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Assessment of High-Speed Rail Service Coverage in Municipalities of Peninsular Spain

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Abstract: The Spanish transportation and housing infrastructure plan has planned that in 2024 all provincial capitals in peninsular Spain are to be connected by high-speed rail lines. Nowadays, 35 stations are already operational. These stations and the roads to access them are very important, as these are the only access points for travelers to benefit from the high railway speed. The goal of this study is to evaluate the railway coverage of high-speed services in Spanish peninsular municipalities in 2018 and planned for 2024. A methodology and research tools related to accessibility from municipalities to stations have been used, based on Geographic information Systems. An interaction model was used based on the floating catchment area in three steps. The resulting thematic maps and the analysis of the number of municipalities and the resident population is based on the degree of coverage in 2018. Likewise, in 2024 almost all of the municipalities are planned to have high high-speed railway coverage, these being the most densely populated. The analysis allowed us to present a detailed view of the problem; a methodology and a specific application framework are offered to make the high-speed rail services in Spain more equitable.

Keywords: floating catchment area in three steps; railway stations of high-speed lines; sustainable and equity planning; territorial accessibility; territorial governance and management

1. Introduction

Public services must have equitable and adequate access for citizens, regardless of personal, socioeconomic or geographic factors [1]. In fact, for the general transport service and rail transport in particular, this becomes even more relevant owing to the important effect they have on Spanish territory and society. Therefore, the planning of high-speed rail service must ensure that it is accessible and effective for the whole of the community it serves [2].

Traditionally, economic profitability has been considered in the planning and execution of transport infrastructures, as well as in the inherent possible environmental impacts. Currently, equitable and effective access is a key element of analysis, either in the implementation of new infrastructures or even

in the improvement of existing ones [3]. In the high-speed rail lines that connect the main cities and the most important economic centers, the benefits are particularly evident. However, these benefits are not as clear in small or medium-sized cities—which are distributed along the high-speed railway’s route but do not have a high-speed train station [4].

This means of transport is characterized by its low capillarity—where the stations are the only point of access to the high railway speed; thus, they become the only points of modal change of transport. The location of stations and roads to access them consequently becomes very important since it determines the benefits that can be obtained from this means of transport [3].

In some cases, the train uses the territory as mere physical support, not allowing access to the use of the rail service. Therefore, the high-speed rail (HSR) that links two cities bring them closer in terms of travel time: people can travel faster from one city to another city.

Nevertheless, it does not benefit the cities in between, due to the fact that people in the intermediate territory cannot access this means of transport since there are no rail stations there. In fact, with this means of transport, higher connection speeds between the main cities will be achieved. Furthermore, the corridor effect is lost, since the train passes through the intermediate cities but does not stop at them—this effect is known as the tunnel effect [5].

Thus, the present study evaluates the high-speed rail coverage of Spanish peninsular municipalities in 2018—which is planned up to 2024. Due to the fact that Spain’s 2012–2024 infrastructure, transport and housing plan (Spanish acronym: PITVI) [6] is committed to high-speed rail as one of the strategic infrastructures to improve peninsular national–territorial cohesion.

In this regard, there are several strategic goals that this plan tries to achieve in 2024: (i) to improve the efficiency and competitiveness of the nationwide transport system by optimizing the use of existing capacities; (ii) to promote balanced economic development as a tool at the service of overcoming the economic crisis; (iii) to promote sustainable mobility by combining its economic and social effects with respect for the environment; (iv) to strengthen territorial cohesion and accessibility of all state territories through the transportation system; and, (v) to promote the functional integration of the transport system as a whole through an intermodal approach.

In fact, it is planned for 2024 that all the provincial capitals of peninsular Spain be connected by high-speed rail lines for passenger traffic exclusively. Also, there are currently 35 stations already in operation. Thus, we have considered the Spanish peninsular territory, since it is the scope of execution of the PITVI in high-speed railway matters.

Likewise, it was decided to work at the municipal level, when local connections prevail over the transport network, and the regional scale was used when considering the stops and services available in each station [4,7].

Furthermore, the specific objectives of this work are: to characterize the peninsular municipalities according to their high-speed railway coverage in 2018 vs. 2024; to assess the degree of improvement of this coverage; and to measure whether this distribution is equitable. In fact, regions in the future that have less accessibility to this means of transport will have less chance of developing from a social and economic perspective.

Particularly, given the analyzed area (Iberian peninsula) and considering the two most relevant ground transport means (road and rail), the methodology proposed has been designed in order to achieve the proposed objectives. Contextually, the results obtained can be used in a practical way for their application in the optimization of land use planning.

In this regard, the present study is considered innovative due to the following attributes: (i) a specific methodology by means of an optimum interaction model is used; (ii) the methodology is specifically used for HSR services and in a specific area in the Spanish peninsula; and (iii) in this approach to transport infrastructure, the analysis of equitable and effective access is new.

2. Materials and Methods

The proposed objectives were achieved using the three-step floating area model (3SFCA), analyzing the population's access to high-speed rail services, from Spanish mainland municipalities to the nearest high-speed train station using the road network present in 2018 [8].

The tasks were executed using R, ArcGIS 10.5 and its included network analysis tool—Network Analyst. All the information used is publicly available and from official sources: road networks were obtained from the Official Road Map (2018) [9]; administrative divisions of the municipalities, and the delimitation of the urban land of the capitals of the municipalities from the National Cartographic Base at a scale of 1: 200,000 (BCN200) [10]; the population of Spanish municipalities in 2017 from the Municipal Register Review [11]; the location of high-speed rail stations [12]; the PITVI 2012-2024 [6]; and the number of services and destinations for high-speed trains [13].

Figure 1 shows the four fundamental phases of the work and also each of the sub-phases that make up these four phases. In the following, the phases will be described.

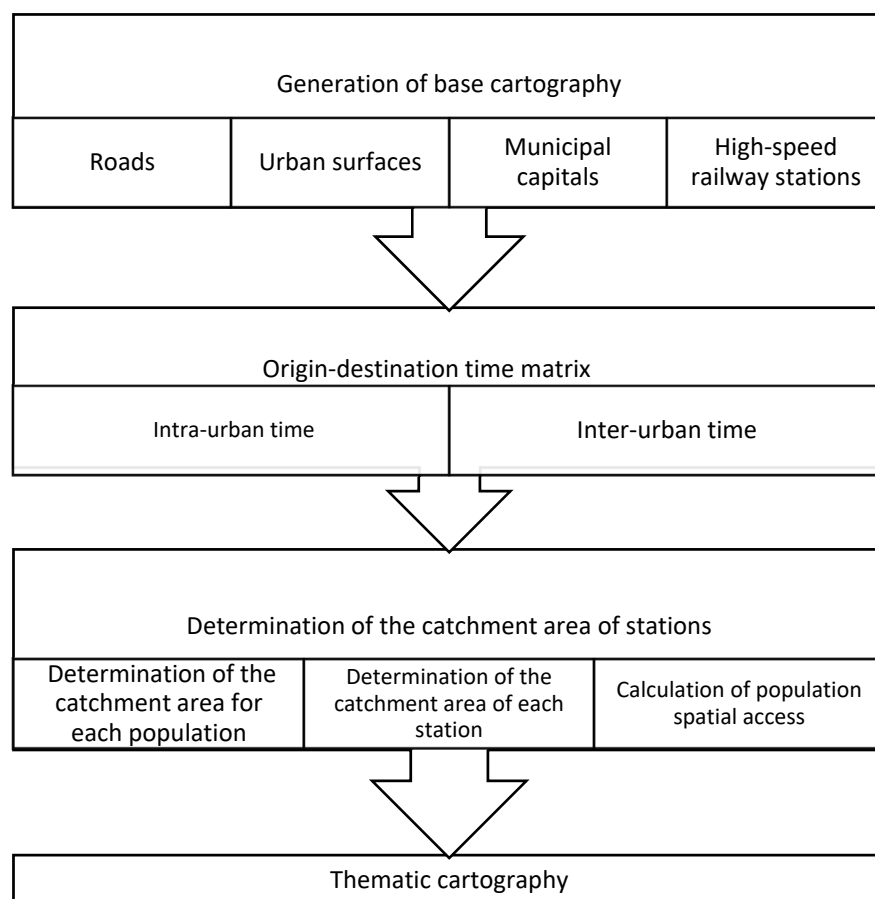


Figure 1. Workflow used by the authors.

2.1. Generation of Base Cartography

The cartography is composed of four layers of information. The first corresponds to the modeling of the road network, using vector arc-node type cartography composed of lines, on which the impedance is calculated in minutes from the municipal capital to the nearest train station.

The second layer of information shows the urban surface of cities and towns through polygonal entities. These polygonal entities are associated as alphanumeric information to the resident population in each one of them.

The third layer of information is represented by points, and contains the mapping of all the municipal capitals, with the resident population in each one of them as associated alphanumeric information.

The fourth layer of information is represented by points, displaying railway stations with some high-speed rail service, and the number of services throughout the day being the associated alphanumeric information.

2.2. Origin-Destination Time Matrix

The time it takes for a resident population in a Spanish peninsular municipality to reach a high-speed rail station determines and conditions the opportunities for socio-economic development of that municipality [3]. This interval was calculated as the expended time of the journey between the municipal capitals and the location of HSR stations in cities that possess a railway station.

However, in addition to calculating the inter-urban time interval of displacement between cities and towns, the intra-urban intervals that it takes to cross urban environments was also calculated. The estimation of intra-urban travel time is based on the road network in the urban areas, the urban surface, and the population of each urban nucleus.

In this regard, the implementation of these two means of transportation increased in greater quantity in 2024 according to the PITVI—more HSR lines, but also more dual carriageways. It should be highlighted that new dual carriageways are going to become more relevant since they are the fastest way to get to an HSR station.

As for the inter-urban time, the internal distance to cross each urban area was calculated according to [14]:

$$D_{ii} = \frac{1}{2} \sqrt{\frac{\text{area (km}^2\text{)}}{\pi}} \quad (1)$$

where the area (Figure 2) is equal to the area of each population center measured in kilometers.

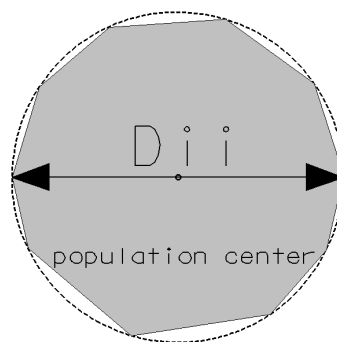


Figure 2. Representation of D_{ii} —the internal distance to cross urban areas.

After, it is assumed that citizens in the most populated areas have more difficulty crossing them due to more frequent traffic jams. Therefore, the intra-urban travel time is estimated using the population density. Thus, a linear adjustment (Figure 3) was used in order to assign a maximum of 80 km/h to areas with the lowest population density—due to the fact it is assumed that it is faster to cross urban areas with the lowest population density and 20 km/h was assigned to the most populated areas (slower to cross urban areas with the highest population density).

Also, the intra-urban time is estimated using the relation between D_{ii} and the estimated speed. As a result, a more realistic transport model is obtained. [15].

Finally, the total time of the journey between the municipal capitals and the urban centers that have a high-speed railway station is obtained by adding the inter-urban interval plus the intra-urban time. Moreover, exceptions occurred when the municipal capital and the urban nucleus that has the station were the same. The total time of the trip is then only exclusively the intra-urban time.

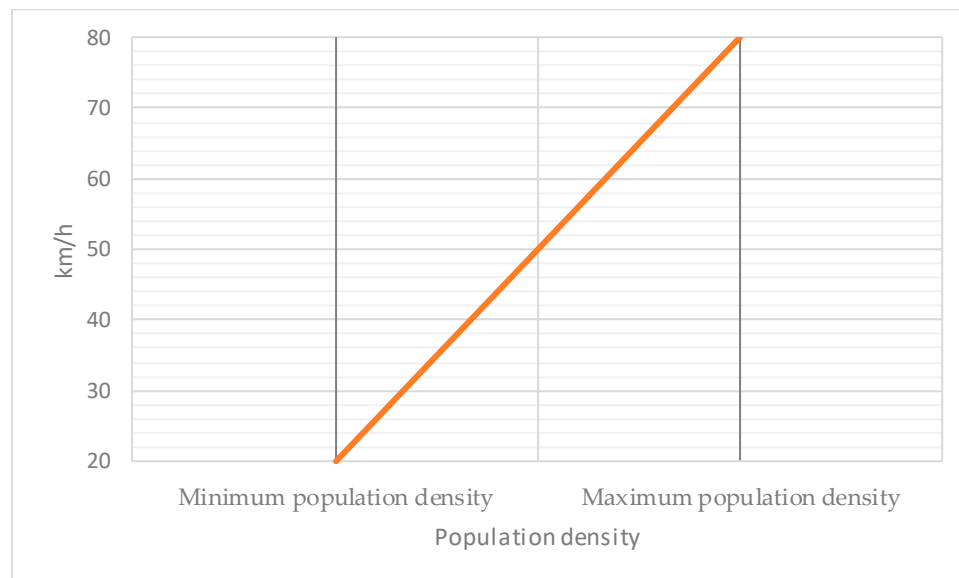


Figure 3. Linear adjustment so as to assign speed (km/h) to cross each population center according to population density.

2.3. Determination of the Catchment Area of Stations

The present study uses a three-step floating catchment (3SFCA), assuming that the population that demands high-speed rail services is influenced by the availability of other nearby stations—assigning a competitive weight based on the travel time for each place with one station which can be seen in Equation (2). This weight was used in the calculation of the demand of locations that have high-speed rail service, minimizing overestimation [16]. Contextually, the method is implemented in three steps:

Step 1: Determination of the catchment of a population i (Figure 4) based on driving time to reach the nearest station from a population. Search for all stations offering high-speed rail services in the catchment area, assigning a Gaussian weight.

$$G_{ij} = \frac{T_{ij}}{\sum_{k \in \{Dist(i,k) < d_0\}} T_{ik}} \quad (2)$$

where G_{ij} is the weight selection between location i (municipality capital) and the place where the high-speed rail service j (railway station) is offered, $Dist(i, k)$ is the cost of travel time (minutes) from any place of service k within the catchment area, and d_0 is the size of the catchment area. In this regard, the catchment area size varies from the number of the closer stations available from each population center and the location of these stations and also with the population center. Besides, the access time also depends on the type of road that allows travel to the railway stations.

Bearing in mind the remaining places where high-speed rail service is also offered, this point j of all available high-speed rail stations within the catchment area is the one that offers the fastest route to the nearest railway station to reach the final destination. In this case, the value can range from simply the travel time within a city that has a station to larger driving distances. The variables T_{ij} and T_{ik} are the Gaussian weights assigned to j and k respectively.

$Dist(i, k)$ represents the cost of travel time (minutes) for the scenario in 2018, which considered the current road network, but for the future scenario of 2024, future dual carriageways were considered to be built by 2024, as per the PITVI. Since dual carriageways are considered to be the best roads to get the closest HSR station they are the fastest road transport routes to access a railway station (Figure 5).

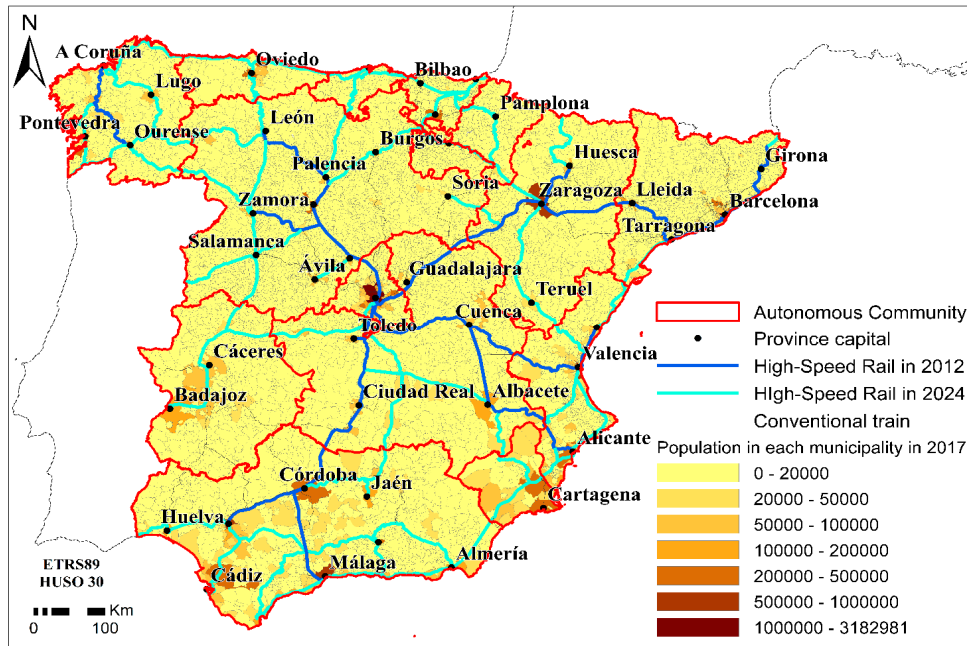


Figure 4. Population in each Spanish municipality in 2017 in the Iberian peninsula.

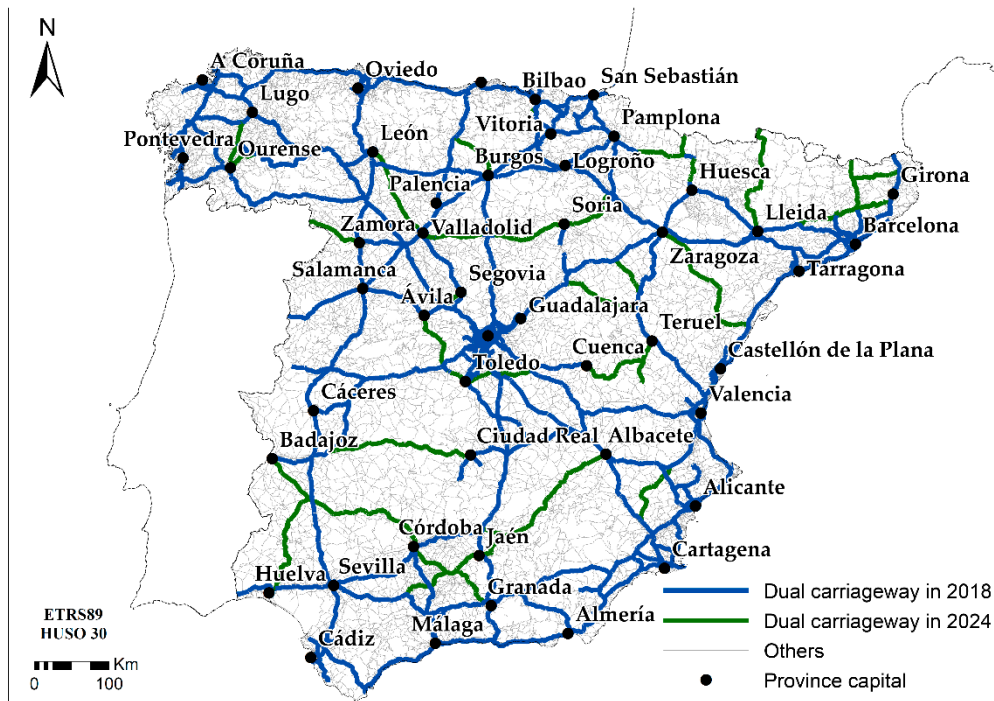


Figure 5. Dual carriageways in peninsular Spain in 2018 and 2024.

Step 2: Determination of the catchment area according to the travel time of each service location j , and division of the catchment area into five sub-zones using the same procedure as in step 1. Search for all the places within the floating catchment area and calculation of the station-population ratio (R) of j by

$$R_j = \frac{S_j}{\sum_{k \in D_r} G_{kj} P_k W_r} = \frac{S_j}{\sum_{k \in D_1} G_{kj} P_k W_1 + \sum_{k \in D_2} G_{kj} P_k W_2 + \sum_{k \in D_3} G_{kj} P_k W_3 + \sum_{k \in D_4} G_{kj} P_k W_4} \quad (3)$$

where S_j is the service capacity of j , i.e. the number of high-speed trains that are offered each day at each station. W_r is the impedance of r_{th} sub-zone D_r . This impedance is understood as resistance to movement and is calculated based on the maximum speed at which drivers can travel on each of the roads. Furthermore, it is also based on its hierarchy from local roads to dual carriageways, and the calculated distance that extends these road sections to move from one point to another.

While G_{kj} is the weight of the selection between j and the location of the population k . and P_k is the size of population k .

For the existing scenario of 2018, the data was acquired directly from the information offered [13]. However, for the future scenario of 2024, it was necessary to estimate S_j value in cities where a station that uses high-speed rail still does not exist [17].

$$N_s(i, j) = \alpha \left(\frac{P_i P_j}{D_r^2} \right)^\beta \frac{1}{IR_n^2} \quad (4)$$

where the number of high-speed trains is estimated by calibrating the parameters arbitrated as α and β . To achieve this goal, the current frequency of existing services was used. Thus, the values obtained for α and β are 3.004 and 0.3219, and 0.67 for the correlation coefficient, P_i is the population that lives in the city where the station is at the beginning of the journey by rail, expressed in thousands of inhabitants, P_j is the population that lives in the city where the station is at the end of the journey by rail, expressed in thousands of inhabitants, D_r is the geographical distance between origin and destination stations, expressed in kilometers and IR_n^2 is the travel time using the high-speed rail network, expressed in hours. In fact, a population estimation for 2024 was made considering the population data shown by the Spanish national statistics institute between 1996 and 2018 [11]. Thus, it was considered that some municipalities disappeared, once they have been agglutinated by other municipalities. Therefore, the more recent municipalities were considered. Besides, using the projection of the values of each series for each one of the municipalities, a regression analysis was carried out. Contextually, an estimation of the population in 2024 was made.

Step 3: Calculation of spatial access of the population of place i by means of

$$A_i^F = \sum_{j \in D_r} G_{ij} R_j W_r \quad (5)$$

where R_j is the station–population ratio of j within the catchment area, G_{ij} is the weight of the choice between i and j , and W_r is the Gaussian weight of the sub-area r_{th} of D_r .

As for G_{ij} , this is equal to 1 when there is only one high-speed railway station accessible to a population, but it decreases as available alternatives increase. In fact, the multiplication of G_{ij} , P_i , and W_{ij} represents the demand of the adjusted population of the location of i , corresponding to each municipal capital, with respect to each high-speed railway station j .

2.4. Obtaining Thematic Cartography

The thematic cartography was made considering the current scenario in 2018 and the planned scenario for 2024—where there will be many more stations and high-speed railway lines, planned by the PITVI. Thus, based on the obtained results regarding the accessibility analysis of the high-speed rail stations, five classes were established in equal intervals. These class intervals were kept constant in both scenarios, to perform the classification of the values corresponding to the coverage maps of the high-speed rail service in 2018 and 2014. Therefore, it was possible to compare them.

3. Results

The high-speed rail coverage available to the inhabitants of each municipality makes it possible to create two thematic maps on a national peninsular scale. The first represents the current high-speed rail

coverage of each municipality in 2018 (Figure 6). Likewise, the second shows the expected coverage of the high-speed rail service of each municipality by 2024 (Figure 8).

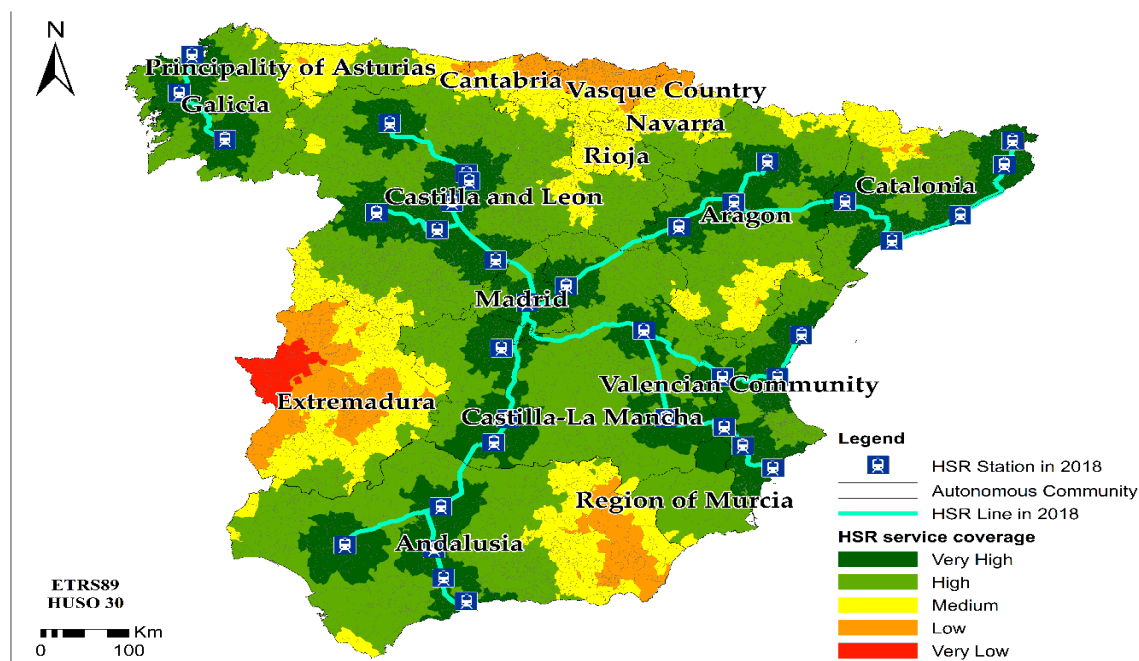


Figure 6. Coverage of high-speed rail service in peninsular Spain in 2018.

Figure 6, shows the coverage of high-speed railway stations. This representation allows the classification of municipalities and autonomous communities (CCAA) with greater and lesser coverage. Those CCAA where there are currently no high-speed rail lines display a very low coverage, such as in Extremadura, Principality of Asturias, Cantabria, Basque Country, Navarra, and La Rioja. However, it stands out that in the Region of Murcia the coverage is high due to the proximity of lines in the Valencian Community. In contrast, we have Extremadura, which is the only CCAA with very low coverage and cross-border municipalities in its north-western half.

Also, several CCAAs present a coverage that is medium, high, or very high in certain parts—leaving large areas with medium, low, or very low coverage, as is the case of Andalusia, Castilla-La Mancha, Catalonia and Aragon. Even the tunnel effect that occurs in some railway lines appears scarce. This effect is produced between (Figures 5 and 6) the following province capitals: Seville and Cordoba; Cordoba and Ciudad Real; Toledo and Cuenca; Cuenca and Albacete; Cuenca and Valencia; Guadalajara and Zaragoza; Zaragoza and Lleida; and, Avila and Leon. This effect is characterized by the fact that the train behaves like an airplane, merely passing by terrain, which is a physical support for the infrastructure [18].

In some CCAAs, a center–periphery model is formed. The center of the model is always in the municipalities that have a high-speed railway station, surrounded by municipalities where coverage of the high-speed rail service gradually decreases—until it reaches the most peripheral municipalities, with the lowest existing coverage. The CCAAs where this model is most common are the ones that have a high-speed rail station. Therefore, the existence of some high-speed railway station acquires such territorial importance, that it produces a center–periphery model around these stations. Regardless of the distribution pattern in each CCAA, there are many municipalities where coverage is either low or very low. Therefore, the possibility that there are more high-speed rail stations and that there is an improvement in the roads to access them would increase the high-speed rail coverage. These are distributed territorially in peripheral areas and between high-speed rail lines.

In addition to the territorial analysis carried out through thematic cartography, we have analyzed the number of municipalities and the population according to the category of high-speed rail service coverage in 2018.

Contextually, Figure 7 highlights how the highest percentage of the population is concentrated in municipalities that have very high coverage. In fact, the high-speed rail network offers very high coverage to more than half of the Spanish peninsula's population: 56.67%. However, this category doesn't present the greatest number of municipalities, at 31.36%. Consequently, these municipalities are densely populated. In contrast, this happens in the category of very low coverage of high-speed rail, where there are few municipalities (0.30%) and where the coverage is very low and the areas are also sparsely populated (0.11%). Also, we observe the progression of the population from the category of greater coverage to the smaller population as it decreases. Therefore, it appears as if the high-speed rail network serves the most populated populations, possibly looking for more users.

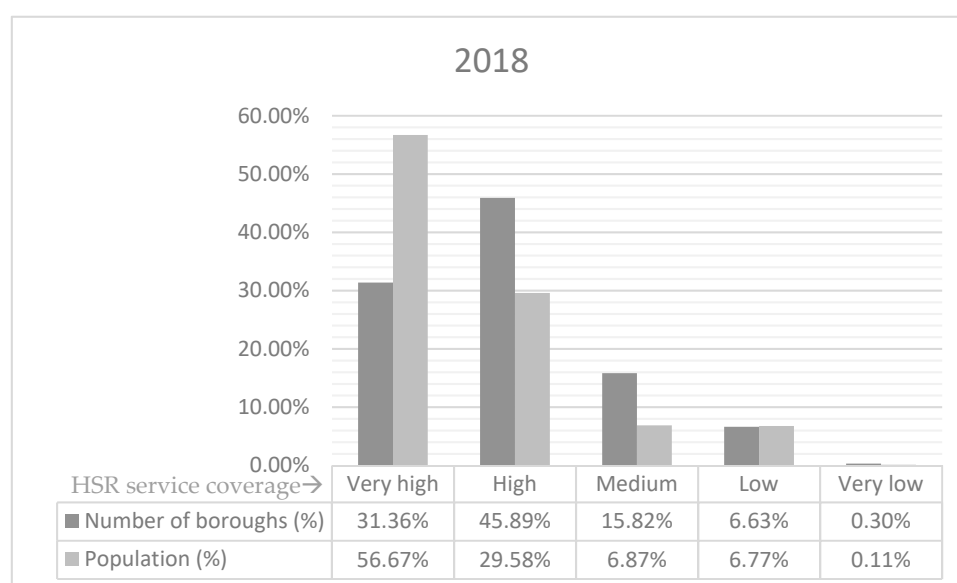


Figure 7. Number of municipalities and population for rail service capacity in peninsular Spain in 2018.

The same analysis was carried out for the expected 2024 scenario, considering all stations and high-speed railway lines planned by the PITVI.

Figure 8, shows the municipal high-speed rail coverage according to the access to the railway stations by 2024. There is a clear predominance of municipalities with very high or high coverage, now has greatly decreased the number of municipalities and areas of low or very low coverage. In fact, there are CCAAs where the predominance is almost entirely that of municipalities with the greatest coverage. This is the case of Andalusia, the Region of Murcia, the Valencian Community, Madrid, Galicia, Cantabria, and Navarra.

Nonetheless, there are still municipalities with very low coverage. Also, there are several municipalities with a medium, low or very low coverage. These are distributed territorially in the peripheral cross-border areas with Portugal and France, as well as located between the high-speed lines. Therefore, despite the evolution of the future high-speed rail network, it is practically impossible to prevent municipalities with scarce high-speed rail coverage in the future, just as the road network is distributed to access to the stations and the distribution of the population in the municipalities.

Even though the tunnel effect is scarce, it was observed on some railway lines, as can be seen in lines where stations have a greater territorial separation or where there are municipalities with a medium, low or very low coverage. This effect is notorious, in the railway line connecting the CCAAs of Castilla and Leon and Galicia, as well as in the railway line that connects the CCAA of Castilla

La-Mancha. Curiously, this effect was not so pronounced in 2018, and now there are more railway stations where rail coverage is expected to be greater.

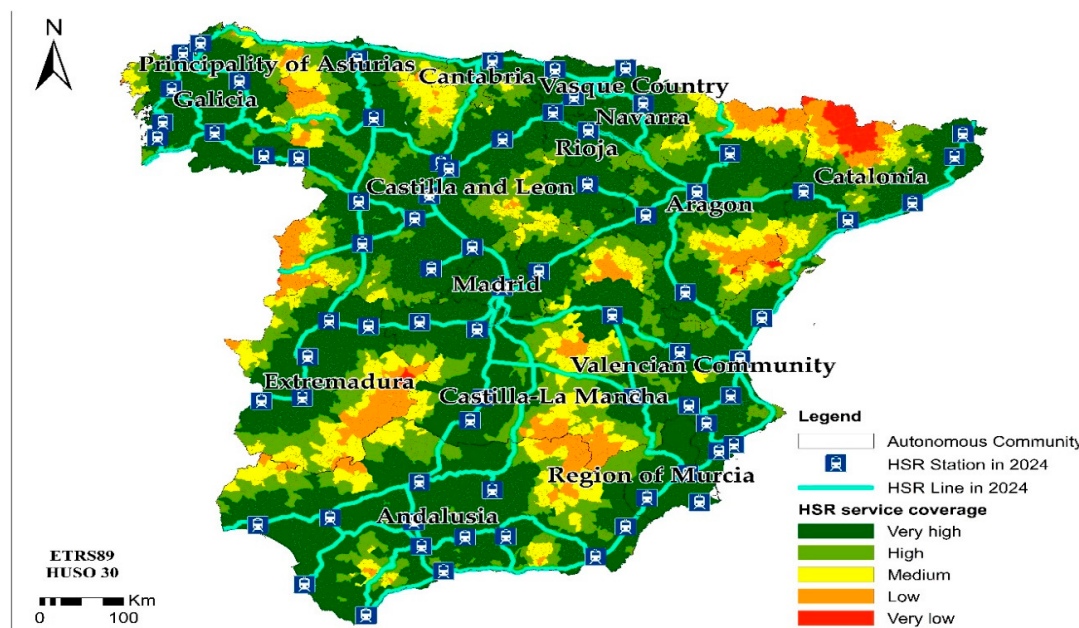


Figure 8. Coverage of high-speed rail service in peninsular Spain in 2024.

It can also be observed (Figure 8) like in 2018 (Figure 6), the enormous territorial effect of the municipalities that have some high-speed railway station on the surrounding municipalities. Again, this effect becomes apparent through the formation of center–periphery models, although there will be a greater number of stations by 2024. In addition, it can be seen how the fusion of different center–periphery models causes true zones of influence around the high-speed rail lines, formed by municipalities with very high or high coverage. In the future, these real brokers may welcome more economic activity.

Nevertheless, it can be observed that the construction of a large number of high-speed railway stations and new dual carriageways will undoubtedly favor the existence of greater territorial coverage of the high-speed rail service for the residents of Spanish peninsular municipalities, even if only around the railway lines. Therefore, works carried out by 2024 in the PITVI on trains and roads will undoubtedly lead to greater rail coverage.

Figure 9 highlights that in 2024 the highest percentage of numbers of municipalities are related to those with very high coverage (67.59%). It is evident to almost the entire population (90.85%), with the second-highest percentage of several municipalities with high coverage, and the third-highest percentage with medium coverage. Barely nonexistent is the percentage of municipalities with the least coverage. Therefore, it can be stated that in the future, the most densely populated municipalities that compose almost the entirety of the Spanish peninsular population, will have very high coverage of high-speed rail.

Thus, like 2018, we observed that the progression of the population from the category of greater coverage to the smaller population decreases. It seems that the future high-speed railway network continues the trend established in 2018 of continuing to serve the largest populations. This is likely for greater efficiency of the network’s services, giving adequate coverage to the highest number of people possible.

Nevertheless, to determine if the distribution of the future high-speed rail network (by 2024) will be more equitable than the current one (in 2018), the Lorenz curve was used (Figure 10). The accumulated percentage of population is shown on the x-axis. Also, the accumulated percentage of

HSR service coverage is shown on the y-axis. Therefore, it is possible to verify that a greater equity is achieved if the value of the cumulative percentage of the population is the same as the cumulative percentage of the service coverage by the HSR. Indeed, the blue line represents the equitable distribution of the high-speed rail service.

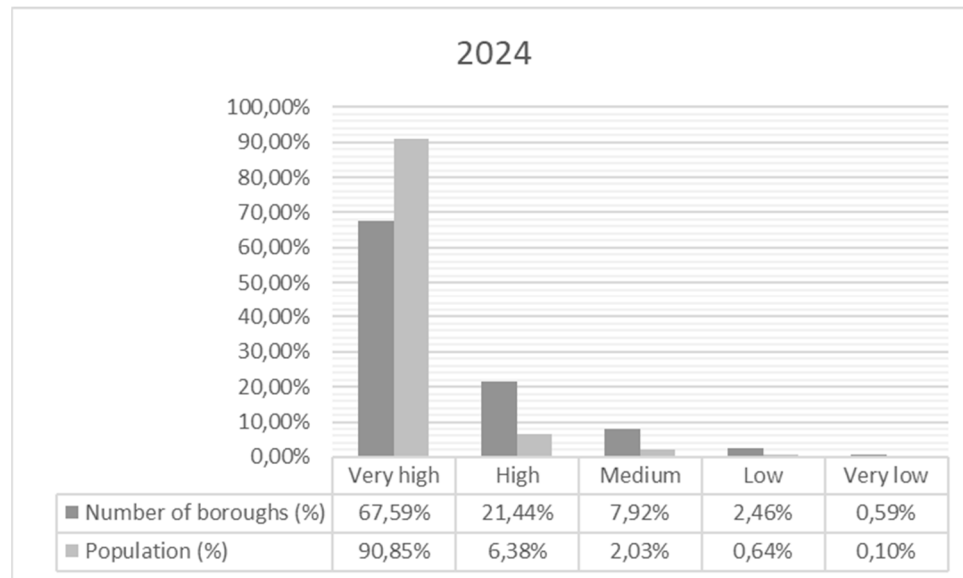


Figure 9. Number of municipalities and population for rail service capacity in peninsular Spain by 2024.

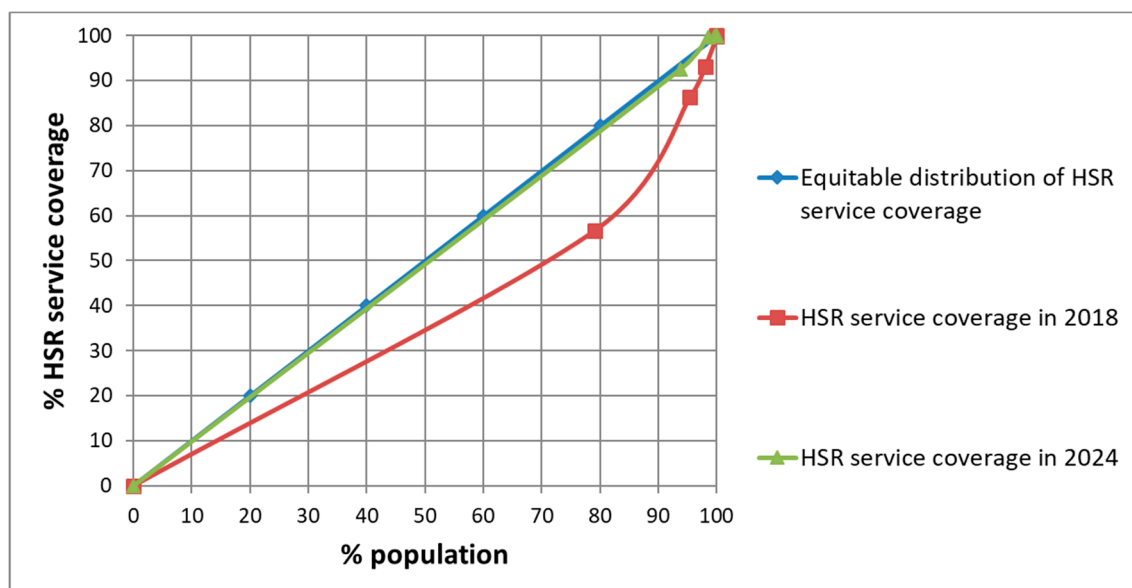


Figure 10. Comparative Lorenz curve of high-speed rail service coverage for residents of Spanish peninsular municipalities in 2018 and 2024.

In this regard, the calculation was made for cumulative percentage intervals in sections of 10% of the population considering the cumulative percentage of HSR service coverage in 2018 and 2024. Then, it is possible to verify that the curve that most closely approximates this line corresponds to the green line representative of the coverage of the high-speed rail service by 2024; and the curve corresponding to 2018 stretches further (Figure 10). Therefore, we can interpret that in the future there will be a more equitable distribution of coverage in comparison with the actual scenario, since more percentage of population has more and better coverage.

Through the analysis of the curves for 2018 and 2024, it is possible to verify a greater downward inflection at higher percentages of the population (Figure 10). Therefore, when this inflection occurs, the distribution of coverage is less equitable among the population. In the case of the representative 2024 curve, the distribution is less equitable when the coverage reaches population percentages above 90%. Also, the representative curve of 2018 presents a greater inflection when the percentage of the population reaches approximately 80%. In both cases, the distribution is less equitable when higher percentages of the population are reached.

Thus, the previous analysis (Figures 6 and 8) enable us affirm that the distribution of the high-speed rail coverage is more different in municipalities with less coverage, and that this effect is much more evident in 2018 than it will be by 2024. Due to the construction of the new high-speed railway stations and dual carriageways by 2024, almost the entire population will likely have very good high-speed rail coverage.

4. Discussion

When we compare the two scenarios, 2018 and 2024 (Figure 8), it is possible to verify the municipal high-speed rail coverage according to access to the railway stations by 2024. Here, there is a clear predominance of municipalities with very high or high coverage. In fact, there are CCAAs where the predominance is almost entirely that of municipalities with the greatest coverage. This is the case of Andalusia, the Region of Murcia, the Valencian Community, Madrid, Galicia, Cantabria, and Navarra.

Nevertheless, there are still municipalities with very low coverage. Also, there are several municipalities with a medium, low or very low coverage. These are distributed in the peripheral transition areas with Portugal and France, as well as located between the high-speed lines. Despite the evolution of the future high-speed rail network, it is a very complex task to prevent municipalities with scarce high-speed rail coverage in the future, just as the road network is distributed to access to the stations and the distribution of the population in the municipalities.

In this regard, from an economic perspective, it would be interesting to strengthen the connection to the more populated municipalities, however, this could lead the less populated municipalities to be even more isolated. In fact, if the railway stations were located in other unplanned places in the PITVI, i.e., in places where there was more population that were not considered provincial capitals; it will be seen as a further step of the research related to this topic. In this scenario, the high-speed rail service would reach more population and the coverage of this service could increase in population terms. Besides, it would be possible to reach more population, probably since the railway stations would reach more populated areas and the stations would be located in more central areas.

Regarding the tunnel effect, it was already observed how this effect now does occur in some railway lines. And also, as can be identified in lines where stations have a greater territorial separation, i.e. where there are municipalities with a medium, low, or very low coverage. This effect is notorious, in the railway line connecting the CCAAs of Castilla and Leon and Galicia, as well as in the railway line that connects the CCAA of Castilla La-Mancha. Moreover, it should be highlighted that this phenomenon was not so evident in 2018.

In fact, it can be observed (Figure 8) like in 2018 (Figure 6), the relevant territorial effect of the municipalities that have a high-speed railway station in the surrounding municipalities. Once again, this effect becomes apparent through the formation of center–periphery models. However, there will be a greater number of stations by 2024. Besides, it can be seen how the fusion of different center–periphery models creates zones of influence around the high-speed rail lines, formed by municipalities with very high or high coverage. In the future, these real brokers could be seen as the catalysts for more economic activity.

Nevertheless, it can be observed that the construction of a large number of high-speed railway stations and new dual carriageways will undoubtedly favor the existence of greater territorial coverage of the rail service of the high speed of the Spanish peninsular municipalities' inhabitants—even if only

around the railway lines. Therefore, works carried out by 2024 in the PITVI on trains and roads will undoubtedly lead to greater rail coverage and territorial cohesion.

The high-speed rail network coverage is of utmost importance, considering the related territorial effects. The implementation of a new railway usually generates great expectations of dynamization. Unfortunately, many of these expectations do not effectively materialize and if they do the changes occur more slowly and less intensively than expected [18–20]. This is because the high-speed infrastructure is embedded in a complex system of territorial relationships, and it must be acknowledged as such [4]. The analysis of the effects must, therefore, consider the characteristics and organization of the space where it is registered before and after the introduction of the new railway services, as well as the strategies developed by the different agents during the decision processes and valuation of the infrastructure [21], as the infrastructures allow, but do not directly cause, the development of the territory [2,18].

Nevertheless, the fact remains that infrastructure provides important comparative advantages when considering places that do not have it. Without being a condition of economic growth and creation of wellbeing only by itself, the high railway speed can substantially dynamize aspects of social and economic structures [5,20,22,23]. In principle, this means of transport has the potential to become an instrument of dynamization based on the following factors: the characteristics of the network and the implementation of the infrastructure in the territory; the level and characteristics of the service; the socio-economic characteristics and territorial context where they are implanted; and finally, the strategies developed by the environmental agents, that is, their capacity to interact with the opportunities introduced by this means of transport [24].

Furthermore, and bearing in mind the concept of sustainable development, this typology of projects along with the used planning strategies are even more relevant. It seeks to foster the basic needs of a human being. Also, it enables the opportunity to provide a more dignified and equitable life to the population in general, and also for future generations, giving them the opportunity to meet their own needs [25].

Moreover, in light of the defined European Sustainable Development Goals (SDGs), this project fulfills, the following SDGs:

- To reduce overall poverty, mainly in the less developed regions—i.e. providing new jobs opportunities, new commercial roots, etc.
- To promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for the populations covered by the project.
- To foster industry, innovation, and infrastructures by the implementation of the project, enabling new opportunities for infrastructures creation and innovation, and by creating a magnet for entrepreneurs and young talented people in the areas covered by the project, etc.
- To reduce inequality through more equitable accessibility patterns to all population.
- To foster sustainable cities and communities by reducing socio-economic disparities among regions, providing better education to all population, enabling new possibilities for planning strategies, etc.

Although this research expands our understanding regarding the high-speed rail service coverage in municipalities of peninsular Spain, some study limitations should be addressed as well as worthwhile prospects of future research lines.

In fact, the Iberian peninsula presents one of the largest border areas in the EU territory. Thus, a study that analyzed the impacts of the project through a across borders is seen as pivotal to reach stronger results towards the theme—i.e., to understand how this typology of the project could have an impact on the Portuguese border population.

Furthermore, several other services and factors could be linked with the high-speed rail service. Thus, if services and factors were linked together, more insights will be addressed regarding this topic. Therefore, and considering the relevance of the theme, further studies/researches, as well as

the assessment of public perceptions of this typology of projects are seen as critical to enriching the literature on this subject.

5. Conclusions

Proper use of accessibility indicators, together with the application of GIS tools, allowed the efficient and sound analysis of the high-speed railway coverage, existing in each CCAA, and the future one that is expected to be in place by 2024. Besides, the comparison of railway coverage at different points in time allows comparative ranges to be established between each of the autonomous regions, since it is possible to observe the zones and municipalities that will be affected by greater rail coverage, to a greater or lesser extent.

In 2018, we can see the scarce coverage that exists in some CCAAs, where there are currently no high-speed rail lines in contrast to the rest. Also, CCAAs that do have high-speed rail lines still present little coverage due to their large area. There are even many municipalities with little coverage, and which are somewhat isolated from the high-speed railway lines, which are distributed territorially in peripheral areas and the intermediate spaces between the railway lines. However, considering the numerical proportion of municipalities and population according to its high-speed railway coverage, it can be stated that more than half of the population still has very good coverage. It remains true that the rail network has been arranged to serve the most inhabited urban centers, possibly due to seeking a larger number of users, and to provide greater access to the rail network.

As for 2024, the current scenario will effectively change owing to an expected clear superiority of municipalities with very good coverage, with the number of municipalities with scarce coverage greatly decreasing. Considering the municipalities around the stations, the construction of a considerable number of high-speed railway stations and the new dual carriageways are undoubtedly greatly favored, and there is an ostensible greater territorial coverage of the residents' high-speed rail service of the Spanish peninsular municipalities, although it is mostly around railway lines. Furthermore, it can also be assumed that it is practically impossible to prevent scenarios of municipalities with scarce high-speed rail coverage in the future, just as the road network is distributed to access the stations and the distribution of the population in the municipalities. Also, considering the population proportion and municipalities according to their levels of coverage, it can be established that the most densely populated municipalities, having almost all the Spanish peninsular population, will have very good railway coverage, but municipalities with a small coverage will too. However, it would be advisable to establish measures so that the latter do not remain isolated from the high-speed rail coverage. The comparison of the distribution of the high-speed railway coverage in the two temporary scenarios analyzed allows us to establish that the distribution of coverage is much different in municipalities with less coverage, less population, and also where the territorial position is in peripheral areas (borderlands) or between the high-speed lines. Likewise, the distribution across municipalities in 2018 presents a higher contrast than it is expected to reach in 2024 since by then the coverage will be very good in a large part of the municipalities and to the population. The importance of the high-speed rail network is clear, considering its immediate territorial effects and over time. In fact, the models of center–periphery distribution obtained can cause a pumping effect of resource absorption, from the peripheral municipalities to those that own a high-speed railway station. Even some of these municipalities with a high-speed railway station can become true poles of attraction for economic activities. That is because the cities where a station already exists or where one will be built can become land transport interchange points between the transport of dual carriageways and the high-speed railway, acquiring greater territorial importance. Furthermore, as previously mentioned, they attract economic activity from the surrounding municipalities as a result of the center–periphery model, but also from other places much further away on a national scale. As these cities with high-speed rail stations are already and will be even more accessible for residents of other cities further away that also have other high-speed rail stations.

As for the spatial distribution of the stations, although the railway network of 2018 presents a spatial distribution of the stations that is more reminiscent of the distribution of airports than conventional railway stations, a more pronounced tunnel effect will be visible yet scarce by 2024. Even considering that in the future there will be a deployment of a large number of stations, and their distribution will be more reminiscent of the distribution of conventional train stations. Possibly, this effect is caused by the trains' minimum acceleration distance to reach maximum speed and thereby achieve greater effectiveness in its operation.

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