A contribution for the evaluation of the territorial impact of transport infrastructures in the early stages of the EIA. Application to the Huelva (Spain) - Faro (Portugal) rail link.

Abstract

The EIA procedure should predict and identify the major impacts of a project development that may cause specific spatial and temporal effects. Early in the EIA, the scoping stage provides all the relevant information on the impacts of the project alternatives. In particular, potential effects on the territorial network such as habitat connectivity loss and accessibility improvements should be taken into account in the various proposed layout alternatives when evaluating transport infrastructure projects. However several authors have identified deficiencies in practice. The aim of this article is to provide a methodology for the assessment of these territorial impacts using adequate indicators in the early stages of the EIA procedure.

The proposed method is based on a comparison of a range of alternative layouts for a railway line linking two population centres, using indicators calculated with Geographic Information Systems (GIS). The methodology was applied to a case study –the rail link between Huelva (Spain) and Faro (Portugal)–, and the HSR and conventional rail were evaluated in different layouts. The method was effective in spatially identifying significant impacts on accessibility improvements, which occurred closer to the cross-border area. The conventional railway alternatives have similar accessibility values to the HSR. The results also reveal that connectivity loss is not limited to the area around the infrastructure, but extends throughout the territory. The results are at variance with the initiative proposed by Spanish and Portuguese transport decision-makers, and raise the possibility of selecting a conventional railway option. An adequate territorial evaluation methodology enables the new action to be correctly assessed, and supplies the information required to propose the most suitable alternative from a socio-economic and environmental standpoint, regardless of whether this proposal was initially included in the transport policy.

Keywords: Environmental Impact Assessment (EIA) procedure; habitat connectivity; accessibility improvements; transport planning.

1 Introduction

Transportation is essential in today’s socio-economic system. Its rise has brought an increased awareness of its attendant environmental problems (Rescia *et al.* 2006), and efforts are now underway to ensure it is as sustainable as possible. This goal requires considering all the related economic and environmental aspects in the decision-making process, rather than addressing them in isolation (Arce *et al.* 2010).

The EIA process allows the effective prevention of a project’s specific environmental impacts and establishes useful mechanisms for their correction or compensation. Its purpose is to guarantee sustainable development by predicting and identifying the major impacts of a project development which have specific spatial and temporal effects (Pavlickova and Vyskupova, 2015). Linear transportation infrastructure projects cause significant impacts (Joumard and Gudmundsson, 2010), and their effects usually extend over large distances; they therefore need to be studied in depth.

The EIA process is divided into several stages, whose exact order and content depends on international and national regulations. In general terms these stages involve screening, scoping, impact analysis, mitigation and impact management, review, approval, and post-approval monitoring and auditing (Macintosh and Waugh, 2014). Prior to the impact analysis stage, screening and scoping are crucial to ensure the preventive character of the EIA process and the efficiency of the decision-making (Weston, 2000; Snell and Cowell, 2006; Macintosh and Waugh, 2014). Screening is the process of deciding whether a project requires EIA. If the decision-makers consider a project is subject to evaluation, the second phase –scoping– identifies the key environmental issues for consideration. This is a crucial phase in environmental studies, and its purpose is to unearth all the relevant information on the impacts of the proposal and the project alternatives (European Commission, 2001). According to Bassi *et al.* (2012) in the general principles for the improvement of the EIA process, scoping should explore all reasonable options (including the do-nothing alternative) to ensure the integration of sustainability in the evaluation.

Although EIA has been implemented in decision-making for decades; several authors have identified deficiencies in practice. Loro *et al.* (2014) conducted a review of 22 reports of road-corridor planning studies for 22 roads. They found the average quality of the studies to be generally acceptable in terms of the justification of the methodology; nevertheless, they concluded that “a number of variables that are crucial to defining environmental constraints such as habitat fragmentation, groundwater impact, and the conservation importance of wild fauna or natural vegetation species are not taken into account due to the difficulties in assessing them”. Nor are socio-economic aspects correctly considered, with the exception of traffic and safety. Along the same lines, Karlston *et al.* (2014) reviewed seven environmental reports and 16 environmental impact statements on road or railway projects, plans and programmes produced in Sweden and the UK. Their conclusions highlighted problems in the evaluation of habitat fragmentation –particularly in the delimitation of study areas–, and failure to use quantitative methods and ecological criteria. Podhora *et al.* (2013) reported that –compared to the environmental and economic dimensions– the social dimension of sustainability was poorly studied and applied in transport impact assessment in Europe. This imbalance was also detected by Jones and Lucas (2012), who pointed out that “the social dimension appears to be the ‘poor relation’ in transport research, policy and practice”, and by Chadwick (2002), who states that “socio-economic effects have an uncertain status in EIA”.

The deficiencies found in the evaluation of environmental and socio-economic aspects in the transport impact evaluation highlight the pressing need to correctly identify the impacts and develop tools to be used in the appropriate phases of the decision-making process (Weston, 2000). The scoping phase should effectively consider the spatial and temporal boundaries of social and ecological values (Baxter *et al.* 2001). It is important to take into account the potential network effects of new developments in the early stages of the environmental evaluation of transport infrastructure projects. Network effects measure the contribution of a particular infrastructure improvement or impact to the transport network as a whole (López *et al*. 2009). These impacts can be understood as the consequences of the development interacting with the impacts of other developments, and include changes to biodiversity (environment) and accessibility (socio-economic impact), which must be considered in terms of the effects on the network (López et al. 2009; Mancebo Quintana *et al.* 2010). Correct approaches are crucial to ensure the sustainability of the project when studying the alternatives.

One of the environmental aspects most seriously affected by the presence of transport infrastructures is habitat ecological fragmentation, which leads to a loss of connectivity and biodiversity in the territory (Joumard and Gudmundsson, 2010). From a social standpoint, improvements in transport infrastructures have a positive impact on regional development due to greater accessibility to goods and services (Vickerman *et al.* 1999; Ozbay *et al.* 2003). The common attributes of these two territorial variables are: (i) their effects are not limited to the proximity of the infrastructure; (ii) they measure connection effects in the territory (loss of ecological connectivity in the case of fragmentation and improvement in a population's connectivity in the case of accessibility); and (iii) in both cases the impact of the new infrastructure depends on the initial situation of the transport and territorial system (Mancebo Quintana *et al.* 2010; Ortega *et al.* 2012; Monzon *et al.* 2013).

Accessibility analysis is a very useful tool when planning new railway infrastructures, as is demonstrated by a large number of studies (Gutiérrez *et al.* 1996; Gutiérrez, 2001; Bröcker *et al.* 2010). Improvements in accessibility allow planners to evaluate aspects relating to the efficiency of the infrastructure network, and use indicators to measure the cohesion or equity deriving from the distribution of accessibility in the territory (López *et al.* 2008; Bröcker *et al.* 2010; Martínez and Givoni, 2012; Monzón *et al.* 2013).

Transport infrastructures affect a wide range of ecological processes (Forman and Alexander, 1998), but one of their overriding features is that they divide ecosystems, thereby provoking a loss of habitat (Reed *et al.* 1996; McGarigal *et al.* 2001). Fragmentation is the process whereby an entity –be it an ecosystem, vegetation unit or continuous habitat– is partitioned into smaller areas known as patches (Forman, 1995). This process can be understood as a loss of connectivity (Serrano *et al.* 2002). Connectivity is defined as the degree of permissiveness offered by the landscape for the displacement of organisms, energy flows and migratory and dispersive movements between patches (Taylor *et al.* 1993; Tischendorf and Fahring, 2000), and is consequently a key element in the landscape structure. Linear infrastructures trigger an abrupt change in patch connections, interfering with population flows and causing concern to the authorities (Trocné *et al.* 2003). In recent years a number of researchers have developed connectivity indicators to model this ecological process (Marulli and Mallarach, 2005; Saura and Pascual-Hortal, 2007; Mancebo Quintana *et al.* 2010; Gurrutxaga *et al.* 2010).

In this literature review we have found that although EIA is already established as an effective impact prevention tool, several authors have identified deficiencies in practice. In particular, network effects –which shape the territory-transport network relationship as a whole– are rarely studied. The aim of this article is to provide a methodology for the assessment of both environmental and socio-economic territorial impacts using adequate indicators in the early stages of the EIA procedure. This methodology contributes to improving the scoping phase of EIA by providing tools for the assessment of alternative layouts for new linear transport infrastructures, taking into account the network effects in terms of accessibility improvements and connectivity loss. The proposed methodology, described in the following section, is applied to the case study of the Huelva-Faro railway corridor, in section 3.

2 Methodology

The proposed methodology is based on a comparison of the social and environmental effects of a range of alternative layouts of a railway line linking two population centres. This comparison is done using indicators calculated with Geographic Information Systems (GIS). The first step is therefore to define the alternative layouts to be assessed (Phase 1). Then we present the methodology selected to assess the social effects in terms of accessibility (Phase 2); and the environmental effects in terms of the fragmentation of the territory (Phase 3). The selection criteria for the indicators are: a) they should assess the effect of an infrastructure on the whole territory and not merely on the area near the infrastructure itself –in line with the aims of the article–; and b) they can be calculated using commonly available data, and provide results that are easy to interpret.

This section also includes the presentation of the case study and the steps followed to apply the proposed methods.

2.1 Phase 1. Defining alternatives and delimiting the study zone

The first points for consideration are the potential environmental impact of the different layouts using previous studies, the current state of the railway network, and the populations to be connected. Once the alternatives have been chosen, the next step is to establish the socio-economic and environmental situation for the various scenarios to be compared. They are constructed by taking into account the suitable railway typology options and alternatives to the design of the railway layout. These scenarios are compared with each other and with the do-nothing alternative.

Afterwards the study zone for the calculation of the indicators is defined, which will need to consider the whole of the territory affected by the infrastructure. This zone is not limited to the infrastructure's immediate surroundings, but covers a greater area of influence that includes all the populations and natural areas impacted by the new rail link.

2.2 Phase 2. Accessibility calculations

The concept of accessibility is represented by a variable which –according to the literature– can be measured by a wide spectrum of indicators (see e.g. Reggiani, 1998), based on formulas to measure the possibility of reaching destinations. Potential economic accessibility indicators have been demonstrated to be the most suitable in terms of their consistency and applicability in strategic transport planning (Ortega *et al.* 2012; Monzón *et al.* 2013). This approach to accessibility measurement is based on the volume of economic activity that can be reached from any given location (Hansen, 1959). The indicator chosen is shown in Equation 1:

$$PA_i^* = \sum_j \frac{P_j}{I_{ij}} \tag{1}$$

Where:
PA_i^* is the accessibility for each origin i to j destinations in scenario *.
P_j represents population at the destination j.
I_{ij} is the travel impedance (usually measured as travel time or generalised travel cost) between each origin-destination pair.

This potential indicator easily connects with the accessibility concept of "possibility of reaching opportunities", as it takes into account both the size of the destinations and the travel cost to reach them, based on the assumption that the attractiveness of a destination increases with its size and declines with travel cost (López *et al.* 2008). It has certain limitations due to its aggregate nature and the fact that it does not use familiar measurement units, and assumes that all individuals in the same zone have the same level of accessibility (López *et al.* 2008).

The path with the minimum displacement time is calculated between the origin and each destination. The travel time equals the sum of the times of the arcs travelled, by the shortest path, according to Dijkstra's algorithm (1959). When calculating the travel time for the rail mode, certain aspects relating both to infrastructure quality and frequency of service must also be taken into account. A detailed description of the generalised travel time calculation is shown in López (2007) and Ortega *et al.* (2011).

The accessibility between alternatives is calculated for each origin *i*, as a percentage with respect to the initial situation using Equation 2. If the accessibility values (PA_i^*) are calculated in alternatives 0 and S, and are PA_i^0 and PA_i^S, respectively, the equation is:

$$Change\ in\ PA_i^*\ among\ alternatives\ k\ and\ s\ (\%) = \frac{PA_i^k - PA_i^s}{PA_i^s} \cdot 100 \qquad (2)$$

The information, in a format compatible with GIS, required to calculate this indicator is –for each scenario– a network of linear infrastructures in the study zone that distinguishes between the different typologies (motorways, roads, conventional railway lines, high-speed railway lines, etc.). This network must include data on travel impedance, and there must be a further layer with the different population centres and their number of inhabitants.

2.3 Phase 3. Connectivity analysis

Fragmentation is commonly determined by means of indicators measuring different characteristics of a landscape's composition or spatial configuration (McGarigal and Marks, 1995; Forman *et al.,* 2003). In the case that concerns us here –fragmentation caused by railway lines– the construction or modification of a railway layout will scarcely affect the variety of classes and habitats present in the landscape, or the distances between them. However, the presence of a new linear transport infrastructure has a major impact on the flows of matter and energy occurring in the ecosystems, and on the natural movement of individuals and on population dynamics (Trocmé *et al.* 2003). To study its effect on the environment, connectivity indicators are frequently used to measure the permissiveness of the territory to these movements (Scolozzi and Geneletti, 2012), although they have a certain degree of subjectivity in terms of the resistance values assigned to the territory.

The fragmentation of the territory is analysed using the connectivity indicator CI_i^* (Mancebo Quintana *et al.* 2010). This indicator is calculated with Geographic Information Systems in a raster format. It assigns a value between 0 and 1 for the alternative * to each pixel in the study zone, and measures the area corresponding to the same type of natural habitat as that of the cell in question, divided by the effective distance between the pixel and the analogous habitat. The calculation is done in an area of influence of each pixel, and the value obtained is divided by the maximum value that could be achieved, so the range of values for *CI* is between 0 (minimum connectivity) and 1 (maximum connectivity).

$$CI_i^* = \frac{\sum_{j=1}^{n} \frac{A_j}{de_{i,j}}}{2\pi de_{\max}} \qquad (3)$$

Where:
CI_i^* is the value of the connectivity index for starting point i in the alternative *.
$de_{i,j}$ is the effective distance between starting point i and destination j.
Aj is the area of each one of the n destinations j that belong to the same class of natural area as starting point i.
and $2\pi de_{max}$ is the maximum possible value of the numerator.

CI_i^* is a function of the effective distance, which is the minimum distance between two points, separated by a resistance matrix that models the difficulty encountered by organisms in moving around the territory. That is to say, the distance between two points that belong to the same type of natural habitat is penalised if there are patches between them in the matrix that can be considered as obstacles (such as infrastructure, artificial or natural areas that correspond to a different type or category). The effective difference is calculated using Dijkstra's algorithm (1959), and the resistance matrix is obtained using the values established in the works of Mancebo Quintana *et al.* (2010).

The indicator CI_i^* is calculated as follows:

The first step is to establish the origins and destinations. The origins are the pixels considered as natural areas in the study zone classified into categories with common characteristics. The destinations are, for each origin, the pixels belonging to the same type according to the categories established. This information must be compiled on a layer in raster format with a cell size adequate for the scale of the work.

In second place we need to create the maps or resistance matrixes. Each cell in the resistance map is assigned a value that is a simplification of the opposition offered by the territory to the movement of the organisms between pixels corresponding to the same type of natural habitat as the origin pixel. These values are assigned taking into account the type of natural habitat, the types of linear infrastructures present in the study zone, and the existence of artificial land uses. The values were assigned with reference to the work of Mancebo Quintana *et al.* (2010).

Finally, the indicator CI_i^* is calculated for each pixel *i* in the territory using Equation 3. This process is repeated in each of the alternatives considered in the case study, making it possible to measure the difference in connectivity between alternatives (k and s) as a percentage with regard to the initial situation (s) using Equation 4:

$$Change\ in\ CI_i^*\ among\ alternatives\ k\ and\ s\ (\%) = \frac{CI_i^k - CI_i^s}{CI_i^s} \cdot 100 \qquad (4)$$

The information, in a format compatible with GIS, required to calculate this indicator is –for each scenario,– a network of linear infrastructures in the study zone that distinguishes between the different typologies (motorways, roads, conventional railway lines, high-speed railway lines, etc.), and a layer that distinguishes the different types of natural and artificial zones.

2.4 Case study presentation: the Huelva-Faro rail link

This subsection presents a case study for the application of the methodology. The infrastructure selected for the study is the rail link between Huelva (Spain) and Faro (Portugal), separated by a Euclidean distance of 90 km and currently only connected by means of a dual carriageway (110 km). Figure 1 shows the location of the study zone.

The selection of this is justified by the importance for Spain, Portugal and the European Commission, demonstrated in the Portuguese-Spanish summits held in 2003, 2004 and 2005. In these summits, Spain and Portugal highlighted the need to improve common transport infrastructures in order to counteract the disadvantages produced by the peripheral nature of the border regions. One of the most significant measures was considered to be the construction of the Faro-Huelva high-speed train. Furthermore, Strategic Infrastructure and Transport Plan (PEIT) of Spain (Ministerio de Fomento, 2005) contemplates reinforcement for cross-border logistical relations with Portugal (Seville-Huelva-Algarve axis). On 25 October 2007 the European Commission approved the Cross-Border Programme for Cooperation between Spain and Portugal 2007-2013 (POCTEP), which promotes the development of border areas between Spain and Portugal and reinforces the existing economic relationships and cooperation networks between the five areas defined in the programme. Within this program it has been developed several research projects, including the "I2TEP: Spain-Portugal Cross-Border Research and Transfer" project. Its framework includes the subproject EAEFERII, which try to define possible alternative corridors (high-speed and conventional) in order to incorporate socio-economic aspects for the promotion of sustainable development into the environmental variables.

Figure 1: High Speed Railway (HSR) project

The study zone is densely populated and has several municipalities with over 20,000 inhabitants, particularly Huelva, Faro, Olhäo and Lepe, with 150,000, 65,000, 31,000 and 27,000 inhabitants respectively. Huelva is on the Spanish high-speed rail network, which links it with Seville, Madrid and the rest of the territory of Spain, whereas Faro is only connected with the rest of Portugal by means of a conventional railway line.

2.4.1 Phase 1. Defining alternatives

There are three proposed alternatives: the first is the layout of a HSR line running through the area of minimum impact between the cities to be connected (Faro and Huelva) calculated at a previous stage to this study (González *et al.* 2012); a second alternative which goes through the same area of minimum impact but with a conventional railway; and a third alternative consisting of rebuilding a former conventional railway line, which is still in use on the Portuguese side but no longer exists in many sections of the Spanish territory. Figure 2 shows the different alternative layouts, as well as the roads existing in the study zone. The railway stations are also shown. Figure 2a corresponds to the current situation and Figures 2b, 2c and 2d to the “HSR”, “conventional” and “old route” alternatives respectively. To take into account solely the effect of the infrastructure, the situation for the socio-economic variables is considered to correspond to 2020, and to 2012 for the environmental variables.

Figure 2: alternative layouts. A represents the current situation; B is the “HSR” alternative; C is the “conventional” alternative and D the “old route” alternative

3.2 Phase 2. Accessibility calculations

The accessibility analysis takes into account a third of the territory of the Iberian Peninsula: seven Portuguese districts (Faro, Beja, Setubal, Evora, Santarem, Lisbon and Portalegre) and 13 Spanish provinces (Huelva, Cadiz, Malaga, Granada, Almería, Jaén, Cordoba, Seville, Badajoz, Cáceres, Ciudad Real, Toledo and Madrid).

The reason for considering this territory is that the effects of a new infrastructure are not limited to the area directly adjacent to it (López *et al.* 2009; Gutiérrez *et al.* 2010; Gutiérrez *et al.* 2011). The new infrastructure will not only serve to join Faro and Huelva, but will also connect them to the HSR network, thereby linking them to a number of other destinations such as Seville and Madrid.

The accessibility values have been calculated for 1,742 municipalities in the study zone (seven Portuguese districts and 13 Spanish provinces, see Figure 3), which are also possible destinations. The accessibility value of each origin is calculated taking into account all the destinations. The calculation was made using a dense network of railways and roads, including information regarding the typology, length, speed of travel and travel time for each arc, as in previous similar studies (López *et al.* 2008; Ortega *et al.* 2012). Information on the location of the stations and their typology has also been incorporated. All the GIS databases are independent. This information is used to calculate the travel time between each origin and destination; this is the travel time by road from the origin until the nearest station, the travel time in the train, and the travel time from the station nearest the destination to the actual destination itself. It also considers the frequency of service in calculating the travel time by train.

The accessibility value (PA_i) for each municipality i is calculated using Equation 1. Accessibility was calculated using two GIS tools, TITIM-GIS tool (Ortega *et al.* 2014) and AccesstUls[1], that operate in ArcInfo following the method described in Ortega *et al.* (2011). Briefly, it involves displacing the municipality centroids and the stations to the

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[1] AccesstUls.aml (Network Accessibility Analysis Toolbox), developed by Santiago Mancebo in 2007. Unpublished.

nearest road; the railway lines are subsequently displaced to coincide with the stations; then both the road network and the railway network are linked together to create the network nodes. Finally, Equation 1 is computed.

3.3 Phase 3. Connectivity analysis

For the analysis of fragmentation or loss of connectivity in the territory, we calculated the values obtained by applying the indicator *CI* (Equation 2) in the three alternatives considered.

In this case, the study area is considered to be a radius of 150 km from the railway infrastructure in the study. Above this value, the results of the connectivity indicator are not perceptible.

The loss of connectivity was calculated between the different natural land uses in the study area[2], which are the origins and destinations between which we will calculated the connectivity. The cartographic layer for natural land uses was obtained from the Corine Land Cover layer (European Environmental Agency, 2000). The road and railway network was incorporated into this layer, in addition to each of the proposed railway routes in this study.

A map of impedance was generated to represent the territory's resistance to the movement of organisms from one natural land use to another identical one according to data from Martín Ramos *et al.* (2008). A resistance map must be created for each alternative.

The cost of displacement is calculated on the GIS database between each origin and all the possible destinations, and the connectivity value is calculated according to the formula for the indicator *CI* using a GIS tool[3] that operates in ArcInfo, following the method described in Mancebo Quintana *et al.* (2010).

3 Results and discussion

3.1 Accessibility improvements analysis

Table 1 shows the values obtained. For each alternative, it includes the accessibility values in the municipalities in the corridor, the average values weighted by the population in the corridor and in the whole of the area considered (Figure 3), as well as

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[2] Initially the aim was to consider the habitats in the study zone as origins and destinations, but we were unable to obtain the information on the habitats on the Portuguese side.

[3] Fragtuls.aml (set of specialised tools for calculating habitat fragmentation), developed by Santiago Mancebo in 2007. Unpublished.

the percentage of change with regard to the current situation. It also shows the coefficient of variation (CV)[4] for the twelve municipalities in the corridor.

Table 1. Accessibility values and changes in the various alternatives.

There is very little improvement in accessibility in the general calculation for the territory analysed. The construction of a small section of about 100 kilometres in length did not affect the territory as a whole, and the improvements were less than 1%. At this planning level, a further finding is that the percentage of improvement offered by the HSR alternative is only slightly higher than the conventional railway alternatives. Ortega *et al.* (2012) obtained similar results in Spain for a corridor at the national level, but the results are even lower in our case, as the corridor does not have a strategic location in the country as a whole. The improvements only become significant when we move towards the cross-border area of the study zone, which has values of between 12% and 17.4%, according to Ortega *et al.* (2012), or Chandra and Vadali (2014) for a HSR corridor in the Appalachian Region.

At the local level, it should be noted that as there is no existing railway infrastructure linking Faro with Huelva. The time taken in making this displacement is not comparable with the time calculated in other scenarios in which the infrastructure already exists. There are two possible alternatives for reaching Faro from Huelva or vice versa: by rail, involving a journey of over 700 km; or on the road network, an alternative which makes use of another type of transport mode, meaning the times are not comparable. This situation does not occur with other municipalities, which –in the Portuguese case– are linked by rail, or where –in the Spanish case– residents would travel by road to the nearest station, which is Huelva (except for Isla Cristina and Ayamonte).

We can compare the results obtained for the different alternatives. This analysis reveals that the HSR alternative produces higher accessibility values in practically all the municipalities, improving from 3.8% to 42.6%. Authors often conclude that the positive accessibility benefits are limited to areas served by stations, and that cities without a HSR station along the corridors are negatively impacted (Levinson, 2012; Martínez Sánchez-Mateos and Givoni, 2012). In our case, although HSR undoubtedly links the two most important municipalities (Huelva and Faro) in a very short time, the other cities also benefit to the same degree, as they are located very near a HSR station that connects them with the whole of the network. This benefit depends mainly on the quality of the transport network from the cities to the nearest HSR station (Monzón *et al.* 2013).

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[4] CV indicates the dispersal of the values from the mean. Low CV values indicate that the accessibility values are distributed more homogeneously in the territory and there is therefore greater territorial cohesion (Ortega et al., 2012).

The two conventional railway alternatives offer lower –between 15% and 40%– accessibility values than HSR. However in absolute terms they are still high –and sometimes even higher–, as in the case of Castro Marim, Vila Real de San Antonio, Ayamonte and Isla Cristina, which have their own station to connect them without the need to rely on the road, and also links them to the rail network.

This points to the possibility of selecting a conventional railway option, which would offer more stations at a lower cost. A comparison of the conventional rail and "old route" alternatives gives higher values for the second, and particularly for Ayamonte and Isla Cristina, which would be more distant from the infrastructure with the other alternative.

Differences can be seen in the results for the Portuguese and Spanish municipalities. The Portuguese municipalities would benefit more significantly from the Huelva-Faro link. The Portuguese municipalities obtain percentages of improvement of over 25% in all cases. In contrast, the improvement in accessibility is much lower in the Spanish municipalities –except in Ayamonte and Isla Cristina–, with values of less than 5%. This is due to three main reasons. The new infrastructure links Faro (and the other Portuguese localities) with Huelva, the destination that has by far the greatest potential for it, and it also connects to the Spanish railway network, offering access to major destinations which were previously beyond reach. The second reason is the current density of the Spanish rail network, which connects Huelva with the rest of the territory and offers access to cities which are highly attractive to it. The creation of a new connection with Faro does not therefore have such a significant effect on accessibility improvements. The third reason is that the Portuguese railway network is relatively undeveloped in the southern part of the country and accessibility values are very low, causing the percentage increase to be very high. This has important repercussions on funding, as noted by Gutiérrez *et al.* (2011). The international nature of this project and the significant differences in the benefits must be considered in the distribution of construction costs and/or the amounts received from the European funding agencies.

Guirao (2013) warned that HSR can modify the urban hierarchy of the regional system since HSR stations can also condition territorial impacts. Figure 3 and Table 1 support this assertion. Figure 3 shows the accessibility values with the HSR alternative and reveals that the highest values are located in the proximity of Huelva and Faro, both with HSR stations. This result –i.e. travel time savings are mainly achieved at the end of the line– is consistent with other previous works (Martínez Sánchez-Mateos and Givoni, 2012; Ortega *et al.* 2012). However, a look at the resulting maps for the other alternatives (not included for reasons of space) shows that the high accessibility "patch" spreads all along the corridor in a more homogeneous way, as there are more railway stations with very similar values (see Table 1), and there are fewer "islands" with enhanced levels of accessibility (Plassard, 1991; Monzón *et al.* 2013). The "old route" alternative is particularly noteworthy, with a CV of 20% lower, thus promoting greater territorial cohesion.

Figure 3: accessibility map with the HSR alternative

3.2 Connectivity loss analysis

This territory in the study zone has undergone considerable anthropic influence; it contains the main population centres in the region and the road and rail networks connecting them, and thus poses a significant impediment to the movement of organisms. The results highlight the very low connectivity values for the study area. The selected indicator provides generic results for ecological communities; however individual species may also be severely affected. Most studies designed for single species are characterised by high model complexity –such as the study developed by Clauzel *et al.* (2013) on the European tree frog or Marcantonio *et al.* (2013) on a type of forest– and are thus not easily applicable to ecological communities (Buchmman *et al.* 2013). Our approach assumes that all the species sharing the same habitat also share the same connectivity model; it is thus free of species-specific variables and can be used for extensive territories, similar to the model previously proposed by Marulli and Mallarach (2005), Saura and Pascual-Hortal (2007) and Gurrutxaga *et al.* (2010).

A look at Figure 4-left shows that the poorest connectivity values (shaded in red) correspond to areas intersected by some pre-existing railway infrastructure, in areas near urban centres or located along the coastline.

Figure 4: connectivity maps. “4-left” shows the connectivity with the “conventional” alternative and “4-right” the loss of connectivity with the “conventional” alternative.

Figure 4-right reveals that the loss of connectivity is not limited to the area around the infrastructure, but extends throughout the territory. As expected, the areas where the connectivity varies most are the zones adjacent to the layout of the new infrastructure where the territory undergoes a change in use, creating a barrier that affects the movement of organisms between homologous land uses. These findings show that the most important losses in all cases occur in the Spanish zone. This is due to the existence of a railway line in the Portuguese part which already acted as a barrier; the new construction does not therefore represent so much loss of connectivity as on the Spanish side.

Table 2 shows the values obtained. For each alternative, it includes the connectivity values for the territory in the zone considered (Figure 4), in addition to the percentage of change with regard to the current situation.

Table 2. Values for connectivity and % loss in the different alternatives

All scenarios reveal a very low and similar loss of connectivity (see Table 2). The HSR scenario shows the highest loss of connectivity –0.8%–, whereas the other alternatives have a loss of 0.56% and 0.27% respectively, compared to the scenario with no new infrastructure. Although the numerical value is low, it should not be overlooked. The effects of loss of connectivity are extensive and ecologically important, and concern the functional isolation of habitat and the loss of biodiversity (Gurrutxaga *et al.* 2011).

4 Conclusions

This article proposes a methodology to assess the territorial effects of major new transport infrastructure layouts, specifically high-speed rail lines (HSR). It consists of a combination of accessibility and connectivity indicators which have been demonstrated to be useful tools in infrastructure planning. This methodology takes into account socio-economic and environmental aspects in the scoping phase of the EIA procedure, in order to ensure adequate assessment of alternative layouts.

The indicators used in this study assess the overall impact of the new infrastructure, and are not restricted to the individual project. They evaluate the repercussions of the infrastructure on the whole of the transport network (improvements in accessibility) and on natural areas in a wider territory (loss of connectivity). Furthermore, the method considers the initial situation of the transport and territorial system, and this is reflected in the results.

The methodology is an effective means for assessing the effects of a possible rail link between Huelva (Spain) and Faro (Portugal). This link was proposed in order to counteract the drawbacks caused by their peripheral location and stimulate development in border zones in Spain and Portugal. After the initial HSR proposal, other alternative layouts and typologies (conventional) were also studied. The results are at variance with the initiative proposed by the Spanish and Portuguese transport decision-makers, and suggest the possibility of selecting a conventional railway option to obtain accessibility improvements, which would provide more stations at a lower cost. The connectivity study points to the conclusion that the infrastructure affects the whole of the territory in the study –and more so the areas immediately adjacent to it– and these effects are greater in the case of the HSR alternative.

In view of these considerations, there is a manifest need to carry out a proper study of the territorial effects of a new infrastructure in the initial decision-making phase of the EIA. An effective methodology for territorial evaluation enables the new action to be correctly assessed and provides all the information necessary to propose the most suitable alternative from a socio-economic and environmental standpoint, regardless of whether this is the proposal initially contained in the transport policy.

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Table 1. Accessibility values and changes in the various alternatives

Municipalities	Value	HSR alternative		Conventional alternative		“Old route” alternative	
	without infra	Accessibility value	Change (%)	Accessibility value	Change (%)	Accessibility value	Change (%)
Faro	109,213	152,296	39.4	139,200	27.5	139,514	27.7
Olhão	109,513	150,680	37.6	138,416	26.4	141,285	29.0
Tavira	103,803	140,773	35.6	130,243	25.5	138,510	33.4
Castro Marim	95,158	129,018	35.6	119,854	26.0	135,238	42.1
Vila Real de Santo Antonio	104,040	138,547	33.2	129,134	24.1	144,990	39.4
Ayamonte	83,423	115,992	39.0	107,318	28.6	121,787	46.0
Isla Cristina	72,687	103,666	42.6	95,577	31.5	108,971	49.9
Lepe	114,407	119,034	4.0	117,196	2.4	118,091	3.2
Cartaya	119,961	124,788	4.0	122,840	2.4	123,793	3.2
Aljaraque	135,303	141,253	4.4	138,718	2.5	139,210	2.9
Gibraleón	146,151	151,700	3.8	149,334	2.2	150,510	3.0
Huelva	146,095	152,184	4.2	149,565	2.4	150,075	2.7
CV	0.20	0.12		0.12		0.10	
Corridor aggregate value	121,159	142,256	17.4	135,732	12.0	139,189	14.9
Zone aggregate value	229,822	231,859	0.9	231,142	0.6	231,293	0.6

Table 2. Values for connectivity and % loss in the different alternatives.

Municipalities	**Value**	**HSR alternative**		**Conventional alternative**		**“Old route” alternative**	
	without infra	**Connectivity value**	**Change (%)**	**Connectivity value**	**Change (%)**	**Connectivity value**	**Change (%)**
Zone aggregate value	631	626	0.8	628	0.56	630	0.27

Figure captions

Figure 1: HSR project

Figure 2: alternative layouts. A represents the current situation; B is the “HSR” alternative; C is the “conventional” alternative and D the “old route” alternative

Figure 3: accessibility map with the HSR alternative

Figure 4: connectivity maps. “4-left” shows the connectivity with the “conventional” alternative and “4-right” the loss of connectivity with the “conventional” alternative