Passenger transport planning. A Benefit-Cost Analysis of the High Speed Railway: The case of Spain

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ABSTRACT

In the current economical and financial crisis, the economic evaluation of transport infrastructure investment projects is of most importance. Given the need of most governments to reduce spending and control the deficit, having tools that facilitate decision-making seems to be a key objective. This paper examines several high speed lines in Spain, by using the benefit-cost analysis (BCA), in order to obtain more information and determine the social costs and benefits linked to each project. Such analysis allows determining whether costs are higher than benefits, so the net social benefit is positive. Similarly, an Internal Rate of Return (IRR) per project is determined, in order to classify investments with positive BCA.

RESUMEN

En la actual crisis económica y financiera, la evaluación económica de proyectos de inversión en infraestructura de transporte es de mayor importancia. Dada la necesidad de la mayoría de los gobiernos para reducir el gasto y controlar el déficit, contar con herramientas que faciliten la toma de decisiones parece ser un objetivo clave. Este documento examina varias líneas de alta velocidad en España, utilizando el análisis de costo-beneficio (ACB), con el fin de obtener más información y determinar los costos y beneficios sociales relacionados con cada proyecto. Este tipo de análisis permite determinar si los costos son más altos que los beneficios, por lo que el beneficio social neto es positivo. Del mismo modo, a una Tasa Interna de Retorno (TIR) por proyecto se determina, con el fin de clasificar las inversiones con resultados positivos ABC.

1.- INTRODUCTION

This study analyses two railway investment projects that will connect Santander with Madrid and Bilbao. This analysis extends to passenger transport.

The benefit-cost analysis method applied to the high speed railway (AVE) from Santander-Palencia-Valladolid-Madrid and Santander-Bilbao, establishes its economic profitability by calculating the present discounted value of its net social benefits and the corresponding internal rates of return of the investment.

The first assumption we make is that the Madrid-Valladolid-Palencia section of railway will be finished before 2011, when works are due to start on the high speed or high performance railway track from Santander to Palencia.

That is, the high-speed section from Valladolid to Palencia is not considered within this analysis because it would be built even if the high-speed network was not to be extended to Santander, since in the Strategic Plan for Infrastructure and Transport (PEIT), it is approved that for the time period 2005-2020, high-speed must connect Valladolid with Palencia, continuing to Leon and from there, to Oviedo and Gijón. Therefore it has been assumed that this section has been included into the benefit-cost analysis of the Madrid-Gijón AVE. The PEIT includes also the high-speed section from Palencia to Burgos and from there to Vitoria. Obviously in the benefit-cost analysis of the Madrid-Burgos AVE only the costs corresponding to the Palencia-Burgos section will be considered. This assumption will evidently facilitate the profitability of the project. It is, in short, a reflection of the network benefits related to the construction of transport infrastructure. We assume that works for the Santander-Bilbao project will start in 2011.

The Santander-Palencia line will integrate Cantabria into the Spanish high speed railway network. The line will connect Santander to Madrid in less than 2 hours 25 minutes at high speed. Meanwhile, the Santander-Bilbao line will integrate Cantabria into the Bilbao-Zaragoza-Valencia corridor and connect both towns in less than 45 minutes. Figure 1 shows both corridors.

Figure 1.- Spanish High Speed network with 2020 horizon.

This paper is organized as follows. Next, the benefit-cost method is applied to quantify the costs and benefits related to each project's useful life and a demand forecast is determined

for both corridors. In section 3 the two investments are assessed in order to obtain the net present value and a sensitive analysis is shown. Finally, a set of brief conclusions and final considerations are explained.

2.- BENEFIT-COST ANALYSIS

The methodology employed for the assessment of social benefits in the benefit-cost analysis of this project is a generalisation of the method used in Dodgson (1984) and Nash (1991) and extensively described in De Rus and Inglada (1994 and 1997), in Thompson (1994), in Coto-Millán and Inglada (2003a, 2003b) and in Coto-Millán, Inglada and Rey (2007) for the case of the high speed train from Madrid-Barcelona-French Border and De Rus (2011).

This framework has been extended with the methodology employed for the assessment of transport externalities detailed in Coto-Millán and Inglada (2003c). In addition, we have used all characteristic assessment criteria for the social assessment of projects: shadow pricing, tax exclusion etc., as detailed in Coto-Millán and Inglada (2003c).

Table 1 shows the summary of costs and benefits considered in the assessment of these projects.

Table 1.- Costs and benefits of the AVE Santander-Madrid and Santander-Bilbao

Costs	Benefits
Total cost of infrastructure, maintenance and operation (TC = I – R + RS + IM + O)	**Total benefits (IGT + TS + CR + REC)**
Infrastructure (I)	**Income from Generated Trips (IGT)**
Residual value (R)	**Time saving (TS) for users from:**
Rolling Stock (RS)	Other methods of transport
Infrastructure maintenance (IM)	**Cost reduction (CR) in:**
Operation (O)	Conventional railway
	Airplane *(Madrid only)*
	Coaches
	Operational car costs
	Reduction of external costs (REC) in:
	Congestion
	Accidents
	Environment
	Infrastructure maintenance

Source: Authors' compilation based on Coto-Millán and Inglada (2003a, b y c)

According to Coto-Millán and Inglada (2003b), the method for assessing costs and benefits is as follows.

2.1 Monetary costs

The project costs can be divided into fixed, semi-fixed and variable, naturally depending on the term considered. Fixed costs are those corresponding to the construction of the infrastructure (in the widest sense) and its maintenance. Semi-fixed costs correspond to the purchase of rolling stock and, lastly, variable costs are those commonly called operating costs, characterised by being highly sensitive to the evolution of the demand.

With regard to the prices we have adopted the assumption that all chapters of the assessment are valued at constant 2008 prices. The methodology used for the quantification of each of the said cost chapters is the following:

Costs of infrastructure construction

The AVE infrastructure includes the track as well as the earthworks, signalling, stations, catenary, etc. We assume that building would start in 2011 and would finish in 2016. The total cost of the 201 kilometres amounts to 1,413 million Euros as at 2008. Meanwhile, the cost of the 101 km of the Santander-Bilbao project amounts to 670.64 million Euros. The information about the construction costs has been collected from the informative studies of the corresponding projects.

Infrastructure maintenance costs

The annual maintenance cost for the infrastructure has been estimated at 11.75 thousand Euros per km, taking as reference the average value of the costs of the Madrid-Seville AVE and the Madrid-Barcelona AVE, which are already operative.

Rolling stock costs

The costs considered for the different types of rolling stock (locomotive and wagons) are as follows: 13.11 million Euros for long-distance trains and 11.04 for regional shuttle trains, according to data provided by the Spanish Ministry of Development and taking into account that the route does not necessarily require it to be high technology, given that the speed being aimed for is 250 km/h instead of 350 km/h.

Costs for obtaining the necessary rolling stock units

Following De Rus (1994), the methodology used to determine the necessary units is as follows. The average of trains is 228 passengers. We have based ourselves on an occupancy rate of 60% and on the average mileage covered by each unit being 400,000 kilometres per year. Therefore, a new train would be needed every 54.72 million passenger-km.

Operating costs

This chapter includes all costs derived from operating the AVE (power, staff, maintenance of rolling stock and services, such as catering, video, etc.) and we take as reference the operating costs of the Madrid-Seville line provided by RENFE Operadora. The cost for the transport of passengers is 8.21 Euro cents per passenger/km.

Residual value

For the rolling stock, the useful life considered is 20 years, and we have assumed a linear depreciation during this period. We have estimated a value of 45 years (MOPT, 1991) for the entire infrastructure. Therefore, after 40 years of operation, and assuming a linear depreciation, the residual value will be minimal, approximately 10% of the value of the investment made.

2.2 Monetary income from generated trips

We have determined the initial demand in the corridor before the introduction of the AVE for each mode of transport, using the data of the operating transport companies, ICANE and the mobility surveys made (MOVILIA (2000). In addition, we have used the data from the Madrid-Seville AVE to determine the size of the passenger demand for the two new lines.

For the application of this methodology it is not only necessary to know the initial demand of the AVE, but also its evolution during the operation period considered, divided into its two components: generated traffic and diverted traffic, as well as the income needed for the assessment of the benefits produced by the generated trips.In order to solve this issue, we have assumed that during the first year of operation only 80% of the expected demand for 2016 will be met. Also, we work on the assumption that as from 2017 the AVE demand will evolve in parallel to the growth of the Spanish GDP, with an elasticity of 1.4. This value is similar to that obtained in Spain's air transport (Coto-Millán et al., 1997) and is in line with those obtained in other countries (Owen and Philips, 1987). Along these same lines, Bonnafous (1997) holds that the French TGV is more similar to an airplane than to a conventional train.

Table 2.- Change in the modal distribution in the Santander-Madrid and Santander-Bilbao routes. (Thousands of passengers in both directions).

Means of Transport	Before the AVE	(%)	After the AVE	(%)
Private vehicle	1,588.1	64.2	1,318.1	47.1
Airplane	274.3	11.1	164.8	5.9
Bus	465.8	18.8	419.2	15.0
Conventional Train	147.2	5.9	22.1	0.8
AVE	------	------	874.5	31.2
TOTAL	*2,475.4*	*100*	*2,798.7*	*100*

Means of Transport	Before the AVE	(%)	After the AVE	(%)
Private vehicle	1,970.3	93.3	1,635.4	68.5
Bus	104.1	4.9	93.7	3.9
Conventional Train	37.1	1.8	5.7	0.2
AVE	------	------	651.9	27.4
TOTAL	*2,111.5*	*100*	*2,385.7*	*100*

Source: Own elaboration

Induction and Substitution Effects

The component of the AVE demand, usually termed induced, is comprised by all the new trips. This "generation effect" must not only include passengers who have never made such a trip, but also another component formed by the increased frequency of trips by those who were already travelling on that route. Based on the results of the Madrid-Seville AVE (Inglada, 1994), we have established the substitution and generation factors for the new demand for trips.

Likewise, the introduction of the high speed train produces significant effects on the demand of the rest of the means of transport, given its competitive advantages in the different components of the generalised cost (travel time, punctuality, comfort, etc.) with regard to other means of transport. Table 2 shows the changes that are estimated would take place in the modal distribution of the demand in both routes as a result of the introduction of the AVE.

2.3 Benefits

Below we detail the chapters of benefits that have been considered in the project. However, the macroeconomic, sectorial and regional effects analysed in depth by Winston (1985), Bonnafus (1987), Aschauer (1989), Alvarez and Herce (1993) and by Inglada (1993, 1994) have not been taken into account.

Reduction of costs in conventional railway

A first chapter of the benefits, inherent to the operation of the new product, consists of the reduction of costs in the alternative means of transport: conventional railway, airplane, buses and car. Thus, the following values are obtained:

Reduction of costs in conventional railway: 4.63 euro cents for the year 2008 per traveller-kilometre. In order to determine the corresponding cost reduction, the structure of the production cost of the average daytime train has been used, it being the most affected by the reduction of the service supply. Of all its components, only half of the cost associated to the category of stations has not been included. However, the entire amortisation category has been included, based on the fact that the train could be used alternatively in another route.

Reduction of costs in air transport: 15.23 euro cents per traveller-kilometre. The transfer of travellers from air transport to the AVE brings about a reduction in costs for air transport operators in the Santander-Madrid route. In this mode of transport, unlike the case of the conventional train, aside from the cut in the number of flights the reduction of the offer takes place through a reduction of the average occupancy.

For this reason, instead of basing itself on a unit cost per traveller-km, the method used is based on establishing the reduction of the number of flights in order to obtain the cost savings for the trip by applying the average cost of a flight.

The cost savings per unit per trip have been obtained by subtracting from the total cost the fixed items such as structural costs and part of the commercialisation costs, as well as all taxes. The amortisation category has been kept, given that an aircraft can be used on another line, as clearly understood when the operator is renting the aircraft.

Reduction of costs in coaches: 3.92 euro cents per traveller-kilometre. In coaches, the effect of the intermodal substitution brought about by the introduction of the AVE generates cost savings for the operating companies, essentially as a result of the reduced number of trips. In order to calculate these savings, the costs structure of a representative coach has been used; according to MF (2008), the average total costs for coaches amount to 1.51 €/km, and applied an average occupancy factor of 70%.

Reduction of car cost: 52.87 euro cents per traveller-kilometre. In the case of private vehicles, it is not possible (except if the vehicle is rented) to substitute the trip planned initially by another one in a different place during the same period of time. Therefore cost categories considered as "fixed", such as part of the amortisation and insurance, should not be included in determining cost savings. As to the part of the amortisation category included, Coto-Millán and Inglada (2003b) has been used as reference, where it is estimated that half of the mentioned category corresponds to the passing of time, whereas the other half is related to the use of the vehicle.

Continuing with this assumption, the structure of the cost savings has been obtained, eliminating the fixed categories as well as the taxes, for each of the routes that make up the corridor. With the aim of obtaining greater precision in the results, these routes have been broken down into several sections which are similar with regard to traffic. The costs considered in each section and for which specific methods have been used are: vehicle amortisation, maintenance, fuel consumption, lubricant consumption and tyre wear.

Reduction of external costs

For the assessment of external costs, we have considered the methodology and the results of Coto-Millán and Inglada (2003c). The end values for the modal social costs per unit

are shown in Table 3.

Table 3.- External marginal social costs per means of transport. (Euro cents per passenger or tonne -km)

	Environmental	Infrastructure Conservation	Accidents	Congestion
Car	1.89	0.84	3.05	2.14
Train (passenger)	0.60	2.62	0.17	-
Coach	0.67	0.16	0.78	0.37
Airplane	2.46	-	-	-
AVE	0.49	-	-	-
Lorry	3.57	1.58	3.53	2.14
Train (cargo)	1.61	3.50	0.15	-

Source: Authors' compilation based on Coto-Millán and Inglada (2003c)

Time savings for users of high speed train

A chapter of the benefits attached to the introduction of the AVE is formed by the time savings for travelers from other modes of transport and new travelers. Thus, the values of time considered, in euro per hour for each traveler, are: 7.36 (car) 31.15 (air) 3.97 (bus) 15.86 (train). For its assessment, it is necessary to know the modal travel times from the origin to the destination for each means of transport (including the times to and from the station or airport) and the monetary values assigned to the total travel time.

Likewise, in order to calculate the savings corresponding to the generated trips it is necessary to have access to the monetary costs of each means of transport, which makes it possible to obtain the income.

The product of the time savings (expressed in hours) by the value of the time hour defines this benefit category.

3.- VALUATION OF THE PROJECTS

In order to determine the final net benefit of the project, it is necessary to update the annual benefits and costs with regard to the year considered as base, by means of a real social discount rate r, in such a way that the present value of the investment is:

$$VAN = \sum_{t=0}^{n} \frac{B_t}{(1+r)^t} - \sum_{t=0}^{n} \frac{C_t}{(1+r)^t}$$

(1)

Where "Bt" and "Ct" represent the annual benefits and costs of the project.

As a basic alternative in our project valuation, a social discount rate of 4% has been taken. In

the same way a 3% GDP growth, 40 years' duration of the project, a period for the execution of the investment of 6 years and 0.93 million Euros as the human life value are considered. The indicators used to quantify the assessment criteria are always calculated by means of the variation between the situation of reference, or without project (object under assessment, which we call the base case scenario), and the scenario that incorporates the project under study (situation with project).

Table 4.- Social benefit of AVE (Case of passenger transport). Millions of Euros in 2008

	AVE Benefits (Santander-Madrid)	AVE Benefits (Santander-Bilbao)
Total cost of infrastructure, maintenance and		
Infrastructure	1230.07	584.83
Residual value	110.04	56.17
Rolling stock	395.49	59.36
Infrastructure Maintenance	144.30	20.43
Operation	1383.22	152.57
Time savings of users from:		
Other means of transport	651.25	93.20
Income for Generated Trips:	735.54	195.00
Reduced costs in:		
Conventional railway	146.86	27.17
Airplane	304.64	-
Coaches	44.97	4.95
Car operation costs	735.89	176.40
Congestion	57.96	17.90
Accidents	224.25	47.50
Environment	102.35	18.30
Infrastructure Maintenance	146.74	29.50
Present discounted net value of the AVE	107.41	-151.10

Source: Authors' compilation based on methodology described in the text

Using the methodology mentioned above we have carried out a benefit-cost analysis of the high speed railway between Santander-Madrid and Santander-Bilbao. This assessment has been carried out in a single stage, where the project's net social benefit has been obtained, on the basis of only passengers being transported. The results obtained are shown in table 4. The present value of the net social benefits is 107.41 million Euros of 2008 for the Santander-Madrid AVE. Thus, the social benefits exceed the social costs in 107.41 million Euros. Similarly, the Internal Rate of Return (IRR) determined for this Project is 5.10%. On the other hand, the net present value of the social benefits is -151.10 million Euros for the Santander-Bilbao case.

3.1 Sensitivity analysis

A sensitivity analysis regarding the variables that have the greatest impact on the project's profitability for the Santander-Madrid case has been carried out. The values of the corresponding internal rates of return are shown in table 5.

Table 5.- Values considered of the most relevant variables

	Project duration 60 years	Human life value 1.5 million Euros	Growth rate 2.5%	Growth rate 3.5%
IRR in real terms	6.24%	5.58%	4.39%	5.80%

Source: Own elaboration

4.- CONCLUSIONS

The results of the benefit-cost analysis carried out clearly show that the Santander-Madrid AVE project is the most economically profitable option, so this could be a valuable information source for public decision making on transport infrastructure investment. In our recent work Casares, Coto-Millán and Inglada (2010) we have obtained a demand threshold of 6.5 million passengers, for an initial basic project in Spain, which seems to contradict the results presented in this research. Nothing is further from reality, as in our research on the demand threshold we already advised that such a result could only be provided for an initial project in Spain with no connections with other high-speed networks. We also noted that for subsequent projects, the network effects would be very positive (see in this context the work of Coto-Millán et al., 2007) so that the threshold of demand can be so significantly reduced that it is possible to get perfectly viable sections as reported here.

We should also point out that our analysis considers other positive effects of a transitory nature which take place during the implementation of the project and which will especially affect production and employment as well as the effect of an infrastructure of this kind in attracting logistics operators and industrial and service companies, which might improve significantly the results obtained in both cases.

It is important to point out that the sensitivity analysis carried out confirms the results obtained for the base case scenario, Santander-Madrid, while for the Santander-Bilbao case a sensitivity analysis carried out in a more favourable scenario (60 years or GDP growth of 3.5%) would significantly improve the results.

This research constitutes an interesting horizon of analysis that allows for better planning of transport infrastructure in a context of scarce resources which obliges to take decisions or at least to temporalize them.

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