TRANSPORT INFRASTRUCTURE ASSESSMENT: THE SPANISH INFRASTRUCTURE MASTER PLAN 2000-2007

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ABSTRACT

Spanish Infrastructure Master Plan 2000-2007 will lead to important changes in the structure of national transport network and its access to transeuropean networks. One of the key objectives of the Plan is to encourage national competitiveness, not only in the current European market, but also to face the imminent UE enlargement, which will intensify our peripheral position.

The projects included in the Plan will produce important changes in national territorial structure, transport costs, accessibility and environment. This paper focuses on the assessment of the impacts of land transport projects on accessibility.

Therefore, after a comprehensive review of the existing literature, a list of specific accessibility indicators is selected, classified into two groups: "absolute" indicators facilitate the comparison between different zones, to assess the impacts on territorial equity or the peripheral situation, comparing the situation "before" and "after" the implementation of the Plan. On the other side, "relative" type indicators eliminate the effect of the geographical situation, assessing the improvements produced in any specific location, independently from its geographical position.

Finally, maps with the results of the location accessibility indicator for road mode are shown, from which conclusions are drawn on the most benefited regions and corridors and the predicted changes in Spanish accessibility patterns, as well as an analysis of accessibility changes in terms of cohesion.

1. INTRODUCTION

Spanish Infrastructure Master Plan 2000-2007, co-ordinated by the Spanish Public Works Department, will include projects up to 103 million Euro, which represents an annual budget equivalent to 1.4% of Spanish GDP.

The high capacity road Program is up to 38.6% of the total budget of the Plan, and its key objectives include the enlargement of the high capacity network from 8,000 km to 13,000 km and to provide the network with a structure that facilitates its integration in the transeuropean road network. The rail Program represents 39.6% of the budget and will increase the length of

the high-speed rail network so that it will include 7,200 km in 2010, in order to reduce travel times significantly and increase demand for rail trips. Figures 1 and 2 show the situation in 2000 and the projects to be implemented in 2010, respectively, for road mode. Figures 3 and 4 show the high-speed rail network for the same time horizons, respectively.

Figure 1: High capacity road network 2000. Source: Spanish Ministry of Public Works

Figure 2: High capacity road network 2010. Source: Spanish Ministry of Public Works

Figure 3: High-speed railway network 2000. Source: Spanish Ministry of Public Works

Figure 4: High-speed railway network 2010. Source: Spanish Ministry of Public Works.

2. ACCESSIBILITY AND ITS ROLE IN ASSESSING TRANSPORT INFRASTRUCTURE INVESTMENTS

2.1 The role of accessibility

Transport demand is derived from the need to reach opportunities not available in the origin point, and any improvement on the transport system modifies the access to these opportunities. The main objective of transport infrastructure investments is to facilitate this access, and therefore, accessibility indicators are one of the most useful tools in its assessment.

In the first studies, accessibility was considered as a measure of separation between different locations, comparing pairs of points or one of them with the rest situated in a defined area. In the following studies, accessibility was also considered as the opportunity or possibility that a person or group has, in a certain location, to reach a pre-determined activity or group of activities. In recent studies, accessibility has been identified as the net benefit reached by a group of people deriving from having a certain location and being able to use a certain transport and land use system.

The concept of accessibility depends, therefore, on the existence of opportunities and the options provided by the transport system to reach them. One of the more suitable definitions of accessibility is the following: (Wegener et al., 2000):

"*Accessibility indicators describe the location of an area with respect to opportunities, activities or resources that exist in other areas or in the same area, where the term "area" can be a country, a city or a corridor*"

Transport infrastructure is one of the key factors influencing regional economic development (Biehl et al., 1986), although the relationship between them is becoming increasingly complex. The implementation of accessibility indicators allows the calculation and representation of the existing disparities between regions, and thus to justify, in case necessary, transport infrastructure investments in the lacking regions, as one of the instruments of Regional Policy.

Some critics at a European scale argue that many new connections do not link peripheral regions to the core but two central regions, and so reinforce their accessibility advantage. Some analysts argue that regional development policies based on the creation of infrastructure in lagging regions have nor succeeded in reducing regional disparities in Europe, whereas others point out that it has yet to be proved that the reduction of barriers between regions has disadvantaged peripheral regions (see Schürmann et al, 1997)

2.2. Classification of accessibility indicators

One of the existing classifications of accessibility indicators considered of interest relates to their degree of complexity (Spiekermann and Neubauer, 2002; Schürmann et al., 1997):

Simplest indicators only take account of the transport infrastructure existing in the area. Some examples are: total length of roads, highways or high-speed rail lines per capita, number of railway stations or links to highways, or travel time to the nearest high-level network node. These indicators provide quite a lot of information about the area, but do not reflect the fact that many of the destinations of interest may be outside it.

More complex accessibility indicators take account of the connectivity of the transport network by distinguishing between the network itself and the activities and opportunities that can be reached using it. These indicators always include in their formulation an impedance term expressing the ease to reach the destinations. Accessibility is expressed as the product of two functions: one representing the activities or opportunities to be reached (activity function) and the other representing the time or cost necessary to reach them (impedance function):

$$A_i = \sum_j g(W_j) \cdot f(c_{ij}) \qquad (1)$$

Where Ai is the accessibility of area i, W_j is the activity W to be reached in area j, and c_{ij} is the cost/time of reaching area j from area i. Functions g and f are called activity function and impedance function, respectively.

3. ACCESSIBILITY INDICATORS SELECTED TO ASSESS THE MASTER PLAN

3.1. "Location" indicator

This indicator calculates, for each node of the network, total travel time to a predefined set of destinations, using their total income as a weighting factor.

The formulation is the one that follows:

$$A_i = \frac{\sum_{j=1}^{n} (I_{ij} \cdot R_j)}{\sum_{j=1}^{n} R_j} \qquad (2)$$

Where:

i= origins of the trips
j= 1,n = destinations of the trips
I_{ij}= impedance: Minimum-path travel time (hours)
R_i= Total income of destination

The appropriateness of this formulation has been proved in earlier studies, as the Master Plan 1993-2007, and in other studies at a European scale. Other possibility is to use population as the weighting variable, obtaining similar results in most cases (Schürmann et al, 1997).

This type of indicators expresses a disutility, therefore, the higher the value of the indicator, the worst accessibility of the area. They are very easy to interpret, as they are expressed in simple units as travel time, and they allow calculating global travel time savings for each node to a set of predefined destinations. The main disadvantages are that they do not difference between nearby and far destinations, and that they don not reflect the improvements on the access to destinations not selected for the analysis.

3.2 "Network efficiency" indicator

This is a "relative" type indicator, which reflects the quality of the transport infrastructure in the relation between nodes, eliminating the influence of the geographical position. The relative accessibility of each node is calculated based on the quality of the infrastructures that connect it with the main economic activity centres.

The formulation of this indicator is as follows:

$$AR_i = \sum_{j=1}^{n} \frac{I_{ij}}{II_{ij}} \cdot R_j \qquad (3)$$

Where AR_i is the relative accessibility indicator of node i, and II_{ij} is the ideal impedance, expressed in hours.

Ideal impedance (II_{ij}), for road mode, is defined as the one corresponding to a highway following a straight line from each origin/destination, and for railway mode, as the one corresponding to a high-speed straight line rail line, without applying any penalty factors in both cases.

The ratio I_{ij}/II_{ij} is an index of the quality of the existing infrastructures between i and j, compared to an ideal network, and its value is always equal or higher than one. The closest to one is the indicator, the better quality the network has. This formulation has been used before in other studies (MOPT, 1993; Gutiérrez et al., 1992)

Therefore, this indicator provides information about accessibility conditions of each node with respect to an ideal situation, eliminates the effect of the node's geographical position, and highlights the effect of the infrastructure.

3.3. "Daily accessibility" indicator

This indicator is aimed at studying one-day round trips, mostly business trips, in which the maximum travel time is estimated between three and five hours. It is also an "absolute" type accessibility indicator. This type of indicators is frequently used in European scale projects (Spiekermann and Neubauer, 2002; Schürman et al., 1997).

Its formulation is the one that follows:

$$A_i = \sum_j R_j \cdot f(t_{ij}) \qquad (4)$$

Where $f(t_{ij}) = 1$ *if* $t_{ij} \leq t_{máx}$

0 *if* $t_{ij} > t_{máx}$

This type of indicators is easy to understand, as it is expressed in familiar units, but it also has the same disadvantage that "location" accessibility indicators: they depend heavily on the selection of the travel time threshold from which destinations are not taken into account.

3.4. Potential indicators

The economic potential model is based on the gravitational models. This type of indicators is based on the assumption that the attraction of a destination increases with its size and decreases with distance or travel time/cost. The size of the destination is usually measured in terms of GDP, population or regional income.

This type of indicators has been used as a peripherality index with GDP or regional income as the destination activity (Keeble et al., 1988; Copus, 1999). They are "absolute" accessibility indicators, which take account of geographical position.

There are many formulations of this type of indicators, depending on the selection of the activity and impedance functions. In this study, the one selected is the following:

$$A_i = \sum_{j=1}^{n} \frac{R_j}{I_{ij}} \qquad (5)$$

This type of indicators has the advantage that they are founded on behavioural principles, as they give a higher weight to the relations with nearby destinations than with far ones. Their main disadvantage is that they are not measured in familiar units, so they are usually standardised to make them easier to understand.

4. IMPLEMENTATION OF ACCESSIBILITY INDICATORS

After the selection of indicators is completed, the process of its implementation in the Geographical Information System starts with the creation of the geodatabase.

The first task includes the creation of the spatial database, with the modelling of the transport system -road and rail networks- and the territorial system -socio-economic data-. After this data are implemented in the GIS, it is possible to calculate travel times across the network [1] and to use them, combined with the socio-economic data[2], to calculate the value of the selected accessibility indicators, in each node of the network. The GIS software allows creating high quality maps showing the calculated values for the two time horizons considered: 2000 and 2010.

From the analysis of these maps and their corresponding numeric values, conclusions can be drawn on the territorial distribution of the improvements introduced by the Master Plan. Each indicator provides complementary approaches to the concept and measurement of accessibility. The following figures show the results obtained for the location accessibility indicator[3], for road mode, and for the two time horizons considered: 2000 and 2010.

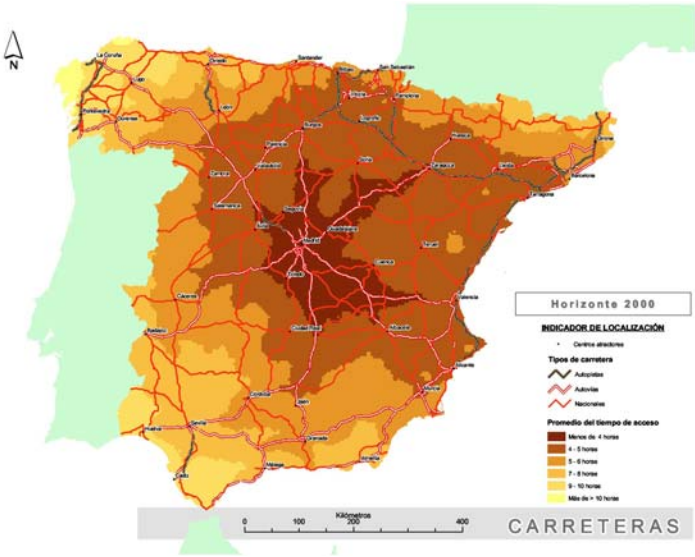

Figure 5: Location accessibility indicator (2000). Road mode

[1] The complete process to calculate travel times is not detailed here. Basically, they are calculated using minimum-path algorithms, and applying penalty factors, e.g. when crossing mountainous areas.
[2] According to the formulation of the indicators selected, Gros Domestic Product and population are the only necessary data.
[3] As all the results obtained cannot be shown in this paper, the location accesibility maps have been selected because of their ease of interpretation. The same process developed for this type has been followed with the rest of the indicators implemented.

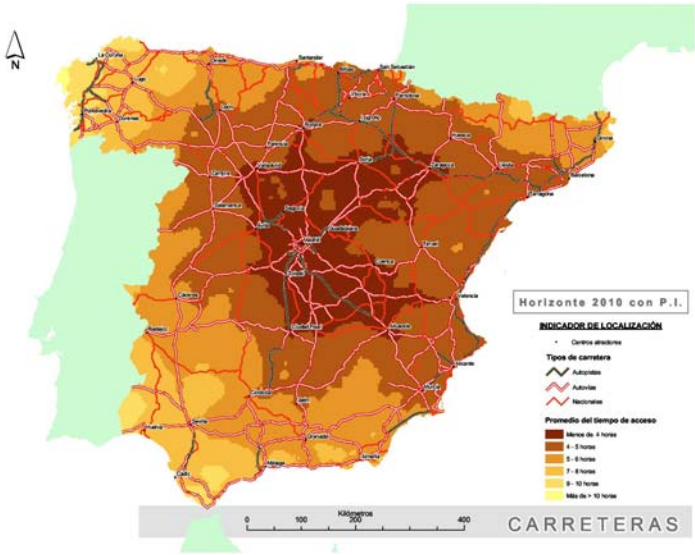

Figure 6: Location accessibility indicator (2010). Road mode

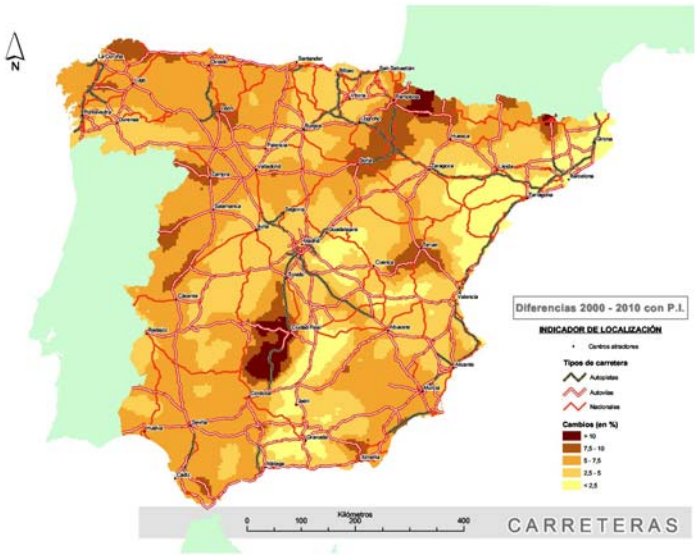

Figure 7: Improvements in location accessibility indicator (%). Road mode.

The situation in 2000 (Figure 5) shows both a clear core-periphery pattern and a radial pattern, with the core in Madrid, with the axis with higher accessibility values corresponding with the main highways that connect it with the rest of the national territory. As this indicator weights destination according to their income, it is logical that the distribution is distorted, as richest regions are located in the north and east of the country.

The situation in 2010 (Figure 6) maintains the same patterns, but the area with the best results suffers a distortion not only in the radial direction, but in cross directions. Therefore, one of the main objectives of the Plan is achieved: to promote the development of a continuous network, instead of improving the access to Madrid, with the implementation of new high capacity roads as Autovía de la Plata or the axis Badajoz- Ciudad Real-Valencia. After the implementation of the Plan, the regions with larger travel times are still concentrated mainly in Galicia, west Andalucía and the French border, although they have improved their situation significantly. As the location indicator weights travel time with destination income, regions with larger geographical distance

from the main economic centres (mainly Madrid) show worst travel times, because the location highly influences its accessibility results.

To assess the impacts of the Plan in terms of accessibility, the situation "before" and "after" the Plan implementation is analysed, using the calculated values of the accessibility indicators for 2000 and 2010. Figure 7 shows the improvements in accessibility (location indicator) produced by the Plan, for road mode, expressed in percentage of 2000 values.

In general terms, most important improvements are concentrated in the axis Madrid-Toledo-Ciudad Real-Córdoba and Madrid-Soria-Pamplona, followed by river Duero and Autovía de la Plata corridors, along with Galicia, Asturias, Murcia and West Andalucía regions. The main projects included in the new high capacity road network are concentrated in these areas, as it was shown in Figure 2.

Figure 8 shows the improvements in terms of reduction of average travel times to the main activity centres, and percentage of population involved. As it can be seen from this figure, there is a sensible reduction in the percentage of population with travel times above 8 hours: from a 4,7% of population in 2000 to only 0,8% in 2010. It is also remarkable that the percentage of population with average travel times below 5 hours-value near 200 mean- increases from 31,7% to 37,4% in 2010. A more detailed analysis on the distribution of accessibility improvements across population and related equity issues, is included in next section.

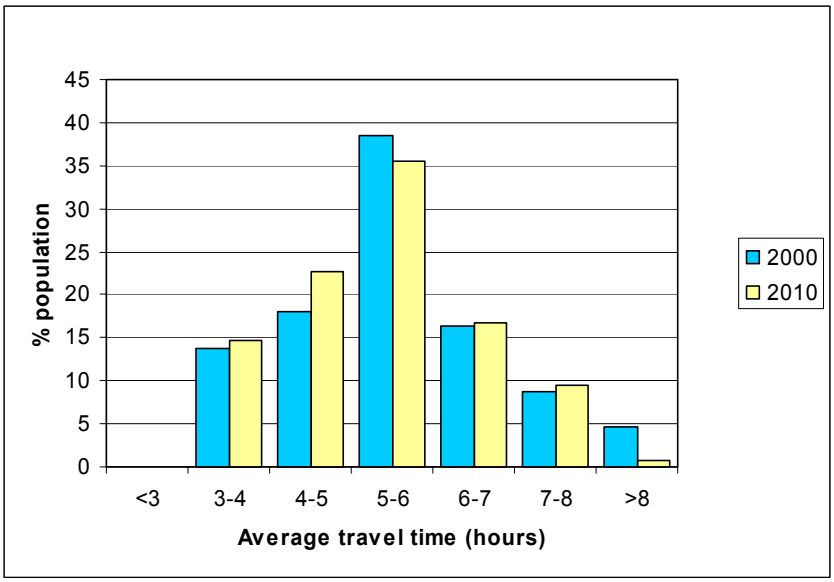

Figure 8: Location accessibility indicator vs. % population in 2000 and 2010. Road mode.

5. ANALYSIS IN TERMS OF COHESION

Changes in accessibility introduced by the Master Plan can be analysed in terms of cohesion, that is, it can be assessed whether after the Plan implementation disparities in accessibility between regions are increased or reduced. Therefore, a selection of cohesion indicators from the existing literature has been calculated from the values obtained of the accessibility indicators.

Table 1 summarizes the results obtained on cohesion indicators for road mode[4]. To facilitate the analysis, values obtained for the three accessibility indicators have been standardised by their mean.

Type of indicator	Time horizon	Max.	Mean	Min.	Coef. of variation	Ratio max/min	Ratio 5max./5 min.	Spearman correlation coefficient	GINI coef.
Location	2000	149,8	100	65,5	20,4	2,29	1,93	0,989	0,480
	2010	147,6	100	68,4	20,0	2,16	1,87		0,476
Daily accessibility	2000	178,0	100	22,3	38,9	7,98	4,54	0,993	0,394
	2010	164,1	100	26,0	36,2	6,31	4,30		0,399
Potential	2000	390,2	100	51,1	56,7	7,63	3,87	0,964	0,568
	2010	380,5	100	52,3	54,4	7,27	3,79		0,559

Table 1. Cohesion indicators calculated. Road mode.

Basic statistic measures, as maximum, minimum, the coefficient of variation or the ratios between best and worst regions give a first idea of the change in the distribution of accessibility between regions.

Values corresponding to the location indicator show a distribution more concentrated near the mean, while the spread of daily accessibility and potential indicators is much wider. In general terms, there are slight reductions in the coefficient of variation and the ratios max/min calculated.

The Spearman correlation coefficient compares two rank orders of regions by decreasing or increasing accessibility, giving information about the changes in the rank positions of the regions. The development of the new infrastructures included in the Road Program of the Plan has relatively little influence on the position of the regions, as the Spearman coefficient shows very close to one values.

Finally, the Lorenz curve-from which the GINI coefficient is derived- compares a rank-ordered cumulative accessibility distribution of regions with a distribution in which all regions have the same accessibility. Lorenz curves obtained for 2000 and 2010 are very similar, and consequently the corresponding GINI coefficients. There is a slight convergence of accessibility for the location and daily accessibility indicators, and a very little divergence for the potential indicator.

Finally, after analysing all the cohesion indicators presented above, the results obtained show that the Master Plan has very slight effects on cohesion, measured in terms of accessibility improvements, for road mode.

6. CONCLUSIONS AND FUTURE DEVELOPMENTS OF THE RESEARCH PROJECT

[4] Cohesion indicators are not calculated for the network efficiency accessibility indicator, because its formulation eliminates geographical position and only reflects the quality of the network.

After the implementation of the selected accessibility indicators for road mode, conclusions are drawn on the situation "before" and "after" the implementation of the Master Plan 2000-2007, as well on the distribution of accessibility improvements between regions. It is also important to analyse whether these improvements contribute to reduce disparities between regions or if they make them larger. The main conclusion obtained on this issue is that the projects included in the Road Program of the Plan have very little effects on the distribution of accessibility between regions. At this stage of the research, it can be stated that the changes on accessibility in terms of cohesion are very slight.

The research project in which this paper is based has just developed its first Report. Accessibility indicators for rail mode are now been implemented in the GIS, and will be included in next report. Next tasks of the research will include an integration of the different impacts measured by other members of the research team, which include mobility effects, with the development of a transport demand model, and environmental effects, developing a Strategic Environmental Assessment of the Plan.

After the assessment of the Plan at a national scale, the next phase of the research project will include the application of the developed methodology at a European scale, aimed at studying its effect on the peripheral situation of Spain, which will change with the imminent enlargement of the EU, as its centre will move to the East.

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