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Assessment of Cross-Border Spillover Effects of National Transport Infrastructure Plans: An Accessibility Approach

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ABSTRACT *Traditional transport infrastructure assessment methodologies rarely include the full range of strategic benefits for the transportation system. One of these benefits is the contribution to cross-border integration, critical for the European integration process. However, this is a key issue in strategic planning and decision-making processes, as its inclusion may increase the probability of large-scale transport infrastructure projects being funded. This paper presents a methodology for the measurement of the contribution of transport infrastructure plans to European integration. The methodology is based on the measurement of the improvement in network efficiency in cross-border regions of neighbouring countries, via accessibility calculations in a Geographical Information System support. The methodology was tested by applying it to the ambitious road and rail network extensions included in the Spanish Strategic Transport and Infrastructure Plan (PEIT) 2005–2020. The results show significant and important network efficiency improvements of the PEIT outside the Spanish border. For the road mode, while the Spanish average accessibility improvement accounts for 2.6%, average improvements in cross-border regions of France and Portugal are of 1.8%. And for the rail mode, the corresponding Spanish value is 34.5%, whereas in neighbouring regions it accounts for 20.2%. These results stress the significant importance of this strategic benefit and the consequent need for its inclusion in strategic planning processes. Finally, the paper identifies the potential of the methodology when applied at different administrative levels, such as the local or state levels.*

Introduction

The effects of large-scale transport infrastructure projects, such as national transport infrastructure plans, spread outside the limits of the corresponding nation, generating 'spillover effects' in neighbouring regions. These effects are related with the contribution of transport infrastructure to cross-border integration with neighbouring nations. In strategic European transport policy documents (see e.g.

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European Commission, 2006) this contribution is acknowledged as playing a critical role in the success of the European integration process (Banister *et al.*, 1999; Peters, 2003).

This critical issue has not been translated into national official assessment methodologies, mainly for subsidiarity reasons, and also because there are significant differences in national assessment methodologies among European Union (EU) nations (Bristow and Nellthorp, 2000; Grant-Muller *et al.*, 2001). Moreover, at the national level, despite the fact that the scientific literature calls for the integration of spillover effects in any integrated assessment methodology, their inclusion is uneven and scarce, notwithstanding that the assessment of spillover effects may justify politicians to enhance its acceptability. Therefore, the development of assessment methodologies for the evaluation of spillover effects is an area where further research efforts are needed.

Accessibility-based approaches are increasingly used by transport planners as valuable spatial impact analysis tools, mainly because of the improvement of data processing capabilities of Geographical Information Systems (GIS), along with the development of methodologies to derive synthetic accessibility indices (see e.g. Martín *et al.*, 2004; Martín and Reggiani, 2007). However, the potential of accessibility analysis for transport infrastructure assessment methodologies is not fully exploited (Halden, 2003; Geurs and van Wee, 2004).

In this context, the paper fills the existing gap in assessment methodologies with the development of a methodology for the assessment of spillover effects of national transport infrastructure plans. The suggested approach is based on the calculation of network efficiency accessibility improvements in cross-border regions of neighbouring countries.

The structure of the paper is as follows. The section 'Spillover Effects' starts with a brief review of the concept of spillover effects and relates them with *cross-border integration* effects. Subsequently, the potential of accessibility indicators to measure spillover effects is justified in section 'The Potential of Accessibility Indicators'. The complete methodology is described in section 'Methodology for the Assessment of Cross-Border Spillover Effects'. The methodology is then tested in next section 'Application of the Methodology' with its application to the Spanish Strategic Transport and Infrastructure Plan (PEIT) 2005–2020, using the network efficiency indicator. Finally, the main conclusions and further research directions are included in the last section.

Spillover Effects

The Concept of Spillover Effects

One of the first steps in the assessment of any transport infrastructure project is the definition of the area in which its effects are to be assessed. In the majority of cases, these effects will extend outside the limits of this area, generating *spillover effects* (Boarnet, 1998; Pereira and Roca-Sagalés, 2003; López-Bazo *et al.*, 2004).

The concept of spillover effects is closely linked with that of *network effects* (van Exel *et al.*, 2002), more commonly used in the literature. These effects take into consideration that the addition or improvement of a single link of the transport network can significantly affect demand on competitive and complementary links, therefore changing interconnections and the resulting patterns of network usage and performance.

Network effects measure the contribution of a certain infrastructure improvement to the transport network as a whole, and therefore are related with concepts such as 'network synergy' (Capello and Rietveld, 1998), 'network integration' (Banister *et al*., 1999; Peters, 2003) or 'network efficiency' (Gutiérrez and Monzón, 1998). However, despite the clear evidence of their significance, much further empirical work is needed before all forms of network effects that appear in the wider economy can be captured by spatial models. Promising tools for assessing large projects or programmes are still under development, such as Spatial Computable General Equilibrium models, which are in their infancy and for which there is still substantial scope for further development (Tavasszy *et al*., 2004; Laird *et al*., 2005).

The importance of assessing network effects is obviously higher at strategic planning levels. For example, at the EU level, the existence of network effects is the basis for transport initiatives such as the trans-European transport networks (TEN-T) and certain trans-border projects (van Exel *et al*., 2002; Roy, 2003; Tavasszy *et al*., 2004; Schade, 2006).

Spillover effects are also related with *distributive* impacts, i.e. impacts that do not focus on the magnitude of the effect, but on its distribution among regions or groups of individuals (Lakshmanan *et al*., 1997; López *et al*., 2008). Improvement of transport infrastructure leads to a reduction of transport costs which may give rise to substantial redistribution effects among economic groups and also among regions (Rietveld and Nijkamp, 1993). This issue is linked with the trade-off between efficiency and equity objectives that arises when planning transport infrastructure investments. Depending on the scale chosen, the assessment of spillover effects may give an estimate of the *transfers* of costs and benefits between different regions and/or groups of individuals (Pereira and Roca-Sagalés, 2003; López-Bazo *et al*., 2004) and therefore may draw conclusions on the distributive impacts of the investment under consideration.

The Relationship between Spillover and Cross-Border Integration Effects

The general concept of spillover effects can be analysed from the particular perspective of a national transport plan of a EU Member State, where the study area is usually set up to cover the corresponding national territory of the country under consideration. The quality of the infrastructure network of each Member State has important implications from a strategic European perspective (Banister *et al*., 1999). In other terms, when a national transport plan is implemented, spillover effects will be generated outside the frontiers of this country, mainly in cross-border regions of neighbouring countries (López-Bazo *et al*., 2004). However, the predominance of national perspectives in transport planning has motivated the existence of 'missing networks' at the EU level (Nijkamp and Vleugel, 1995; Peters, 2003), among which several cross-border links are included. These missing networks exist because "transportation systems are developed in a segmented way, each country seeking for its own solution for each transport mode without keeping an eye on the synergetic effects of a coordinated design and use of advanced infrastructures" (Maggi *et al*., 1992, p. 316).

Moreover, it is widely argued that the European economy will remain critically dependent on well-functioning networks as catalysts for future economic developments (Nijkamp and Vleugel, 1995). The integration of new areas through the establishment of new links or networks can promote regional development, but these should be accompanied by a development of regional and national networks (Maggi *et al*., 1992).

Recent studies have made estimations extending the infrastructure to include the geographically adjacent regions, as it is expected that the positive external effects—especially in the case of roads and railways—will be of greater intensity in relation to the nearest regions. For example, for the case of Spain, Cantos *et al*. (2005) estimated not only the effect of a region's own transport infrastructures on its productivity, but also the spillover effects caused by the infrastructures of the most 'closely related' regions. They used data from 1965 to 1995 transport infrastructure on the productivity of Spanish regions. They found that the elasticity grew from 0.042 to 0.146 when spillovers were taken into account. Another interesting approach is included in the research by Pereira and Roca-Sagalés (2003), in which the impact of public capital formation on private input was evaluated. They found that aggregate effects are due in almost equal parts to public capital and spillover effects measured as the public capital of the rest of the regions. These results reflect that transport infrastructures generate positive external effects beyond the regions where they are located.

Following this rationale, in most EU-related studies, these spillover effects are linked with the concepts of 'European added value' (van Exel *et al*., 2002), 'community component' (Roy, 2003) or the contribution to 'cross-border integration' (López, 2007). This latter term is the one that will be used in this paper. Moreover, from a financing perspective, the measurement of the contribution to cross-border integration is crucial for the appraisal of certain transport infrastructure projects which would not be profitable if only the effects inside the national frontiers are assessed (Roy, 2003). Moreover, recent research conducted at the EU level evidences that spillovers may not be fully picked up if networks are "artificially truncated at regional or national boundaries" (Tavasszy *et al*., 2004; Laird *et al*., 2005). The existence of these strategic benefits would therefore provide the justification for national authorities to apply for EU Funds, such as in the case of the projects included in the TEN-T (van Exel *et al*., 2002; Schade, 2006).

The most relevant European transport policy documents address the above issues and reflect the need that EU Structural and Cohesion Funds co-finance those transport infrastructure projects, such as the TEN-T, which have a European interest. These projects are mainly concentrated in peripheral and structurally lagging regions, on the assumption that an enhanced efficiency of the transport infrastructure network may result in increased economic activity (Schade, 2006).

In particular, the recently published Mid-Term Review of the European Commission's 2001 Transport White Paper (European Commission, 2006) states that:

> By co-financing transport infrastructure, the Structural and Cohesion Funds will continue to help the regions lagging behind in terms of economic integration or suffering from structural handicaps. The outermost regions suffer from a strong accessibility deficit not only in relation to the continental internal market but also in their own hinterland. Transport policy instruments and state aids could be used to reduce the effects of remoteness on their competitive position and to improve connections with the rest of the EU and with neighbouring third countries (…)

> (…) considering the limited resources available, the EU will need to focus its co-financing from the TENs budget on the critical border-crossing sections and the other main bottlenecks on the priority projects. Moreover, Member States should optimize the use of the EU Structural and Cohesion Funds to support the financing of transport infrastructure. EU funds will be concentrated on those projects which offer the greatest added value for Europe and where active collaboration with national and other financing organizations is guaranteed.

The above arguments justify the need for a new appraisal methodology capable to take into account cross-border spillover effects. In order to move one step forward in this research direction, our methodological approach takes advantage of the unexploited potential of accessibility measures. The next section provides evidence on this potential.

The Potential of Accessibility Indicators

Applications of Accessibility Indicators in Appraisal Methodologies

There is a wide spectrum of existing formulations which attempt to measure the concept of accessibility. Still today the concept of accessibility is still evolving with new approaches that continuously enrich the concept with new connotations.[1] Recent research has identified the role and application of robust quantitative approaches, allowing accessibility measures to take a more central role within transport appraisal (Halden, 2003; Geurs and van Wee, 2004). Accessibility analysis has major presentational advantages by describing the impacts of transport investment in terms that people can easily understand, which is an added value, given the increasing influence of public opinion on these issues.

Accessibility indicators have a wide potential for their application in strategic planning processes (see e.g. Gutiérrez and Monzón, 1998; Baradaran and Ramjerdi, 2001; Geurs and van Wee, 2004; Martín *et al*., 2004). However, it is widely claimed that this potential of accessibility analysis for transport planning purposes is not fully exploited (Geurs and Ritsema van Eck, 2003; Halden, 2003). Indeed, although the concept of accessibility has been widely reported in geographical studies, it has rarely been used for policy evaluation. It had very little practical impact on policies (Handy and Niemeier, 1997; Halden, 2003), despite recent interesting attempts to draw formulations related to wider policy objectives.

Accessibility is an important determinant of regional macroeconomic changes; transport infrastructure investments can affect the pattern of interregional linkages, which can provide accessibility benefits similar to those of agglomeration economies (Weisbrod and Treyz, 1998). Changes in generalized transport costs and accessibility are therefore used as input variables to measure impacts of transport infrastructure on spatial economic development, in terms of productivity changes and (re)location behaviour (Rietveld, 1994). For example, Forslund and Johansson (1995) assessed production effects of transport investments using regional accessibility values as arguments of a general production function. They found a consistent correlation between these production effects and the results from cost-benefit analysis (CBA) assessments of a set of 53 investment alternatives in the Swedish road system. Another relevant study is the one conducted by Linneker and Spence (1996), who found that accessibility changes caused by the construction of the M25 motorway were positively related to changing levels of economic development.

However, the use of accessibility indicators in order to measure spillover effects is still in its infancy. The research conducted by Gutiérrez *et al*. (2007) is one of the most interesting attempts so far to measure and monetarize spatial spillovers. In their study, the distribution of accessibility benefits is used to obtain a measure of the extent that the investments in the motorway network in a given region produce benefits in other regions. Their method can be used in order to find a new assignment of the total costs of the investments among regions.

Given the above advantages of accessibility analysis, one would expect that accessibility indicators were fully integrated in conventional appraisal methodologies, such as CBA or multicriteria analysis (MCA). However, the use of accessibility indicators is mostly restricted to support research studies and policy recommendations (Geurs and Ritsema van Eck, 2003; Halden, 2003), and has not yet been included in national official assessment methodologies of EU Member States. This is mainly due to the perceived complexity of their formulations and the risk of double counting of effects (Beuthe, 2002). In this context, the integration of accessibility measures as input variables of CBA and MCA frameworks constitutes a current research challenge (Beuthe, 2002; Halden, 2003; López, 2007).

The Measurement of Accessibility

Each of the formulations of accessibility indicators is particularly suited to address a certain transport planning problem. However, the selection of the appropriate indicator for a particular case is a complex task. In general there is no single best ‘ideal’ indicator, but it is argued that the analysis is enriched if a set of indicators is computed and their results analysed in a complementary way (see e.g. Gutiérrez, 2001; Martín *et al*., 2004; Martín and Reggiani, 2007). Among the existing classifications, travel cost, potential, cumulative opportunities and network efficiency indicators are the most commonly used in recent literature (López *et al*., 2008). They are briefly described in what follows.

Travel cost indicators are widely used in accessibility studies (Gutiérrez, 2001; López *et al*., 2008). Among them, the location indicator is of special interest. It calculates a weighted average travel time from each node to a set of destinations, according to the following formulation (Gutiérrez *et al*., 1996):

$$L_i = \frac{\sum_{j=1}^{n} I_{ij} \cdot P_j}{\sum_{j=1}^{n} P_j} \tag{1}$$

where L_i is the accessibility (location) of node i, I_{ij} is the impedance: travel time between nodes i and j, and P_j is region’s j population (or another variable representing the attractiveness of j).

Gravity-based indicators are other type of commonly used accessibility measures. This is the case of the *potential indicator*, in which the opportunities (accessibility) for interaction between nodes are positively related to the mass of the destination and inversely proportional to some power of the distance between both nodes. A commonly used formulation is included in Equation (2):

$$Pot_i = \sum_{j=1}^{n} \frac{P_j}{I_{ij}^{\alpha}} \tag{2}$$

Cumulative opportunities indicators estimate accessibility in terms of opportunities available within predefined limits of travel time (or distance) (Handy and Niemeier, 1997). An example is the daily accessibility indicator, in which this limit is usually set up between three and four hours, so that it is possible to travel to a certain city, conduct business there and return within the day. Its formulation is as follows:

$$D_i = \sum_{j=1}^{n} P_j \cdot \delta_{ij} \tag{3}$$

where D_i is daily accessibility of node i, $\delta_{ij} = 1$ if $I_{ij} < 3$–4 h, and 0 otherwise.

*Network efficiency accessibility indicator*s measure accessibility from a completely different approach. They measure, for each origin-destination (*i*-*j*) pair, a weighted mean of ratios between travel time using the network (I_{ij}) and an 'ideal' travel time (II_{ij}), measured as 'as the crow flies' travel time using an ideal transport infrastructure. Its formulation is as follows (Gutiérrez and Monzón, 1998):

$$E_i = \sum_{j} \frac{\frac{I_{ij}}{II_{ij}} \cdot P_j}{\sum_{j} P_j} \tag{4}$$

where E_i represents network efficiency accessibility of node i.

Methodology for the Assessment of Cross-Border Spillover Effects

Spillover effects, measured in terms of accessibility improvements, can be evaluated from different perspectives, mainly following the formulations described in subsection 'The Measurement of Accessibility'. The first step of the methodology consists of selecting the accessibility formulation—or the set of them—to be computed, which is intimately linked with the perspective under which spillovers are to be measured.

The necessary accessibility calculations are subsequently made with the support of a GIS, in the following three stages:

Stage 1: Definition of the Study Area

This stage includes the delimitation of the study area, which includes both the national territory of the plan under consideration and the cross-border regions in neighbouring countries. The area of the neighbouring country to be included has an influence in the results, as the improvements in accessibility are lower as the cross-border area increases. Therefore, in this stage the definition of the limits of the study area should be agreed between planners and decision-makers.

The level of aggregation and the zonification is also defined in this stage. This is needed to select the centroids both for the origins (*i*) and destinations (*j*) for the accessibility analysis. The set of origins *i* includes the centroids located in cross-border regions of neighbouring countries, while the set of destinations *j* includes both these centroids and national ones. Hence, benefits accruing outside the national boundaries, i.e. spillover effects, are accounted for.

Stage 2: Implementation of the Transport and Socio-economic System in the GIS

In this stage, each of the centroids *i* of the study area defined above is characterized in terms of its transport and socio-economic data. Ideally, the level of zonification should be similar in the national area and the areas in neighbouring countries. However, the quality, accuracy and availability of national data are frequently better than those of neighbouring countries. These data limitations frequently force transport planners to use more aggregated data and lower zonification levels in neighbouring countries.

The transport system is modelled in a vectorial GIS, resulting in an intermodal graph containing the road and rail networks. For each arc on the road network, the length, estimated speed according to type of road and resulting travel time are also recorded (for more details, see Gutiérrez and Monzón, 1998; Martín *et al*., 2004). For the rail mode, each arc is given a commercial speed according to both infrastructure and quality of service characteristics.

Stage 3: Accessibility Calculations

The next step after the input database is stored in the GIS consists of the calculation of the road and rail travel times between each *i-j* pair. These travel times, along with population destination data, are subsequently introduced in Equation (4) to obtain each node accessibility value.

Finally, the accessibility values of each origin centroid are computed and stored in the GIS. The contribution to cross-border integration is measured as a population-weighted aggregated value of the percentage accessibility improvements neighbouring regions. These improvements are considered as an index of the contribution of the plan to cross-border integration. The methodology is tested in the following section by applying it to the Spanish PEIT 2005–2020.

Application of the Methodology

Spanish Strategic Transport and Infrastructure Plan 2005–2020

The Spanish PEIT 2005–2020 includes an ambitious extension of the Spanish high capacity land transport networks. The PEIT objectives have a strategic nature and they include the enhancement of the transport system's efficiency and its general sustainability, the contribution to social and territorial cohesion, and the promotion of economic development and competitiveness.

The PEIT network extension includes the construction of 5000 km of high capacity roads (HCR) and 6000 km of high-speed rail (HSR) lines, which amounts to €32.105 billion and €83.450 billion, respectively. The HCR and HSR network extensions planned in the PEIT are shown in Figures 1 and 2, respectively.

Due to Spain's status as an EU 'cohesion country' in the 1980s and 1990s, with GDP per capita below 75% of EU average, it received substantial support from the EU Structural and Cohesion Funds for infrastructure development. This was

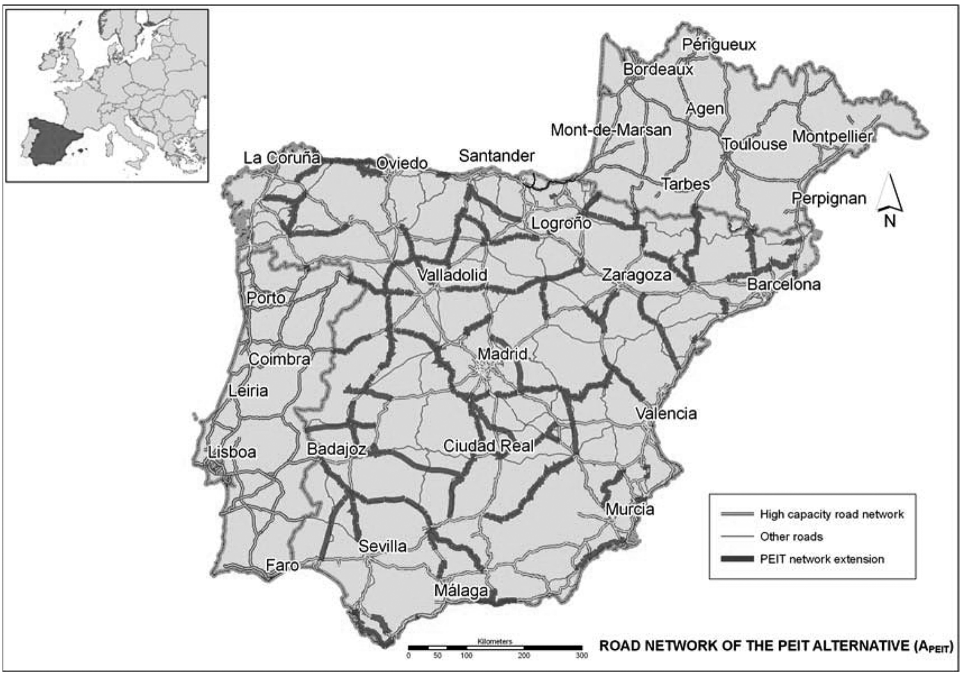

Figure 1. Road network of the alternative A_{PEIT}

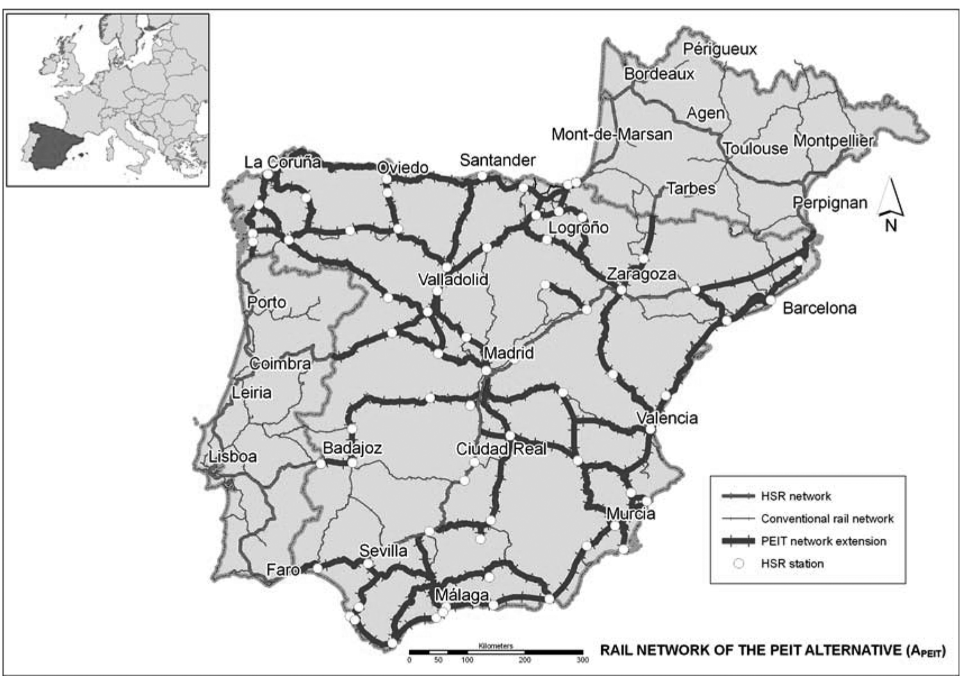

Figure 2. Rail network of the alternative A_{PEIT}

particularly the case for transport, in which Spain received a third of the total EU investment in improving the transport network over the periods 1994–1999 and 2000–2006, contributing on average some 20–30% of the Spanish Ministry of Public Works and Transport infrastructure expenditure. These investments were mainly used for the extension of the Spanish HCR and HSR networks, as part of the priority projects of the TEN-T. The result is that Spain has reduced significantly its disparities in network endowment with the rest of the EU. This fact, along with the progressive convergence of Spanish GDP per capita values, has meant that this financial support will be substantially reduced in the near future.

However, there is an increased need for additional capacity of the Spanish transport infrastructure network. This is mainly because the growing integration of European economies has caused international transit traffic in Spain to rise significantly in recent years. Moreover, there is also potential for expansion of the traffic flows between the North of Africa and Europe, which inevitably cross the Spanish mainland.

Case Study Application

In this case study application, our approach consists of measuring accessibility improvements using the network efficiency formulation, included in Equation (4). This indicator has been previously used for the assessment of national Master plans (Gutiérrez and Monzón, 1998; López, 2007; López *et al.*, 2008) and constitutes a useful planning tool to evaluate disparities of transport network stock at the regional level. Hence, following this approach, spillovers are measured in terms of the reduction of transport infrastructure needs in neighbouring regions.

The fact that the results offered by most accessibility indicators, such as travel cost or potential indicators, are heavily influenced by the geographic position of the nodes, and therefore makes these measures unsuited for determining the transport infrastructure needs of each region. The formulation of the efficiency indicator neutralizes the effect of the geographic location, and allows making judgements on the relative 'ease of access' (i.e. network efficiency) of each location. In other terms, the results from this indicator highlight the infrastructure effect from that of having a peripheral geographic location.

Moreover, the term efficiency embraces different concepts, such as competitiveness, network efficiency, regional development, economic development or growth. The efficiency of transport links between major economic activity centres is considered as one of the factors determining competitiveness. These activity centres may be located inside or outside the national boundaries; therefore the improvement of cross-border links is frequently included as a policy goal for improved competitiveness, particularly in European peripheral countries, such as Spain or Portugal. Cross-border cooperation is intended to develop cross-border economic and social centres through joint strategies for sustainable territorial development (Peters, 2003; European Commission, 2006).

The assessment of spillovers is carried out on the basis of the comparison between the 'construction alternative' (A_{PEIT}) and the 'do-nothing alternative' (A_0). Cross-border integration effects of the PEIT are calculated as a percentage change in network efficiency accessibility of neighbouring regions, as shown in Equation (5):

$$CB_{PEIT} = \frac{\left[\sum_i E_i \frac{P_i}{\sum_i P_i}\right]_0 - \left[\sum_i E_i \frac{P_i}{\sum_i P_i}\right]_{PEIT}}{\left[\sum_i E_i \frac{P_i}{\sum_i P_i}\right]_0} .100 \quad (5)$$

in which E_i, representing the network accessibility value of each node i in cross-border regions of neighbouring countries, is computed using Equation (4).

The accessibility calculations were made using a network accessibility analysis GIS toolbox (Mancebo, 2006). The general methodological stages explained in the previous section are given as theoretical background for the case study application which follows next.

Stage 1: Definition of the Study Area

The study area basically comprises the Spanish mainland and its corresponding cross-border regions in neighbouring countries, which include Portugal and the three southern French NUTS-2 (Nomenclature of Territorial Units for Statistics, defined by the Statistical Office of the European Communities, i.e. EUROSTAT) regions. The study area and the corresponding aggregation level used (municipalities in Spain, districts in Portugal and departments in France) are represented in Figure 3.

Stage 2: Implementation of the Transport and Socio-economic System in the GIS

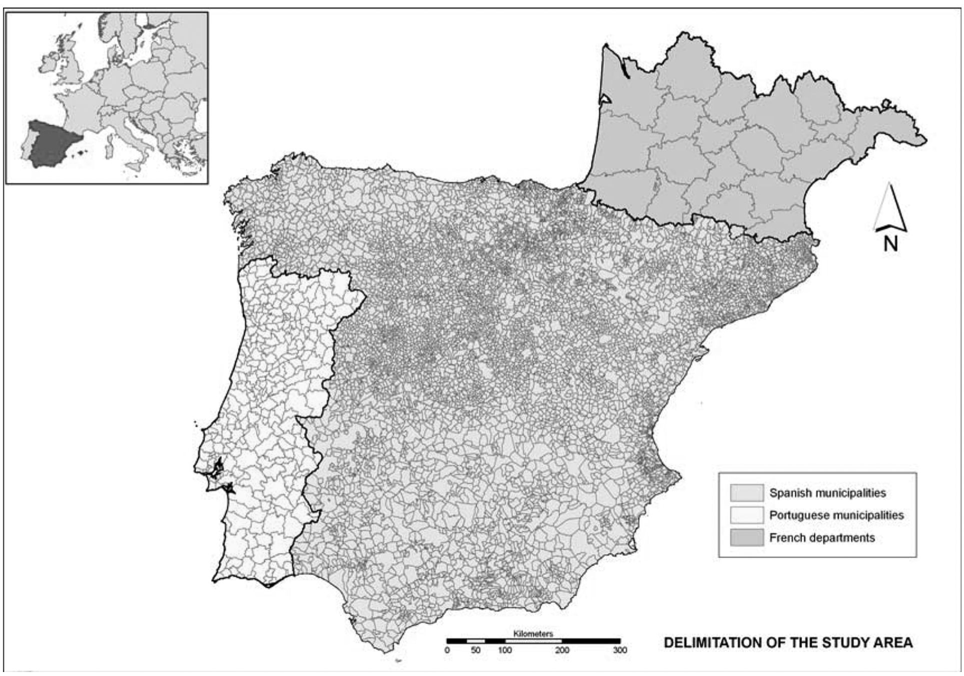

Figure 3. Study area and zonification

Transport system

In order to calculate accessibility values, a dense intermodal (road and rail) network was modelled with the support of a GIS; in this case the ArcGis software was used. The road and rail networks of the PEIT alternative are shown in Figures 1 and 2, respectively.

Accessibility values are obtained for each node of the network, which coincide with the nodes of the road network, which is nearly 12 000 km. Using interpolation techniques, aggregated NUTS-5 values in Spain and NUTS-3 values in Portugal and France are derived from node values.

The first task consisted of modelling the road network of the do-nothing alternative (A_0). A vectorial GIS was used, in which the network is modelled as a graph with a set of nodes and arcs. For each arc on the road network, the length, estimated speed according to the type of road (following Gutiérrez, 2001; Martín *et al*., 2004; Holl, 2007; López *et al*., 2008 these speeds were 120 km/h for highways, 110 for expressways, 90 for interregional roads and 80 for other roads) and resulting travel time were also recorded.

The use of free-flow speeds is a commonly used procedure (Linneker and Spence, 1996; López *et al*., 2008). Ideally, the calculation of travel times should take into account congestion levels of the network. However, data on congestion are not available at the national level. Moreover, a national travel demand model is not available for Spain, although it is one of the research priorities of the Ministry of Public Works. Hence, congestion expressed as traffic link loads cannot be taken into account. To compensate for this, so-called 'agglomeration effects' were introduced representing speed penalties—of 50 km/h—in the surrounding areas of large agglomerations. This is a common practice in similar Spanish studies for the estimation of congestion effects (Martín *et al*., 2004; Holl, 2007; López *et al*., 2008). The implementation of the PEIT will have an effect on congestion levels, as it will transform the radial pattern of the HCR network into a grid cell, and long-distance traffic will therefore select itineraries which do not cross major agglomerations.

For the rail mode, each arc is given a commercial speed according to both infrastructure and quality of service characteristics. Rail network modelling tasks are significantly more complex than those of the road mode, as it is necessary to include track gauge (Iberian/UIC) data, the location of the stations and frequency of service information in order to calculate travel times, as described in López (2007), which is not possible to detail in this paper for space reasons.

Land transport infrastructure networks in Portugal and France correspond to the estimates of the European Commission for 2020. This way the effects from the Spanish network extension can be isolated from those derived from the development of socio-economic variables and the infrastructure extension in neighbouring countries in the period 2005–2020.

Socio-economic system

The population is the selected variable to measure each destination's attractiveness in the accessibility model. The population for Spain and cross-border regions for 2020 has been estimated on the basis of prognosis of available historical data series. The information sources used were the corresponding three national statistical institutes. In the three countries, population data correspond to prognosis based on past trends of these variables for 2020, based on linear regression models.

In Spain, the selected destination centres correspond to the centroids of the approximately 8000 municipalities of the Spanish mainland. Centroids in Portugal and the three southern French regions were included as destination centres at a more aggregated level, namely the 278 municipalities in mainland Portugal and the 19 departments in the three southern French regions. These are shown in Figure 3.

In the accessibility calculations with origins in Spain, populations in France and Portugal have been reduced by a factor of 0.25 to take into account that destinations in neighbouring countries are visited less than national ones. The value for this reduction factor is the one used in similar studies (Gutiérrez and Monzón, 1998; Martín *et al*., 2004; Holl, 2007; López *et al*., 2008).

Stage 3: Accessibility Calculations

In this stage, the accessibility values of each origin centroid i are computed, using Equation (1). Intermediate calculations include the measurement of each i-j travel time, using minimum-path algorithms embedded in the GIS. Subsequently, following Equation (2), the cross-border integration index of the PEIT is computed as the percentage improvement of the construction alternative (A_{PEIT}) with respect to the do-nothing alternative (A_0).

For clarity reasons, the results were calculated independently for road and rail modes. Therefore, the analysis of results described below is split in the two corresponding subsections.

Road mode

Figure 4 (left) and Figure 5 (top) represent relative percentage improvements in network efficiency accessibility values in Portugal and French cross-border regions, respectively, due to the completion of the PEIT, for the road mode.

It is beyond the scope of this paper to analyse comprehensively the spatial distribution of the resulting changes. However, some general considerations can be made. First, the key issue that arises when interpreting the maps is that the spatial pattern followed by relative improvements is a result of both the planned cross-border links included in the PEIT and, to a lesser extent, the network distance to most important destinations.

On the one hand, in Portugal (left, Figure 4), since the northern and southern links (via Porto and Faro, respectively) already existed in the do-nothing alternative, these are the regions with lower benefits. In contrast, the central Portuguese regions, such as Guarda, Castelo Branco, or Portalegre, are the links which benefit most from the new cross-border links. The values obtained in each Portuguese district capital, in both alternatives, and the corresponding percentage improvements are included in Table 1 and are coherent with what the maps have pointed out. Percentage changes vary from the 4.10% improvement achieved by Portalegre to the 1.15% obtained by Beja. In summary, the resulting value of population-weighted average accessibility improvement in Portugal is 2.03%.

On the other hand, in the French case (top, Figure 5), given that the highway connection with Perpignan already existed in the do-nothing alternative, lower percentage increases concentrate in the eastern part of the French territory. This means that, as we move westwards, higher accessibility improvements are

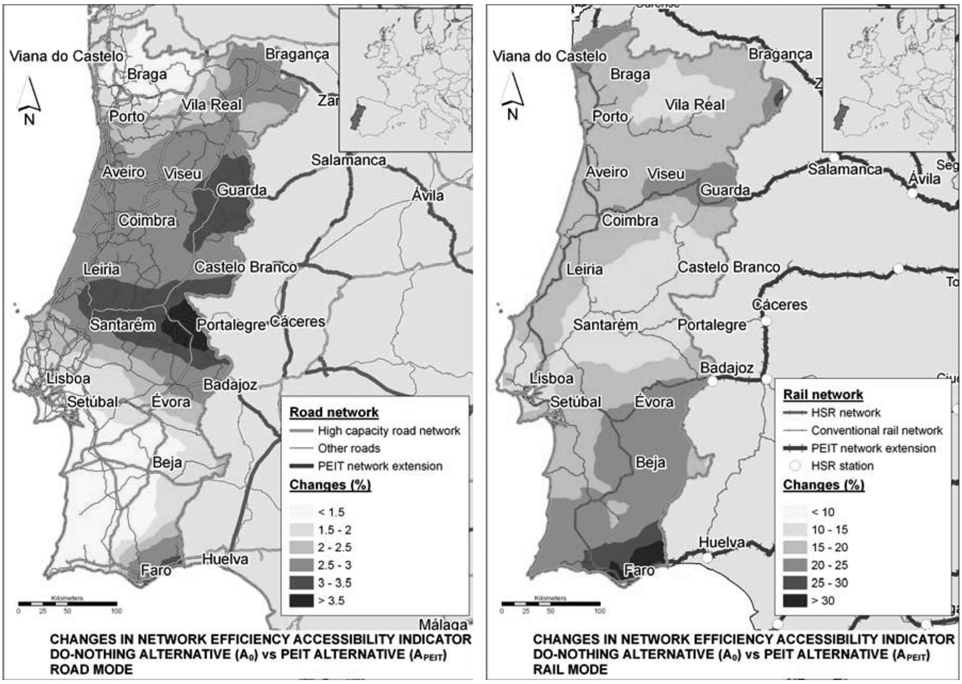

Figure 4. Network efficiency improvements in Portuguese cross-border regions – (left) *road* and (right) *rail* modes

achieved. Moreover, accessibility improvements are progressively reduced with the distance to the frontier. Table 1 includes the network efficiency results obtained in French NUTS-3 centroids in both alternatives, as well as the percentage change between them. Indeed, it can be observed that lower (below 1%) percentage changes concentrate in eastern departments capitals, such as Ales, Mende, Nimes, Montpellier or Perpignan. Higher percentage increases do not surpass the 2.60% value recorded in Pau, with the lowest value (0.45%) being recorded in Ales. In summary, the resulting value of population-weighted average accessibility improvement in France is 1.48%.

After this initial assessment of accessibility benefits, and following Equation (2), the contribution of the PEIT (CB_{PEIT}) to cross-border integration is computed as a population-weighted average percentage change in the network efficiency accessibility indicator. This average was computed for both Portuguese and French territories, resulting in an aggregated value of the indicator of $CB_{\mathrm{PEIT}} = 1.80\%$.

An important conclusion can be drawn at this point. If the same indicator is computed, the resulting average network efficiency improvement of Spanish regions is 2.6%, as detailed in previous studies (López, 2007). This means that the 1.80% average network accessibility improvement in cross-border regions corresponds to a relatively high value, if compared with the 2.60% value obtained in the Spanish territory.

Rail mode

Figure 4 (right) and Figure 5 (bottom) represent relative percentage improvements in network efficiency accessibility values in Portugal and French cross-border regions, respectively, due to the completion of the PEIT, for the rail mode. The

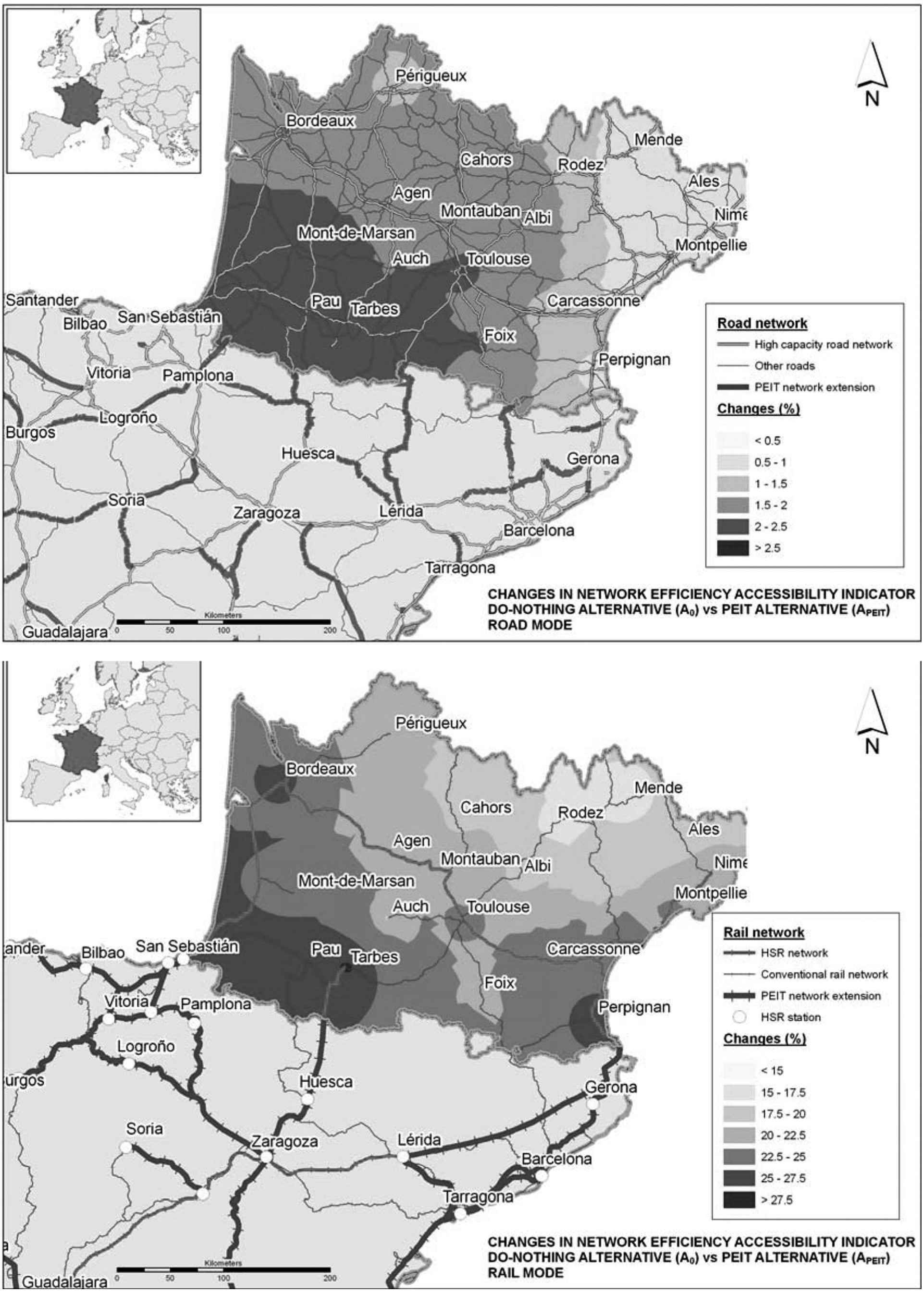

Figure 5. Network efficiency improvements in French cross-border regions – (top) *road* and (bottom) *rail* modes

interpretation of the resulting values requires a combined analysis of each centroid's population, its starting situation in terms of accessibility, and its proximity to new HSR stations. Although this analysis is beyond the scope of this paper, general considerations can be made, similarly to the road mode.

Table 1. Network efficiency accessibility (E) in the do-nothing alternative (E_0), the PEIT alternative (E_{PEIT}) and % change – Road mode

Portugual				France			
Name	E_0	E_{PEIT}	Change (%)	Name	E_0	E_{PEIT}	Change (%)
Aveiro	1.363	1.327	2.64	Agen	1.328	1.307	1.64
Beja	1.333	1.317	1.15	Albi	1.367	1.342	1.85
Braga	1.369	1.350	1.41	Ales	1.357	1.351	0.45
Bragança	1.363	1.320	3.18	Auch	1.360	1.333	1.96
Castello Branco	1.464	1.421	2.94	Bordeaux	1.272	1.250	1.72
Coimbra	1.363	1.325	2.77	Cahors	1.378	1.357	1.57
Évora	1.338	1.313	1.82	Carcassonne	1.336	1.320	1.20
Faro	1.286	1.250	2.80	Foix	1.355	1.326	2.16
Guarda	1.420	1.374	3.30	Mende	1.409	1.397	0.84
Leiria	1.339	1.298	3.07	Montauban	1.339	1.312	1.98
Lisboa	1.329	1.313	1.23	Mont-de-Marsan	1.349	1.320	2.18
Portalegre	1.421	1.363	4.10	Montpellier	1.262	1.256	0.52
Porto	1.370	1.335	2.56	Nimes	1.257	1.251	0.49
Santarém	1.332	1.297	2.63	Pau	1.347	1.312	2.60
Setúbal	1.308	1.291	1.26	Périgueux	1.350	1.333	1.30
Viana do Castelo	1.362	1.341	1.50	Perpignan	1.300	1.292	0.60
Vila Real	1.428	1.395	2.31	Rodez	1.384	1.364	1.49
Viseu	1.428	1.387	2.87	Tarbes	1.376	1.346	2.20
				Toulouse	1.297	1.268	2.21
Portuguese average			2.03	French average			1.48
Portuguese and French average (CB_{PEIT})							1.80
Spanish average							2.60

Starting with the Portuguese results, in this case, the location of HSR stations is a key factor influencing the final results. Indeed, it can be observed in Figure 4 (right) that the centroids in which a HSR station is not planned, such as Portalegre or Castello Branco, suffer from lower accessibility gains. Moreover, the effect of the new links spreads through the corridors of the already existing HSR network. The corresponding values obtained in Portuguese district capitals are included in Table 2. The average population-weighted accessibility improvement in Portugal is 17.23%.

In the French case (bottom, Figure 5), and as happened in Portugal, the proximity to the stations of the HSR network is one of the main factors determining the final percentage improvement. This is reflected in the higher percentage gains, in some cases above 25%, which are located in the regions with a better connection with the stations of the three cross-border planned links (through both frontier extremes and the one connecting with Tarbes). These observations are verified with the numerical results included in Table 2. Indeed, Bordeaux, Pau, Tarbes and Perpignan appear as the capitals with higher percentage increases (in all cases above 25%), while capitals located far from the planned HSR links, such as Rodez or Mende, have lower accessibility increases, with values around 15%. The resulting value of the average population-weighted accessibility improvement in southern France is 23.51%.

The contribution to cross-border integration is computed, similarly to the road mode, as a population-weighted average percentage change in the network

Table 2. Network efficiency accessibility (E) in the do-nothing alternative (E_0), the PEIT alternative (E_{PEIT}) and % change – Rail mode

Portugal				France			
Name	E_0	E_{PEIT}	Change (%)	Name	E_0	E_{PEIT}	Change (%)
Aveiro	3.833	3.030	20.95	Agen	3.459	2.667	22.91
Beja	3.598	2.686	25.34	Albi	3.980	3.238	18.64
Braga	4.667	3.868	17.10	Ales	3.211	2.591	19.31
Bragança	6.853	5.817	15.11	Auch	4.694	3.809	18.84
Castello Branco	5.311	4.599	13.41	Bordeaux	2.911	2.118	27.23
Coimbra	3.775	2.952	21.80	Cahors	3.872	3.149	18.69
Évora	3.721	2.888	22.39	Carcassonne	3.281	2.467	24.81
Faro	3.592	2.437	32.16	Foix	4.466	3.538	20.78
Guarda	4.215	3.202	24.03	Mende	4.226	3.613	14.49
Leiria	3.832	3.058	20.21	Montauban	3.502	2.725	22.19
Lisboa	4.619	3.920	15.12	Mont-de-Marsan	4.077	3.096	24.06
Portalegre	4.849	4.124	14.94	Montpellier	2.843	2.177	23.42
Porto	5.610	4.804	14.36	Nimes	2.851	2.227	21.89
Santarém	4.560	3.881	14.90	Pau	4.238	3.076	27.41
Setúbal	4.369	3.650	16.46	Périgueux	3.608	2.909	19.37
Viana do Castelo	3.751	2.887	23.03	Perpignan	3.152	2.285	27.51
Vila Real	3.902	3.151	19.23	Rodez	4.238	3.567	15.84
Viseu	4.473	3.567	20.27	Tarbes	4.496	3.200	28.82
				Toulouse	3.299	2.480	24.82
Portuguese average			17.23	French average			23.51
Portuguese and French average (CB_{PEIT})							20.21
Spanish average							34.52

efficiency accessibility indicator, following Equation (2). This average has been computed jointly for both Portuguese and French territories, resulting in a value of the indicator of CB_{PEIT} = 20.21%. As happened with the road mode, the value obtained confirms the significant spillover effects in neighbouring countries due to the extension of the Spanish HSR network, when compared with the 34.52% improvement of Spanish regions.

The analysis of the above results allows detecting the investments included in the PEIT that maximize cross-border integration effects. These should concentrate in those 'missing links' connecting with major agglomerations in the neighbouring countries. For the road mode, the completion of the Lisboa-Cáceres-Madrid corridor appears as the most relevant investment for the Portuguese neighbours, whereas for the French regions, the links crossing the Pyrenees on its western side result in higher spillovers. For the rail mode, the connection of the Spanish and the Portuguese HSR networks through the Sevilla-Faro corridor appears as the one resulting in higher spillovers for the Portuguese neighbours, whereas the completion of the Barcelona-Perpignan and the crossings through the Vasque Country and Huesca result in similar accessibility benefits for the French cross-border regions.

The detailed results obtained for the road and rail modes and a comprehensive analysis of these differences can be found in López (2007). However, it is worth pointing out here that the rail percentage change (20.2%) is significantly higher than that of the road mode which is 1.8%. The main causes for this phenomenon are the differences between the initial situation of both networks and the higher differences between HSR and conventional rail speeds, when compared to those of highways and conventional roads.

However, the large differences between road and rail percentage improvements do not allow drawing conclusions of a higher effectiveness of road versus rail improvements. On the contrary, rail investments would appear as less effective than road ones following a CBA approach, mainly due to their higher construction costs and lower demand, along with the frequent inaccuracy of these estimations (Skamris and Flyvbjerg, 1997). Moreover, in the case of Spain, the output elasticity of rail projects is smaller than that of road projects (Cantos *et al*., 2005).

Implications for the Appraisal of Transport Infrastructure Plans

The aim of the planning exercise carried out in this paper is to provide evidence on the relevance of the spillover effects that the improvement of the Spanish transport network generates in neighbouring countries. Unfortunately, there is no general agreement on the relevant framework or appropriate methodology for the consideration of these cross-border effects in the decision-making process. We believe the solution would require a political decision on a balanced distribution of investment costs between the governments of Spain and neighbouring countries, with the financial support of the EU.

Despite the above remarks, in order to fully exploit the potential of the methodology suggested in this paper, the next research task requires its integration in an appraisal framework. This is a current research topic under development (see e.g. Tavasszy *et al*., 2004; van Exel *et al*., 2004; Laird *et al*., 2005).

Promising research directions point to the definition of appraisal models in which a CBA is supplemented with a MCA. This is the case of the research work by Salling *et al*. (2007), for the assessment of the Øresund Fixed Link, in which a computable general equilibrium (CGE) model was used in order to obtain an estimate of the socio-economic value of the wider economic effects. Our research is currently focused on further developments of strategic appraisal frameworks, as described in López (2007). This research work developed a MCA methodology to assess national transport infrastructure plans, in combination with a CBA. The MCA comprises a set of assessment criteria, which were defined by a group of experts in the field of transport infrastructure, in accordance with strategic policy objectives. The MCA included the following criteria: (1) network efficiency, (2) cross-border integration, (3) regional cohesion, (4) social cohesion, (5) global warming, and (6) habitat fragmentation. The performance of each alternative in the cross-border integration criterion is measured following the methodology described in this paper, which allowed testing its consistency. In order to calibrate criteria weights a survey among policy-makers and relevant stakeholders—based on the Analytical Hierarchical Process—was carried out. The calibration showed that the weight attached to the cross-border integration criterion was equivalent to a 14% to the total 100% of the six assessment criteria. This MCA framework was applied for the case study of the Spanish PEIT. Our current research is focused on the application of this MCA methodology to a set of scenarios for the development of the Spanish transport network, as well as to national transport plans of other EU countries.

Conclusions and Further Research

The assessment of cross-border integration effects of transport infrastructure plans is important from a strategic transport planning perspective. In a European context, this contribution is critical for the success of the European integration process which is currently underway. This paper has suggested a methodology for the strategic assessment of cross-border spillovers of transport infrastructure plans. We believe that the proposed methodology will serve in the process of large transport investment decision-making and may, with its transparency and descriptive nature, help in the consensus building process.

The methodology has been tested with its application to the Spanish PEIT. This application has made it possible to determine the improvement in network efficiency allocated in neighbouring regions of Portugal and France. These improvement values have resulted in relatively high levels if compared with the ones obtained in the Spanish territory. They correspond, for the road mode to a 1.8% increase, compared to an increase of 2.6% in Spain; whereas for the rail mode they amount to a 20.2%, when compared to a 34.5% average Spanish improvement.

A current research challenge is to agree on the relevant framework or appropriate methodology for the consideration of cross-border effects in the decision-making process. There is a need to arrive at a consensus among EU Member States on integrated appraisal frameworks to support policy-making at strategic levels. Clearly, much remains to be done before harmonized procedures throughout the EU are agreed in relation to the application of impact modelling tools, the definition of impact indicators and the design of common appraisal methodologies.

Moreover, it would be necessary to have indicators measuring the distribution of benefits among groups of individuals, regions or sectors (López *et al*., 2008). A critical element here is that the spatial structure of the network (morphology) is to a large extent responsible for geographically discriminating effects (Lakshmanan *et al*., 1997). This is a largely under-researched area which needs to be explored more thoroughly, in which the possibilities of accessibility indicators should be fully exploited. Other research perspectives include the integration of the accessibility model with a Land Use and Transport Interaction model or with a CGE model, in order to assess wider socio-economic effects and their spatial distribution. Other research directions are related with introducing modifications in the case study application in order to assess the sensitivity of the resulting spillover effects. These mainly refer to changes in the formulation chosen to measure accessibility and in the extension of the cross-border area.

The methodology could also be validated with historical data on the evolution of network efficiency accessibility and economic development variables in Spain and in neighbouring regions. This validation would complement other studies carried out for the case of Spain, such as the study on historical accessibility data by Holl (2007), or the research work by Cantos *et al*. (2005) and Pereira and Roca-Sagalés (2003), which conclude that, although there is clear evidence of the importance of public infrastructure on economic development, the output elasticity presents a high degree of variation.

The main conclusion of this study is that accessibility benefits located outside the borders of the country under consideration should not be left out of the planning process. They have shown to constitute important additional benefits, which should justify a co-financing of the corresponding transport infrastructure investments. In the PEIT case, this co-financing may be sponsored by the EU Structural and Cohesion Funds, or even by funds from the Ministries of Public Works of neighbouring countries. The paper also highlights the transferability of this methodology to lower administrative levels, such as the assessment of regional/state transport plans, or to higher levels, such as the assessment of international corridors, like those included in the TEN-T.

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Note

1. This subsection is not aimed at providing an exhaustive list of all scientific contributions to the concept of accessibility. Extensive reviews and existing classifications of accessibility indicators/measures can be found in, for example, Baradaran and Ramjerdi (2001) and Reggiani (1998).

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