Traffic forecasting for high speed rail services: applying the European experience

Richard Paling

Director
Steer Davies & Gleave (NZ) Ltd

Abstract:

The construction of a new high speed rail link between Madrid and Barcelona will provide an important link in the Spanish rail network, and could form part of a Europe wide high speed rail network. Experience from France and Britain indicates that the impact of accelerated train services can be substantial, especially where important time thresholds are crossed. These may be dificult to incorporate in conventional modelling approaches, especially if the time or data available is limited. The paper reviews this experience and then describes the development of a forecasting model applying the relationships observed to the situation in Spain.

Steer Davies & Gleave
P O Box 3848
Wellington
New Zealand
Telephone: (04) 732 693 Fax: (04) 733 414

Background and introduction

The construction of the proposed route for a high speed train (TAV - tren de alta velocidad) between Madrid and Barcelona in Spain will form an important link in the rail network within the country, connecting the two largest urban areas, with a combined population of about 13 million. In addition to connecting the two cities, it is also planned that this will form part of a link connecting Sevilla in the south of Spain and Madrid with the rest of the European high speed rail network. This should allow rail to compete vigorously with air for international traffic within Europe. A map showing the location of the line is set out in Figure 1.

The construction of the line by RENFE, Spanish Railways represents a major investment estimated to cost the equivalent of about NZ $50 billion. Unlike the French TGV, a new track has to be provided for the entire length of the route since it is intended to operate the services with trains using the European gauge rather than the broader gauge used by the rest of the Spanish network. This will allow the line potentially to be interconnected to the rest of the European network, but increases the cost of the route.

The distance between Madrid and Barcelona is about 600 km and the volume of long distance traffic within the corridor in 1988 was estimated to be 8 million journeys. The route is served by three main competing modes of transport. The Spanish air carrier Iberia provides an hourly shuttle service between the two cities, and carries a dominant part of the traffic between the two. City centre-city centre times are about 3 hours although these are affected by traffic congestion in the roads giving access to the airports particularly in Madrid and delays at the airports themselves. Rail services are provided by a mixture of high class TALGO trains and slower trains with station- station journey times of between just less than seven hours and about 11 hours. The road link between the two cities is part dual carriageway toll road, the autopista, and part a single carriageway road, giving typical journey times of about 7.5 hours or more. The single carriageway section is in the process of being upgraded to dual carriageway status, and it is expected that this work will be completed by the early 1990's. This should reduce the journey time to about 6 hours.

Between Madrid and Barcelona there are two major towns in the corridor, Zaragoza and Lerida, each of which generates considerable volumes of traffic. The share of air traffic to these cities is however small.

The overall split of long distance traffic in the corridor is set out in Table 1 and Figure 2. It should be noted however, that the figures for the movement by road (bus and car) are much less reliable than those for rail and air.

FIGURE 1 LOCATION OF PROPOSED HIGH SPEED RAIL LINE

FIGURE 2 MODAL SHARES FOR SELECTED MOVEMENTS IN THE MADRID–BARCELONA CORRIDOR

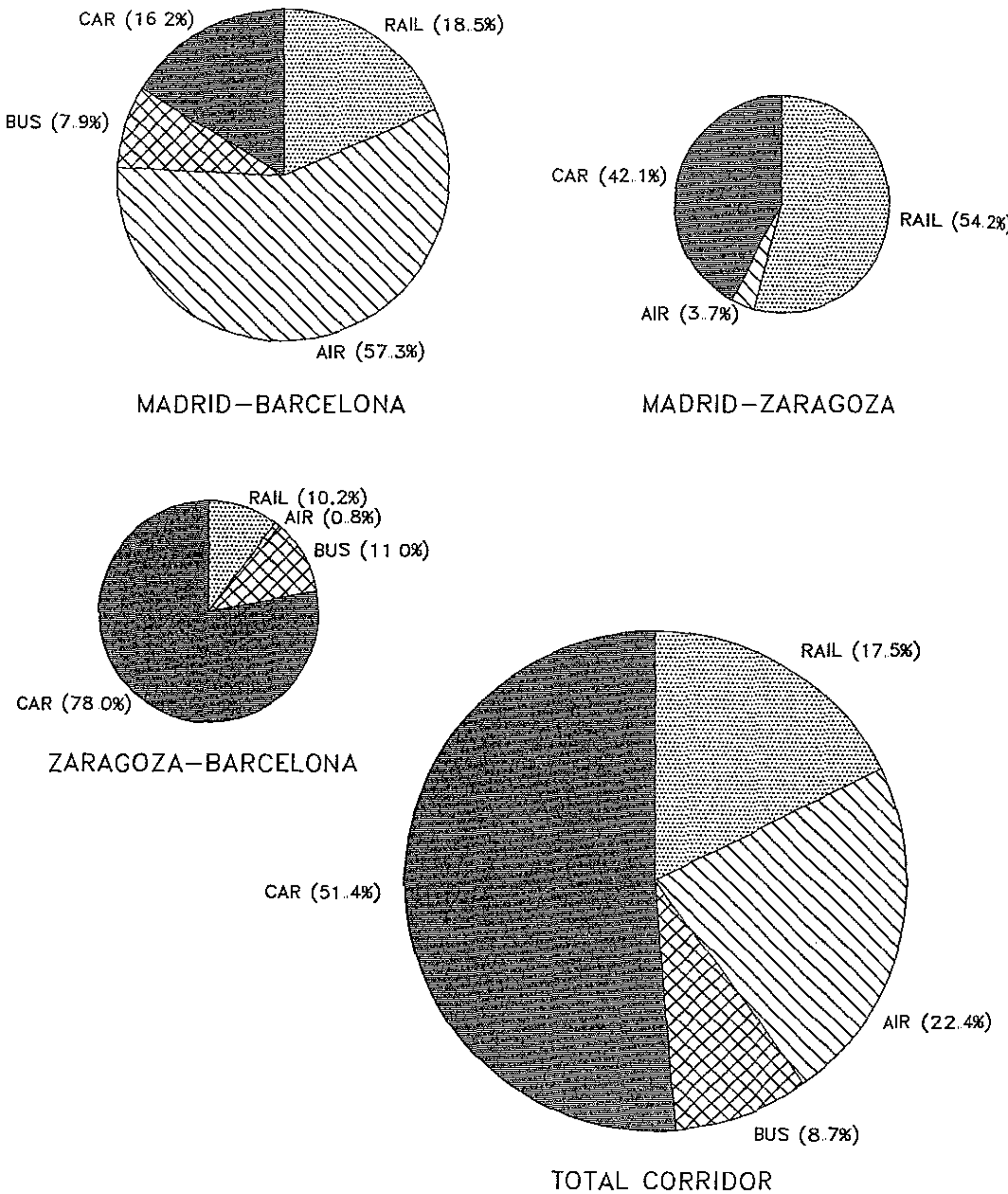


Table 1 Observed Flows in the Madrid-Barcelona Corridor: 1988 (thousands of journeys)

	Rail	Air	Bus	Car	Total
Madrid-Barcelona	560	1,730	240	490	3,020
Madrid-Zaragoza	580	40		450	1,070
Madrid-Lerida	50			90	140
Barcelona-Zaragoza	120	10	130	920	1,180
Barcelona-Lerida	60	250		1,670	2,000
Zaragoza-Lerida	20		70	460	550
Total	1,380	1,780	690	4,080	7,950

Source: RENFE
Dobeson 1989(a)

Note: Totals may not equal the sum of the individual elements because of rounding errors

For the longest movement between Madrid and Barcelona air travel dominates the market with a share of over 50 per cent. For the shorter movements where there is no real competion from air, the share of rail varies from about 50 per cent in the south between Madrid and Zaragoza where the competing road link is poor, to about 5 per cent in the north, where the road network is of a high quality and distances between the major cities are smaller.

The scope of the work undertaken

Work on the demand forecasts for the new line has already been undertaken, but no allowance has been made for any traffic generated by the new route, as opposed to diverted from competing modes (INECO (1989)). In the light of the perceived experience of the TGV in France where traffic growth was very rapid this felt to be a major shortcoming. As a result a team of consultants led by SRI of the United States and including Gibb and TecnEcon of the UK, was invited to undertake a review of the traffic forecasts to take particular account of European experience.

It was originally anticipated that this work should be completed within 8 weeks. This therefore precluded the construction of a large analytical model. The work undertaken was therefore based on an analysis of the changes in traffic flows that had arisen in Britain and France following the introduction of accelerated train services. It was hoped that the relationships derived could then be applied in Spain to give estimates of the total traffic that might be attracted to the new high speed trains (TAV).

The rest of this paper therefore considers the evidence of the effects of upgrading train services in Europe and the way in which these could be incorporated into the forecasting process for the Madrid - Barcelona link.

French and British experience

French experience

The TGV ("Train de Grand Vitesse") was first introduced by SNCF in 1981 on services between Paris and Lyon in the South East of France and between Paris and Geneva. To enable maximum benefit to be achieved from the new trains, new track was constructed, and over the period to 1984, this gradually extended from Paris to a point just north of Lyon. The TGV trains were capable of operating on both the new purpose built routes and the existing lines, albeit at reduced speeds. Unlike the position in Spain, it was therefore possible to introduce TGV services to a number of destinations from the outset. As additional lengths of new track were completed, the journey times for these services were gradually reduced and services to further towns and cities were also added to the TGV network.

The network has recently been expanded by the introduction of the TGV Atlantique, providing services between Paris, Le Mans and areas further west in Brittany and the Loire Valley. It is however too soon to assess the impact on the number of travellers and the patterns of movement in this corridor, so attention has been concentrated on the movements between Paris and the South East.

The patronage of the TGV and other "classic" train services in the South East corridor is set out in Table 2.

Table 2 Numbers of Travellers on TGV and Other Train Services in the Paris-South East Corridor

(Millions)

	TGV	Other	Total	TGV share %
1980		12.2	12.2	-
1981	1.2	11.5	12.7	9
1982	6.0	8.4	14.3	42
1983	9.0	6.7	15.7	57
1984	13.3	5.0	18.4	72
1985	14.7	4.4	19.2	77
1986	14.9			
1987	16.3			

Source: Dobeson 1989 (b)

After substantial growth in the early years following the introduction of the new trains into service, the growth of the numbers of passengers carried by the TGV has slowed, averaging about 7 per cent over the period between 1984 and 1987.

The introduction of the TGV has clearly led to substantial increases in the numbers of travellers carried by rail. It has been estimated that overall the elasticity of demand with respect to journey time experienced was in the order of about 1.5 (or strictly speaking -1.5). In addition to considering the total increases in traffic, however it was important to identify the source of the additional journeys, in particular whether these are diverted from other modes such as air or road travel or whether they represent new travel, journeys which would not have been made in the absence of the TGV.

Over the period between 1980 and 1984, the numbers of rail travellers in the corridor grew by about 6.2 million, an increase of about 50 per cent. Over the same period, the numbers of air travellers between Paris and Lyon fell by over 40 per cent, and between Paris and Marseilles grew by only about 45 per cent. These can be compared to typical growth factors of about 60 per cent for routes between Paris and other major cities in France away from the South-East axis.

The increase of the 6.2 million was estimated to arise as follows:-

Diverted from air	2 million
Diverted from private car	1 - 1.5 million
Induced	2.5 - 3 million

Information was also available on the movements between Paris and Lyon. The total number of trips by TGV between Paris and Lyon in 1984 was about 4.5 million compared with a total of about 1.7 million trips in 1980. The share of this movement in the total therefore increased from about 10 per cent to about 25 per cent.

Of the increase, about 0.9 million were estimated to be diverted from air. No direct information is available for traffic diverted from road, but this was estimated to be about 0.5 - 0.6 million, giving a total diversion of road and air travellers of about 1.4 to 1.5 million. Induced or generated traffic therefore amounted to 1.2 - 1.4 million per year. This represented about 40 - 50 per cent of the total induced traffic in the corridor.

Given that the share of travel between Paris and Lyon in total TGV traffic was somewhat lower, at about 35 per cent, this would imply that there was a greater degree of induced traffic for this movement than for other, mainly longer journeys.

The growth of traffic between Paris and Lyon reflects the reduction in the journey time of about 1 hr 50 mins, from 3 hours 50 mins to 2 hours. Given the increase in demand of about 150 per cent this would imply an elasticity of demand for train passengers with respect to time of about 3.1. This is a very high figure and probably reflects:-

(a) A threshold effect as the time by TGV is now below that of air travel between Paris and Lyon and there is thus likely to be a major switch of time sensitive traffic to train away from air.

(b) With the reduction of the journey time to 2 hours, day trips to Paris for a range of purposes become attractive, resulting in a considerable degree of new "induced" traffic.

If the total elasticity of demand is broken down into its components, using the increases in traffic described above, the cross-elasticities derived are as follows:-

Diversion from air	0.31 x 3.1 =	0.95
Diversion from road	0.22 x 3.1 =	0.70
Total diversion		1.65
Generation of new traffic		
	0.47 x 3.1 =	1.45
		3.1

In interpreting these elasticity figures, it is important to appreciate that it is not only the reduction in journey times that is generating additional trips, but also the "image" projected by the TGV. In addition the high elasticity figures probably only apply to a situation where certain critical thresholds have been crossed, and the elasticity may thus alter with the magnitude of the time saving, and the base from which it is measured.

British experience

The experience in Britain has been rather different from that in France, since:-

(a) the development of high speed services has been largely an incremental process and

(b) services operating at the very high speeds achieved by the TGV in France have not been developed.

Improvements have been achieved by increasing train speeds on existing routes. As a result, there has been no opportunity to market the high speed trains as a new separate type of transport, but merely as the extension of existing services. Lower elasticities of demand with respect to time than for France are therefore likely to be recorded.

The two main service changes that have occurred and that have been investigated are the electrification of the West Coast Main Line (WCML) services which took place in the late 1960's and the early 1970's and the introduction of the High Speed Train (HST) over a number of non-electrified routes during the later 1970's.

The effects of the electrification of the WCML services between London, Manchester and Liverpool indicated that for rail travel there was a high elasticity of demand with respect to time of about 1.3, although this is somewhat below the figure experienced for the TGV (Evans (1969)). Some of this additional demand was transferred from air travel, but there appeared to be little diversion away from road travel. Much of the increased demand therefore appeared to consist of journeys which would not otherwise have been made, a finding that is consistent with the evidence from the introduction of the TGV in France.

Of particular importance to the proposed construction of a high speed link between Madrid and Barcelona was the finding which arose from subsequent research that if rail could achieve door - door journey times comparable to those by air, and at lower prices, then air would retain little traffic other than that feeding into other air services. This suggested that particularly large increases in traffic would come from reducing rail journey times to a threshold of around three hours, as was the case for Manchester and Liverpool.

The results derived from the initial research are set out in Table 3.

Table 3 Effects of the Electrification of the West Coast Main Line Services on Major Flows

Movement between London and:-	Per cent change in rail traffic	Per cent change in journey time
Manchester	+27	-26
Liverpool	+58	-24
Preston	+46	-16
Crewe	+35	-34

Source: Evans (1969)

The changes set out above were estimated on the basis of surveys carried out just after the opening of the new rail service. These probably represent minimum estimates of the traffic attracted by the reduction in journey times, since over the longer term, passengers and potential passengers have more opportunities to adjust their travel behaviour to take advantage of the new opportunities offered. Examination of the impact of the introduction of High Speed Train services, discussed below, suggests that the long term elasticities are higher than those experienced over the short term, typically by a factor of 30-50 per cent. It is therefore considered that with a longer adjustment period, the elasticity of demand for movement between London and Manchester calculated to be about 1 in the short term, would increase to about 1.3 to 1.5. The figure for Liverpool would similarly increase from 2.4 to 3.1-3.6, figures that are broadly comparable with those for Lyon considered above.

Further studies examined the impact of the introduction of the High Speed Train, and the main findings of this work are summarised in Table 4

Table 4 Impact of Introduction of High Speed Trains in Britain

(Per cent increase in traffic on routes to and from London)

	First class	Second Class	Total
Bath	84	43	54
Swindon	112	30	42
Cardiff	57	27	34
Bristol	55	26	28
York	22	17	23
Leeds	28	15	19
Plymouth	0	0	0
Median of all routes examined	32	16	23

Source: Owen and Phillips (1987)

The largest effects of high speed rail services were felt for travel between London and Swindon and Bath, the stations closest to London, and which therefore might be expected to generate the largest commuter, and presumably leisure trips. It may also be significant that services calling at these stations were the first to operate with the High Speed Trains, and this may have contributed to the large increase in traffic experienced.

An analysis was also made by Owen and Phillips of the speed of response to the introduction of the new train services, and the effects were examined over the short-term, ie immediately after the introduction of the new services, and the long-term, the period over which all the effects were considered to have worked themselves out. In general it appeared that the long-term effect was about 30-40 per cent higher than the increase in patronage which took place immediately after the introduction of the new services.

Overall the studies of the impact of the introduction of the High Speed Train Service suggested an elasticity of demand of about 0.8. This is lower than the figures derived from the examination of the West Coast Main Line electrification. There are a number of reasons why this difference may have arisen. The base traffic figures for the West Coast Main Line were low, and thus a relatively small increment of traffic would give rise to high estimates of journey time elasticity. In addition the improvement of journey times probably crossed important thresholds on the routes between London and Manchester, allowing rail to compete effectively with air which had up to that point carried large volumes of passengers. This situation did not occur for high speed service to the west. The journey time elasticities experienced on the WCML of 1.3 or 1.4 are broadly similar to those experienced with the introduction of the TGV in France where similar conditions, particularly in terms of crossing critical time thresholds, prevail.

Conclusions from French and British experience.

The experience of France and Britain indicates that the impact of high speed trains has been broadly similar in the two countries, if allowance is made for the different circumstances in each. With the introduction of the new high speed trains, the elasticity with respect to travel time appears to be about a minimum of 1 - 1.5 with higher figures being experienced when critical time thresholds are crossed or where there are opportunities for diverting high volumes of traffic from competing air routes. For the case where the service improvement simply represents an acceleration of existing train services, the British experience suggested that an elasticity of 0.8 was appropriate.

Where new high speed trains are introduced but where no critical time thresholds are crossed or where there is no opportunity for the large-scale diversion of traffic from air a higher elasticity was judged to apply. A figure of 1.2 was used in these cases. The experience from the Paris-Lyon route suggests that for routes where important thresholds are crossed, but where there is again no opportunity for substantial diversion from air, the elasticity with respect to travel time is about double, and a figure of 2.4 was used. Such a value would apply to movements between Zaragoza and Madrid, Zaragoza and Barcelona, and Zaragoza and Lerida.

For only one of the movements considered, Madrid-Barcelona, is travel by air an important element of the total. The potential increase in traffic on this route with the introduction of the TAV is considered separately below.

The approach to traffic forecasting

The method of traffic forecasting used in the study had to take into account a number of factors including:-

(a) The limited time scale for the study
(b) The need to take account of the potential for the generation of new movements in the corridor with the construction of the high speed line
(c) The limited reliability of data on existing traffic movements for modes other than rail and to a lesser extent air.

The approach adopted therefore took as a base the existing observed flows by rail and air and considered explicitly the effects that the improvements in journey times and journey quality would have on the pattern of movement along the route. The form of the model used meant that the development of detailed and accurate forecasts for road transport was not required. In addition use could be made directly of the relationships observed both within Spain and further afield in France and Britain.

In addition to the journey time elasticities discussed above, information was also required on fare elasticities. The elasticity with respect to fares derived from British experience was in the order of about 1. However, work undertaken in Spain (INECO 1989) indicated that a lower elasticity of about 0.9 was typical and this figure was therefore used in the analysis.

As well as the proposed construction of the new rail route, a number of other improvements to the transport links in the corridor were under construction or proposed at the time of the study. These included

(a) the construction of the dual carriageway link between Madrid and Zaragoza, completing the high quality highway route linking Madrid and Barcelona.
(b) the improvement of journey times on the existing rail network
(c) the reduction of through travel times by air with the construction of a new rapid transit link between the centre of Madrid and the airport, reducing the access time and particularly its variability by a considerable margin.

The model developed therefore had to be able to take these factors into account, as well as the effects of different fare levels for the TAV and different reactions from the competing air carrier or carriers on the route. In addition there are a number of route options which would affect the times taken for the movements along the route, and hence its attractiveness.

Forecasting steps

Having derived the various elasticities and parameters the steps to forecasting volumes of traffic using the new high speed trains are summarised in Figure 3.

Preparation of Base Forecasts for 2000 and 2010.

The base forecasts for 2000 and 2010 were derived taking into account three major elements:-

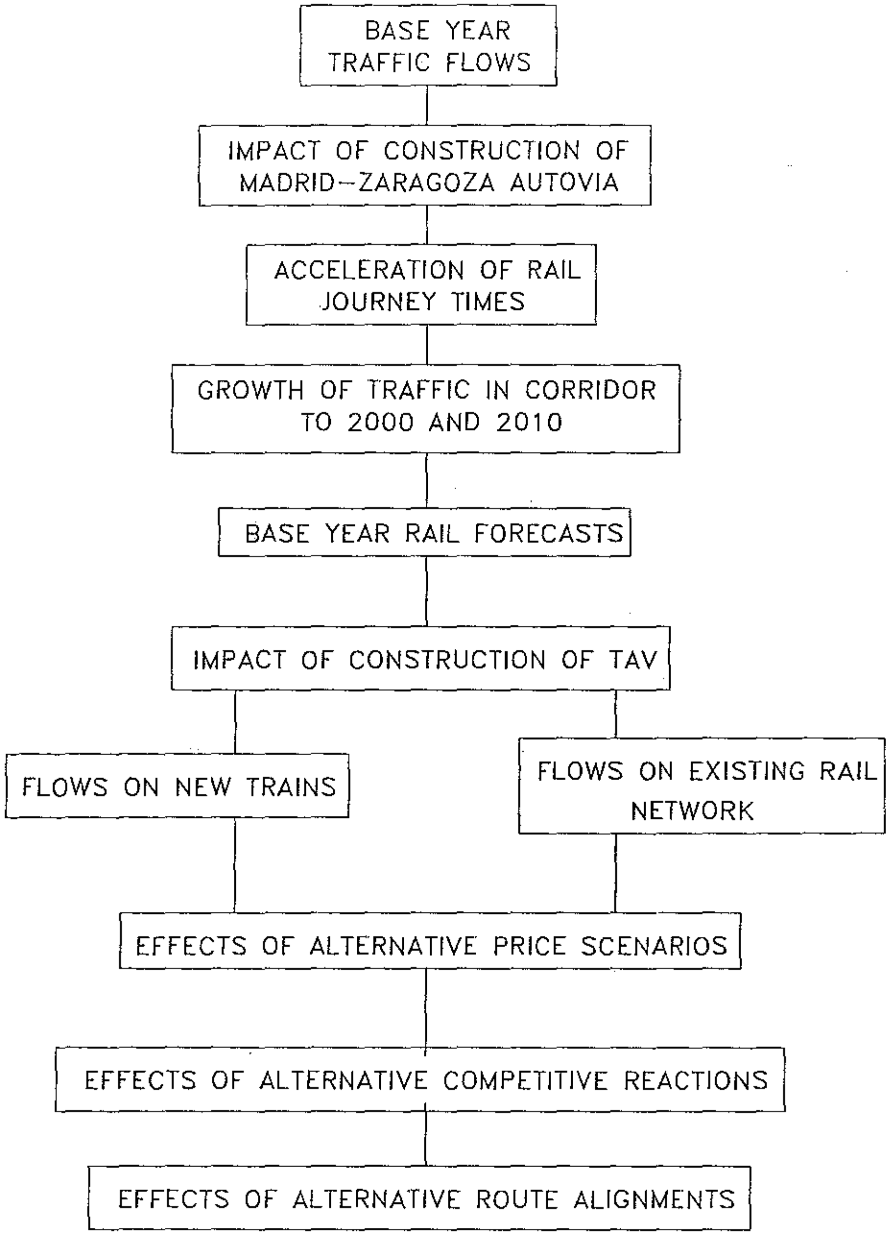
(a) The impact of the upgrading of the road link between Madrid and Zaragoza.
The distances between Madrid and Zaragoza and Zaragoza and Barcelona are similar. The impact of the construction of the dual carriageway between Madrid and Zaragoza was therefore estimated based on the experience from the section of the route between Zaragoza and Barcelona between 1983 and 1988 (Dobeson 1989 (b)) when this road was upgraded. This indicated that the effects on rail traffic could be substantial and its share of the traffic between Madrid and Zaragoza was forecast to fall by a third.

(b) Improvements in rail journey times.
In part the fall resulting from the improvement of the road network would be offset by increases in traffic as a result of the reductions in rail journey times planned for the period up to 1991. These were assessed using the elasticity of 0.8, derived from British experiences. The overall effect of these two changes was to reduce rail traffic in the corridor by about 8 per cent.

(c) The impact of economic growth.
Between 1988 and 2000 and 2010, the forecast years, the traffic in the corridor was estimated on the basis of an expected growth in GDP of about 3 per cent per year.

The effect of these factors was to give a forecast rail base traffic in 2000 about 40 per cent higher than in 1988, equivalent to an annual growth of about 3 per cent.

FIGURE 3 DEVELOPMENT OF THE TRAFFIC FORECASTS



Assessment of the Impact of the TAV.

The construction of the TAV would permit the rail journey between Madrid and Barcelona to be reduced to about 3 hours. This is about 45 per cent less than the time with conventional trains even after the planned upgrading has been undertaken. To assess the effects of the improved journey times the range of elasticity values discussed earlier were applied to the different movements along the route. For the movements where journey times were reduced below about 2 hours, the higher elasticity value was applied reflecting the particularly high growth likely in day trips between the centres. This factor was applied to the movements between Madrid and Zaragoza, Zaragoza and Barcelona, and Barcelona and Lerida. For the movements between Lerida and Zaragoza and Barcelona and Lerida the lower elasticity of 1.2 was applied.

The Diversion from Air Transport

The movement between Madrid and Barcelona was treated as a special case because of the high volume of air traffic which potentially could transfer to rail. As discussed above, the evidence from Britain and France has indicated that there is likely to be a considerable switch from air travel if city centre - city centre journey times by rail are reduced to be similar or lower than those by air. The air travellers on the route can be divided into two main categories: those interlining at either Madrid or Barcelona, and those who were simply travelling between the two cities using the "Puente Aero", the air bridge, estimated to account for about 80 per cent of the total. The improved rail services would in general only be attractive to the second group. Based on the experience elsewhere in Europe, it was forecast that in the absence of any competitive reaction from the current carrier, Iberia or new airlines entering the route, about three quarters of the Puente Aero traffic was likely to switch to rail.

The final step in the forecasting was to determine the split between the conventional rail services and the new TAV services. Based on the observed split between the higher speed and higher priced express trains, and slower and cheaper stopping trains, it was estimated that about 80 - 90 per cent of rail travellers would choose the new high speed services.

The initial forecasts developed were based on a continuation of the existing fares policy, the shortest of the various route options considered and the lack of a competitive reaction from air transport. Subsequent refinements of the forecasts considered alternative assumptions as well as other potential sources of traffic from the smaller towns en route and the possibility of using the route for commuter traffic and long distance traffic with origins and or destinations outside the corridor. In general however, these were based on the same procedures developed for the main long distance forecasts.

Conclusion

The experience of Britain and France indicates that the acceleration of train services can give rise to substantial increases in traffic in particular conditions. These responses can be enhanced with the introduction of new and existing forms of rail transportation. The application of the factors derived to existing traffic flows and the proposed improvements in service, provided a rapid and flexible means of forecasting the traffic likely to be generated by the construction of a new high speed rail route connecting the major urban centres in Spain.

References

Dobeson, K (1989b) La Experiencia Francesa con el Tren de Alta Velocidad (TGV) desde 1981 internal document for RENFE Spanish Railways

Dobeson, K (1989a) Estimacion del Potential a Largo Playo de la Demanda Inducida de Viajeros TAV internal document for RENFE Spanish Railways

Evans, A W (1969) Intercity Travel and the London Midland Electrification, Journal of Transport Economics and Policy. Vol III 69-95

INECO, (1989) Previsiones de Demanda en la Relacion de Alta Velocidad Madrid-Zaragoza-Cataluna internal report for RENFE Spanish Railways

Owen AD & Phillips GDA (1987) The Characteristics of Railway Passenger Demand: An Econometric Investigation, Journal of Transport Economics and Policy. Vol XXI 231-253