish territory, after the implantation of the new HSR infrastructures planned by the PITVI. If the future stage is compared with the current stage, it is discovered that the growth of accessibility from such infrastructures involves a significant degree of improvement only in the peninsular Centre (Madrid). For the rest of the Spanish territory, these new infrastructures cause a negative impact, since it is clearly seen how increase the accessibility deficiencies in the North and West, along the corridor formed by the eastern regions of Castilla León, Castilla La Mancha and Andalusia and Aragon Southwest. The rest of the territory does not suffer changes in this regard.

Finally, the results are showed about how the accessibility improving affects to the peninsular social cohesion. Because of the spatial distribution of selected variables to determine the 3 classes of backwardness structural from the structural backwardness of the analyzed peninsular municipalities, a positive effect from the point of view of social cohesion would take place if the value of this proposed indicator is higher than the average value (46.72%) for those municipalities which are economically backward o potentially backward. This affirmation has its justification in the fact that these nucleuses are those that require greater opportunities for socioeconomic development, which would be come by the implementation of the new HSR infrastructures proposed by the PITVI. This increase of opportunities would involve a greater degree of social cohesion among all the municipalities of the territory object of study.

Figure 1
EFFECTS OF IMPROVEMENT OF ACCESSIBILITY BY THE INTRODUCTION OF NEW LINES AVE



Source: Prepared by the authors.

The most noteworthy after analyzing the resultant cartography of the accessibility improvement effect caused by the new HSR lines about social cohesion, is the disparity that has the implementation of HSR infrastructure planned by the PITVI about social cohesion. Likewise in the municipalities whose effect is positive for the social cohesion we are able to estimate that they are the most numerous of all them. Nevertheless, in the Madrid Autonomous Community is observed that is an area defined by the grouping of not backward municipalities where the social cohesion would improve. Since these would obtain a value of social cohesion indicator below the average.

On the contrary, the municipalities who are backward o potentially backward and where the effect by the new railway infrastructures is negative present a peripheral location in the territory. As consequence, it is possible to take advantage of their position to provide them greater accessibility to get that they will be able to become not backward municipalities. In addition, it is in these municipalities where it should act to correct the imbalance between all the municipalities, since in these that already backward or potentially backward municipalities, the accessibility improvement for the new railway lines, their social cohesion get worse and worse, even their social cohesion would be worse than now compared to the rest of the municipalities.

VI. CONCLUSIONS

The methodology presented in this paper can be used for future studies that, in addition to examining rail transport, also address other modes of transport, such as aircraft (linked to the high-quality road network through airports). Another aspect of the study is that the use of socioeconomic indicators and accessibility, together with the implementation of the analytical tools of the GIS's own networks, enables efficiently and correctly analysing the impacts of new motorways and rail corridors set in PITVI on social cohesion, which in turn allows directing fair distribution of investments and transport services. Furthermore, applying this methodology prior to an infrastructure's execution increases the ability to detect a priori large changes, its usefulness for decision-makers and policy-makers and its application in future infrastructure plans.

As a result of the foregoing, accessibility is one of the main objectives of national transport policies. The greatest degree of socioeconomic development is traditionally associated with regions with greater accessibility, while the lack of accessibility is related to peripheral regions characterised by significant problems in accessing economic markets and their low socioeconomic dynamism. Therefore, taking into account that changes in the transport system have an immediate impact on accessibility transmitted through infrastructure and transport services, these changes can affect the spatial locations of different socioeconomic activities in the long term.

In this way, certain predominance of municipalities where the implementation of infrastructure causes negative effects on the social cohesion (South East of Extremadura, Castilla La Mancha, Murcia and Alicante) can be seen in South-Central peninsular. Within these areas there are backward or potentially backward municipalities where priority should execute actions to get that their comparative gap do not increase of these from the rest of municipalities. Although it is true too, that there are others municipalities where the implantation of infrastructures would be positive for the social cohesion.

On the other hand, in those municipalities where a negative effect would be produced for the social cohesion and which are considered not backward municipalities, highlights the Valladolid and Zaragoza area, because of these two zones would receive benefits from the new accessibility above the average. In addition, due to the fact that they are municipalities with great demographic and economic dynamism and geographic advantages due to its location, possibly these centres would become new influence centres in the existing centre-periphery model.