ACCESSIBILITY IMPACT OF HIGH-SPEED LINES IN PERIPEHRAL REGIONS: THE CASE OF THE FUTURE LINE MADRID-BARCELONA-FRENCH BORDER

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Abstract

The aim of this paper is to evaluate the impact of high-speed lines in peripheral regions, as exemplified in the Madrid-Barcelona-French border line. This line is essential for Spain, because it will bring the two main Spanish metropolises (Madrid and Barcelona) closer to each other and will connect the Spanish high-speed network to the European one. Potential effects of the new infrastructure on the urban sytem are measured by means of accessibility indicators. These effects will be important not only in cities served by the new line (such as Barcelona, Zaragoza and Madrid), but also along the Madrid-Seville and Barcelona-Murcia corridors. Outside Spain, Portugal and south-southeastern regions of France will also reap significant benefits. Our conclusions that the signs of these effects depend on the geographic scale: polarizing effects at the national level and balancing effects at both corridor and European levels are identified. A Geographic Information System was used to carry out this study.

Keywords: Accessibility, railway transport, high-speed train, Spain, European Union, Geographic Information Systems (GIS).

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INTRODUCTION

The high-speed train permits links between cities in conditions of time, price and quality of service hitherto unimaginable. with obvious consequences for the development potential of the regions affected. By shortening travel times, it brings about changes in accessibility conditions and hence in the relative location of places, with obvious consequences for the development potential of the regions affected.

This paper aims to evaluate the accessibility impact of a new high-speed line in a peripheral space: the Madrid-Barcelona-French border line, which is planned to be completed by the year 2005. In order to reflect exclusively the impact of the new line, two scenarios are considered: the year 2005 “with” and “without” the new line.

From the European point of view, this line will enable a peripheral space (the Iberian Peninsula) to link up to the centre of Europe; from a national perspective, it will link the two main cities in Spain and other urban agglomerations along an important corridor of the country. This is a situation similar to that which will result in Italy with the building of the Rome-Milan line. Therefore the problem of scale has to be carefully taken into account: I analyse whether the new line will increase or reduce the degree of polarization in the urban system on the international, national and corridor scales.

It is hypothesized that, in a similar way to what Dundon-Smith and Gibb (1994) predicted for the new Channel Tunnel link, the effects of the new line will not merely affect the north-east part of the Iberian Peninsula, but will also be significant over the whole territory, albeit unequally, according to the travel time of Iberian cities from the new line and their position with regard to. However, these effects must be different to those observed for the Channel link: in the first place, because Spain is not in an insular situation, although it should be borne in mind that trains currently waste time at the border (about 20 minutes) due to the change in track gauge, a delay that would be eliminated in future as the new line is to be built in standard track gauge; secondly, because Iberian urban agglomerations have less weight in the ensemble of the European Union than British ones, which suggests that the effects of the new line will be markedly asymmetrical (this being important for the Iberian peninsula, yet of little relevance to the rest of the European Union).

In order to define the study area, it should be borne in mind that much of the territory of the European Union (including cities such as London, Amsterdam or Brussels) will be less than 10 hours away from Madrid or Barcelona once the new line is built and connected up to the French TGV, so that apart from day services for short or medium distances, there is a possibility that night trains be put into service for longer links. For this reason, and in accordance with the available demand data, it would seem reasonable to extend the study to the whole of the territory of the European Union, with the exception both of the islands and Sweden, Finland and Greece. For these spaces, the benefits of the new line can be considered irrelevant at the outset on account precisely of their insularity (in the case of the former) or their great distance from the new line (in the case of the latter three countries), although they could nevertheless distort the values of certain accessibility indicators. Great Britain should logically be taken into account due to its relative proximity and to the fact that the Channel Tunnel has eliminated its erstwhile island condition. Consequently, the countries which will be taken into account are Spain, France, Portugal, Belgium, Holland, Luxemburg, the United Kingdom, Germany, Denmark, Austria and Italy, to which Switzerland must be added because of its geographical proximity and economic connections.

ACCESSIBILITY INDICATORS

There is a wide variety of indicators to measure accessibility (see for example Bruinsma and Rietveld, 1998). This variety responds to the numerous approaches as to the concept of accessibility. Usually, by accessibility, we mean "the ease with which activities can be reached from a certain place and with a certain system of transport" (Morris, Dumble and Wigan, 1978). At the regional, national or international levels, activities are particularly concentrated in the urban agglomerations, so that it would seem logical to measure accessibility with respect to such cities.

Most accessiibility measurements combine the travel cost *to*, and attractiveness *of*, different destinations in a single indicator (Geertman and Ritsema van Eck, 1995). Cost of transport is a measure of the effect of friction of the distance (the resistance to movement between two points). It can be expressed in different cost units, such as distance, time or generalised cost of transport. The capacity of attraction of urban agglomerations depends on their volume of economic activity. Given the available data, different indicators of capacity of attraction can be used, such as population, employment or income. Time is normally used as an indicator of friction of the distance and income or population as an indicator of capacity of attraction.

To carry out this study, I have selected three indicators which provide complementary information as to the problem of changes in accessibility conditions brought about by a new infrastructure, by adopting different approaches: locational (reduction of travel times), economic (changes in economic potential) and socio-economic (changes in the total number of population one can reach within a certain travel time limit).

Weighted average travel times

The weighted average travel time between each node and all urban agglomerations is calculated taking as weight the income of the centres according to the following:

$$L_i = \frac{\sum_{j=1}^{n} (T_{ij} \bullet M_j)}{\sum_{j=1}^{n} M_{j)}} \qquad 1$$

where:

L_i is the accessibility (location) of node i

T_{ij} is the travel time through the minimal-time route through the network between node i and urban agglomeration j (in minutes), and

M_j is the mass (income) of the destination urban agglomeration.

The income of the urban agglomerations is used as weight in order to value the importance of the minimal-time routes (Gutiérrez and Urbano, 1996; Gutiérrez, González and Gómez, 1996). The measure is not a gravity-based indicator (there is no distance-decay), so that, unlike economic potential, it does not place the emphasis on short distances. Thus, for example, in the economic potential model, the relation Madrid-Guadalajara could weigh more than the relation Madrid-Paris, for Guadalajara is much closer to Madrid than Paris. But it is quite clear that, from the European perspective, the first of these relations is irrelevant, whilst the second is indeed one of the key trans-European connections.

This average-distance-based indicator should be interpreted from the locational rather than the economic point of view. It expresses the relative location of each place and the extent to which a new infrastructure modifies this location by reducing access times to the main urban agglomerations.

Economic potential

The economic potential is a gravity-based measure, widely used in accessibility studies (see, for example, Harris, 1954, Keeble, Offord and Walker, 1988, Linneker and Spence, 1992, Smith and Gibb, 1993, and Spence and Linneker, 1994). It is a measure of the nearness or accessibility of a given volume of economic activity to a particular point/region and can be interpreted as the volume of economic activity to which a region has access, after the cost/time of covering the distance to that activity has been accounted for (Dunbon-Smith and Gibb, 1994). According to this model, the level of opportunity (accessibility) between a node *i* and a destination node *j* is positively related to the mass of the destination and inversely proportional to some power of the distance between both nodes. Its classical mathematical expression is as follows:

$$P_i = \sum_{j=1}^{n} \frac{M_j}{T_{ij}^{a}} \qquad 2$$

where
P_i is the economic potencial of node *i*
a is a parameter reflecting the rate of increase of the friction of distance (distance decay)
and the other terms are still known.

In this paper (as in most accessibility studies) the parameter value *a* used is 1. Using higher values than 1 means giving too much importance to relations over short distances (which would not seem appropriate when analysing the effects of a new infrastructure of a national and inter-national nature such as the line which is the object of this study) and it also means increasing the problem known as self-potential (see Frost and Spence, 1995 and Bruinsma and Rietveld, 1998).

When analysing the former indicator (weighted average travel times), it has been argued that in the evaluation of the impact of large transport infrastructures it would seem reasonable to point out the long distance effects. Yet from a merely economic point of view, there is no doubt that the economic effects of a new infrastructure are inversely related to the distance, so that in this context it would seem appropriate to use a gravity-based operationalization.

Therefore, the interpretation of the results provided by this indicator must be carried out from an economic viewpoint: the indicator measures the economic potential of each place in each of the scenarios considered and the changes in potential caused by the new infrastructure.

Daily accessibility indicator

This indicator consists of calculating the number of population or income that can be reached from a node within a certain travel time limit. The time limit is usually established in 3 or 4 hours, so that it is possible to go and return within the day and carry out an activity at the visit location (Lutter et al., 1992). The limit of 4 hours travel is considered as a critical cut-off point since it represents the likely limit of comfortable day return business traffic, although the limit of 3 hours is the likely cut-off point for major transfers from air to rail transport. A recent study by the Institute of Air Transport suggests a loss of 30-50% of air traffic for a 3-hour rail connection, 15-30% at for four hours and less than 20% at more than six hours (see Vickerman, 1995). On account of lack of space, in this paper the results will only be expressed in number of inhabitants within the travel time limit of 4 hours.

This measurement is particularly useful for calculating accesibility in business and tourist trips, for the need to stay overnight in the destination city means an important extra expense for both companies and individuals. In fact, the empirical evidence shows that new high-speed lines produce an increase not only in the number of travellers in the relations served by the line, but also in the proportion of those who return within the same day (Bonafous, 1987).

One should interpret this indicator from the social point of view, with obvious economic implications: in the context of the high-speed train, it provides the number of possible business contacts (for business trips) and the market potential (for tourist trips). This indicator measures how much population can be reached from a place (or can reach a place) in a certain travel time limit and the changes in accessible population brought about by a new infrastructure. The result are of the following type: from city A, within a time of four hours, 10 million inhabitants can be reached in the scenario “without the line” and 15 million in the scenario “with the line”, which means an increase of 5 million inhabitants.

MODELLING OF NETWORKS AND CALCULATION OF INDICATORS

To this purpose, a System of Geographic Information (ARC/INFO) is used, in which an intermodal network was represented with about 7000 arcs and 4000 nodes. The main focus of interest is logically the railway network, but the road network is also included, for this latter enables access to railway stations from places which have no station. Data of the railway- and road networks for the foreseen situation in 2005 and predicted population and income data for the main urban agglomerations in the same year were stored in the GIS.

When modelling the railway network, all lines at the inter-regional and international levels were taken into account. Stations at which long-distance trains stop were considered as nodes, as likewise railway crossings. For each arc on the railway network, the length, speed and travel time was registered. This travel time was calculated in terms of foreseen speeds for the 2005 scenario. Likewise, in a table of turnings, penalties times were recorded in order to simulate certain movements on the nodes, basically the change in track gauge and the change from road to rail mode.

A dense road network was also used in order to guarantee access to stations from places which are not directly served by the railway. The nodes on the road network were selected so that not only all places with a significant demand were included (in accordance with their population), but also a number of minor cities in order to cover the whole territory homogenously, to guarantee the necessary accuracy in mapping accessibility by using interpolation techniques. For each arc on the road network, the length, estimated speed according to type of infrastructure and travel time were also recorded. The new links foreseen in the Transeuropean Road Network Outline Plan were also taken into account, assuming that such links will be finished by the year 2005.

In accessibility calculations are necessary not only network data, but also population and income data of the destination centres. Only the 88 urban agglomerations with a population of over 300000 inhabitants in the study area were selected as destination centres. The population data of these agglomerations come from the official statistics of each country, whereas income was calculated on the strength of the population of each agglomeration and the per capita income region (NUT) in which each agglomeration is located. This latter variable was obtained on the basis of REGIO data of the European Union, which gives standardised data to this respect. For the year 2005 were predicted both population (based on former growth tendencies of agglomerations) and income (assuming an annual increase of 2%) of the selected urban agglomerations.

For each of the scenarios (2005 “with” and “without” the new line), minimal-time routes between each node and each destination city was calculated, bearing in mind the times associated with the arcs covered and the movements that have to be carried out on certain nodes. When the node of origin has a station, the travel time between this node and the destination city is equal to the sum of the travel times of the arcs on the railway network plus, where necessary, penality times for doing certain movements on the nodes of the railway network (change in track gauge and changes of train). When the node of origin has no station, access time by road to the nearest station was added and a penalization for the change from road to rail mode. Once the access times were obtained, the accessibility values were calculated and mapped.

IMPACT OF THE NEW LINE ON ACCESSIBILITY

Weighted average travel times

The new line will bring about a reduction of 25 minutes (about 5%) in the average travel times between the selected agglomerations. Logically, the greatest benefits were recorded in the Iberian Peninsula, for the new line offers its cities better access with each other and with cities in the rest of Europe; on the other hand, the improvements recorded in the rest of Europe are scant, for the new line only enables its cities to improve their connection with the cities in the Iberian Peninsula, these latter having relatively little weight with respect to the ensemble of the cities of the study area.

The greatest benefits logically occur in cities with a station on the new line, but the effects on the Mediterranean corridor are also important, as likewise on the corridor of the high-speed Madrid-Seville line. The agglomeration which obtains the highest time saving (160 minutes, which is equivalent to 22.0%) is Zaragoza. It should be borne in mind that Barcelona (with a 17.8% improvement) uses the least amount of kilometres on the new line in order to reach most European cities (situated on the other side of the broder) and that Madrid (with a 13.7% time saving) gains a few minutes in its relations with blue banana cities (Paris, London, Brussels, Amsterdam) due to the fact that this connection before the construction of the new line is made via the Basque Country and after via Barcelona with a considerable detour.

The cities served by the high-speed Madrid-Seville line will benefit not only from the new line, but also from the suppression of penalty times for changing trains (due to change in track gauge) that before had to be carried out in Madrid. They will have a percentage improvement around 15%, somewhat higher even than that of Madrid, above all because the need to change trains in Madrid will be eliminated. The cities of the Mediterranean corridor will also benefit considerably, for they will take advantage of the Tarragona-Perpignon stretch in their relations with most of the European urban agglomerations. The average saving of such cities as Valencia, Alicante and Murcia is around 109 minutes, which is equivalent to 13-14%. In the north, north-west and west of the Iberian peninsula, the benefits will be less. This is the case, for example, of Valladolid (4.5% improvement), La Coruña (2.7%), and Bilbao (2.0%), which will use the new line for their relations with cities located in the east (Barcelona, Marseilles, Milan), but for which the new line will not offer anything as regards their relatons with blue banana cities.

Over the border, the greatest benefits in absolute figures (21 minutes) are located on the natural prolongation of the line eastwards (south of France, Italy). In other directions the effects of the new line become weaker: 10 minutes for most German cities, 8.7 for Paris and British cities and Benelux, and only 4 for Bordeaux and Nantes. If time savings are measured in percentages, these will logically be lower for further cities within each of the forementioned directions. Thus, travelling eastwards, Marseilles (5.3%) will give an improvement higher than that of Naples (2.7%); the same thing occurs travelling north-east with Lyon (6.2%) as against Copenhagen (1.3%) or northwards with Paris (3.2%) as against Edinburgh (1.5%). However, in any case, the lowest values correspond to south-west France (0.9% in Bordeaux), where the new line hardly brings any benefit at all.

Economic potential

The average variation in the economic potential of the selected urban agglomerations (it only increases by 1.45%) is much less than the one which corresponds to the location indicator (travel times are reduced by 5%). This is due to the fact that the potential indicator is a gravity-based measure, so that most European cities located far from the new line undergo very little variation in their potential values.

In fact, changes in accessibility are concentrated on cities most directly affected by the new line to a greater extent than the former indicator. The city that most benefits from the new line is Zaragoza (37%), which is located very close in time to two large agglomerations such as Madrid and Barcelona and greatly improves its relations with cities located beyond the French border. Benefits are less for Barcelona (16%) and above all for Madrid (8%).

In relative figures, Madrid (8%) grows even less than Cordova (14%), Seville (13%) and Malaga (12%). This apparently anomalous situation is due not only to the fact that it is no longer necessary to change trains in Madrid, but also that self-potential in Madrid represents a very large part of the total potential (self-potential of all the cities is equal on both situations, “with” and “without” the new line). However, if we bear in mind the absolute values of differences, we observe that due to the distance decay, Madrid’s potential has a greater increase (603 million units) than those of Cordova (520), Seville (454) or Malaga (360).

We should also point out the benefits (around 10%) which the line brings to cities in the southern stretch of the Spanish sector of the Mediterranean arc, such as Valencia, Alicante and Murcia, which obtain better connections not only with Barcelona, but above all with many of the European cities located beyond the French border. In north and north-west Spain the changes are less. Thus, for example, Bilbao and La Coruña only record increases of 2.0% and 2.5% respectively.

Outside Spain, improvements in percentages are somewhat reduced, more so when their distance in time from the new line is greater. Both in Portugal (Lisbon, Oporto) and in the south of France (Toulouse, Marseilles, Toulon) potential increases higher than 2% are recorded. In French regions even further from Spain and in the north of Italy, the potential variatons are even around 1% and 2%. But in the rest of the study area, the changes are almost irrelevant (below 1% and even below 0.5% in the farthest regions).

Daily accessibility

With the building of the new line the average accessible population within the four-hour limit for the selected urban agglomerations rises from 20.7 to 21.1 million inhabitants, which means an increase of 1.64%. The main benefits of the new line are logically located along the Madrid-Barcelona corridor, but in in other parts of Spain and in southern France. It should not be forgotten that Barcelona is one of the chief metropolises of southern Europe and that it will be accessible in under 4 hours from most of the south of France. Logically, most European cities will record no benefit according to this indicator, which only reflects daily accessibility.

The increase in accessible population is particularly important in Barcelona (7.7 million inhabitants, which fundamentally corresponds to the population of Madrid, Valladolid, Marseilles and Toulouse). Zaragoza gains 2.7 million through improvements in its relations with Valencia, Seville and Valladolid. The increase in 3.2. million for Madrid, Murcia, Toulouse and Marseilles are due to the fact that with the new line they can reach Barcelona in under 4 hours. Finally, the 0.59 million increase in Valencia and Cordova is due to their improvements in travel time to Zaragoza.

Table 1: Accessiblity indicators for selected cities: changes brought about by the construction of the new line (units in minutes, thousends of ECUS of 1995 and thousends of inhabitans, respectively)

Cities	Average travel time		Economic potential		Daily accessibility	
	Difference	in %	Difference	in %	Difference	%
Alicante	109.1	13.5	412116	10.5	0	0.0
Amsterdam	8.7	2.7	41638	0.3	0	0.0
Barcelona	109.2	17.8	1084023	16.9	7778	138.9
Bari	20.9	2.1	27060	0.9	0	0.0
Berlin	10.2	2.4	28943	0.2	0	0.0
Bilbao	13.3	2.0	94655	2.0	0	0.0
Bordeaux	4.0	0.9	50396	0.7	0	0.0
Bruxelles/Brussels	8.7	3.1	48894	0.3	0	0.0
Córdoba	148.2	16.5	520222	14.7	596	8.0
Edinburgh	8.7	1.5	20567	0.3	0	0.0
Frankfurt	10.2	3.4	43838	0.3	0	0.0
Geneve	20.8	5.4	137180	1.6	0	0.0
Granada	69.5	6.8	152606	5.5	0	0.0
Grenoble	20.9	5.0	157068	2.2	0	0.0
Kobenhavn	9.9	1.2	13596	0.2	0	0.0
La Coruña	26.6	2.7	70304	2.5	0	0.0
Lisboa	31.7	2.5	50464	2.1	0	0.0
London	8.7	2.6	38567	0.2	0	0.0
Lyon	20.8	6.1	179346	1.7	0	0.0
Madrid	101.5	13.6	603228	8.4	3264	32.8
Málaga	148.2	14.3	24095	12.3	0	0.0
Marseille	20.9	5.2	218289	2.6	3264	19.2
Milano	20.9	3.9	70149	1.0	0	0.0
Murcia	109.1	13.1	381279	10.5	3264	48.0
Nantes	4.6	1.1	25898	0.3	0	0.0
Napoli	20.9	2.7	39784	0.9	0	0.0
Paris	8.7	3.2	65637	0.3	0	0.0
Porto	26.6	2.3	51339	2.3	0	0.0
Roma	20.9	2.9	45284	0.7	0	0.0
Sevilla	148.2	15.7	454796	13.0	945	13.3
Torino	20.9	3.8	79230	1.2	0	0.0
Toulon	20.9	4.7	169662	2.6	0	0.0
Toulouse	14.1	2.7	211008	3.5	3264	64.9
Valencia	109.9	14.8	526469	11.3	596	5.7
Valladolid	31.7	4.4	224828	4.7	4326	50.9
Wien	10.2	1.5	17343	0.2	0	0.0

Zaragoza	160.6	22.0	1574773	37.8	2761	28.4

INEQUALITY MEASURES

Finally, there is the question of whether the new line will contribute to increasing inequalities between European cities, or whether it will on the contrary favour a reduction in same. Increase or reduction in disparities between cities can be measured by the coefficient of variation. The changes on the coefficient of variation of the three indicators used clearly point in the same direction: the new line will reduce existing disparities by 1.87% in travel times, by 1.37 in economic potential and by 2.30% in daily accessibility (table 4). This evolution was predictable in accordance with the analysis of the spatial distribution of the effects of the new line, which basically favoured the Iberian Peninsula. And when a transport infrastructure mainly favours a peripheral space, it is obvious that it lessens the centre-periphery disparities.

Table 4: Changes on the coefficient of variation for selected accessibility indicators: urban agglomerations in the study area

Indicators	Scenario 2005		
	"Without" the new line	"With" the new line	Differences
Location	44.30	42.43	-1.87
Economic potential	41.90	40.53	-1.37
Daily accessibility	71.97	69.67	-2.30

However, if we change the scale and look merely at the impact of the new line on Spanish interior relations, the results are quite different (Gutiérrez and Jaro, forthcoming) (table 5). In all the selected indicators, the new line brings about an increase in the coefficient of variation, that is, an increase in the differences in the accessibility values of the ensemble of Spanish cities. This is not surprising given that the new line connects a number of cities to each other (as Madrid, Zaragoza and Barcelona) that at the national level are already highly accessible in the situation "without" the new line, and that these cities are those which most benefit from the new line, which logically results in an increase in disparities between cities.

Table 5: Changes on the coefficient of variation for selected accessibility indicators: Spanish cities

Indicators	Scenario 2005		
	"Without" the new line	"With" the new line	Differences

Location	28.20	33.15	4.95
Economic potential	46.36	49.75	3.39
Daily accessibility	63.70	67.25	3.55

Finally, if we once more change scale and consider exclusively the centres situated along the corridor Madrid-Barcelona-French border, the results are very different: the value of the coefficient of variation clearly drops in all the indicators (table 6). This is because, as we have already pointed out, the three indicators selected reflect the effects of a new infrastructure asymmetrically, so that the smallest cities on the corridor (less accessible than the large ones in the "without" situation") are those which obtain greatest improvements in accessibility from the the new line, above all in the indicators which express their results in units of activity (indicators of economic potential and daily accessibility).

Table 6: Changes on the coefficient of variation for selected accessibility indicators: cities along the corridor

Indicators	Scenario 2005		
	"Without" the new line	"With" the new line	Differences
Location	21.60	16.15	-5.45
Economic potential	46.81	28.34	-18.47
Daily accessibility	29.00	12.16	-16.,84

FINAL REMARKS

The new high-speed line will substantially modify the map of rail accessibility of the Iberian Peninsula, but will have a reduced effect at the European level. The average improvement in accessibility for the ensemble of European urban agglomerations is around 1%-2% (except in the location indicator, with 5%). However, the spatial distribution of the effects of the new line will logically be unequal. These will be important not only in the cities served by the new line (such as Barcelona, Madrid and Zaragoza), but also on the Madrid-Seville and Barcelona-Murcia corridors. Outside Spain, the areas which most benefit from the new line are the south-southeast of France and Portugal.

The three used indicators respond to different conceptualizations and offer complementary information about the issue accessibility. Logically the results are quite different: very concentrated effects in the daily accessibility indicator, less concentrated in the economic potential one and more dispersal in the location indicator (see maps).

According to the results obtained, everything seems to indicate that at the national level the new line will have polarized effects on the urban system, for the cities which have greatest increases in accessibility are already highly accessible in the “without the new line” situation. Nevertheless, both at the corridor and at the European level the effects will be balanced out: within the corridor because the small and medium-sized cities will obtain greater increases in accessibility than the large ones, which suggests that spreading processes for economic growth will be induced; and at the European level because better communication of Iberian cities with each other and with the central regions will result in a greater increase in accessibility of Iberian cities and therefore, in a reduction of centre-peripheral imbalances.

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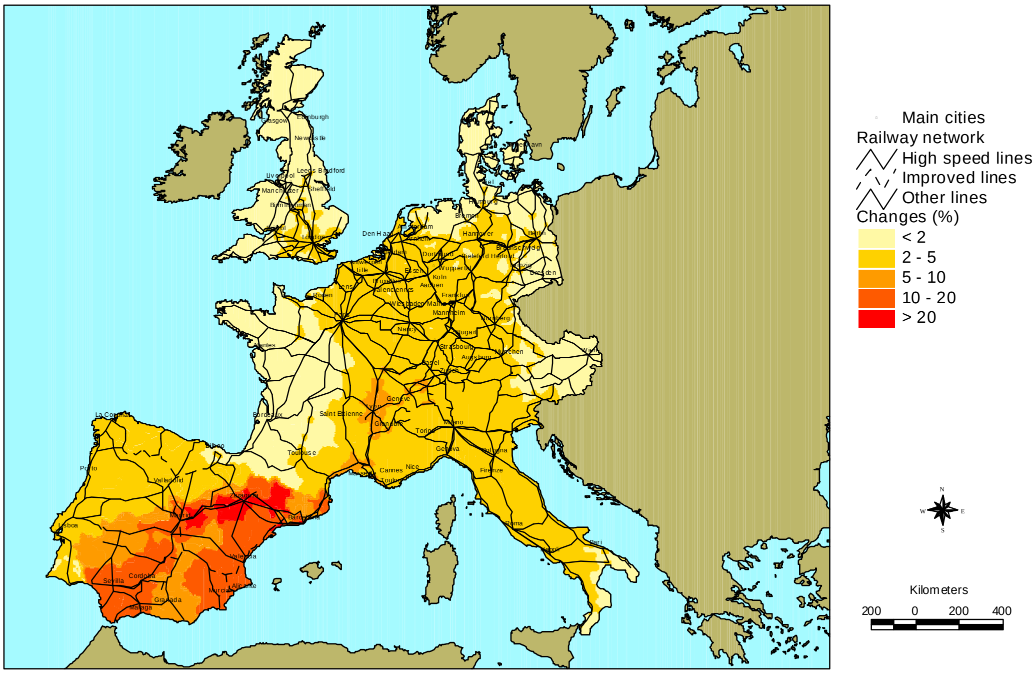
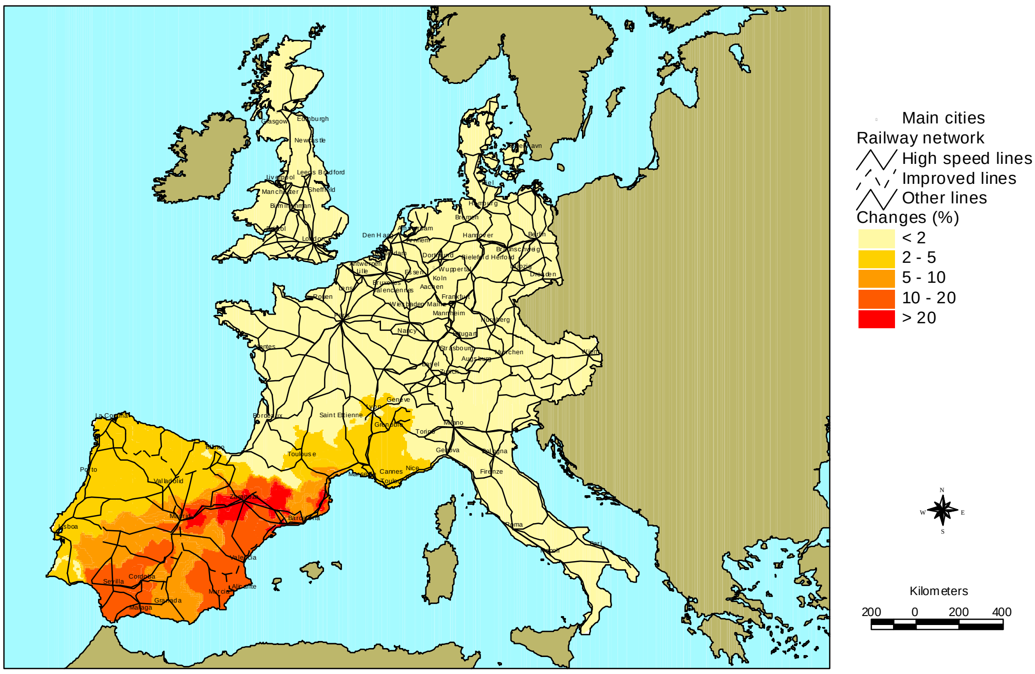
Location indicator



Economic Potential



Daily accessibility