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SESSION 2: ADAPTING THE INTERMODAL NETWORK TO THE PASSENGER MARKET – LONG-TERM PLANNING AND ASSESSMENT

When to invest in high-speed rail links and networks ?

by

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1. Introduction

Definitions of high speed rail (HSR) differ, but a common one is rail systems which are designed for a maximum speed in excess of 250 kph (UIC, 2008). These speeds invariably involve the construction of new track, although trains used on them can also use existing tracks at reduced speeds.

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A number of countries have upgraded existing track for higher speed, with tilting technology on routes with a lot of curves. However such trains do not normally run at speeds above 200 km p h. Their rationale is to upgrade services at relatively low cost in countries which have sufficient capacity to cope with increased divergence of speeds on routes shared with all forms of traffic. Most of the countries which adopted this strategy initially, such as Britain and Sweden, are now considering building HSR.

The only form of totally new technology that has come close to being implemented is maglev. However, no country yet uses such a system for inter city transport. It was proposed to introduce such a system between Hamburg and Berlin, but this project has been abandoned; it is still under discussion for the Tokyo-Nagoya route in Japan. The technology is capable of very high speeds, but apart from cost considerations, it has the inflexibility that the trains are not able to make use of a section of new infrastructure and then to transfer to existing tracks to finish their journey. The latter mode of operation is a feature of all new high speed rail systems worldwide, even where – as in Japan and Spain – the new lines are built to a different track gauge from the existing lines (Spain uses bogies capable of adjustment to the different gauge, whilst Japan has undertaken installation of limited sections of multi gauge track). Maglev technology has its greatest chance where there is sufficient traffic to justify both a new self contained route and the existing one, and the most likely corridor to satisfy that requirement in the near future is the Tokaido corridor in Japan.

Thus the only high speed inter city projects to have been completed to date use conventional rail technology with purpose built new lines for some but not all of the route network . That is therefore the focus of this paper.

In the next section we consider the motivation behind the introduction of HSR around the word. We then examine evidence on its impact on mode split. Following this consider the approach to appraisal of HSR followed by some actual examples. We then discuss a model that has been constructed to identify the key parameters that determine its social viability. After this we consider network effects and track access pricing before reaching our conclusions.

2. Motivation for the introduction of high speed rail.

The first country in the world to build a dedicated line for new high speed trains (originally at 210 km p h, so not satisfying the above criterion) was Japan. The background to this was that the original Tokaido line was narrow gauge (3 feet 6 inches) and unsuitable for high speeds. It was also at capacity. It was the twin desire for a big increase in capacity in one of the most densely used corridors in the world, and for a major improvement in journey time to be competitive with air that led to the approval of the construction of a new high speed line at standard gauge. The Tokaido Shinkansen started running between Tokyo and Osaka on October 1, 1964, and was an immediate success, carrying 23m passengers in its first year and leading to demands for its extension countrywide (Matsuda, in Whitelegg et al 1993). Wider economic considerations such as regional development and equality led to the development of Shinkansen investment on progressively less busy and profitable routes. When Japanese railways were reorganised as a set of separate regional commercial organisations in 1987, the high speed infrastructure was placed in a separate holding company (the Shinkansen holding company) and the new operating companies were charged for its use on the basis of ability to pay, thus permitting cross subsidy between profitable and unprofitable routes. (Ishikawaka and Imashiro, 1998). Whilst this decision was later reversed and the Shinkansen sold to the operating companies in order that it should appear on their balance sheets, the principle of basing the charge on ability to pay rather than historic construction cost was maintained.

The success of the Japanese high speed system, particularly in gaining market share from air, was undoubtedly a major factor inspiring European railways to follow the same path. The next in line was France, where intensive economic and technical research led to the proposal to build a new high speed line from Paris to Lyons. Again the background was a shortage of capacity on the route in question plus the growing threat of competition from air (Beltran, in Whitelegg et al 1993). In 1981 the TGV Sud-Est between Paris and Lyon opened with speeds up to 270km/h. The name Sud-Est was itself designed to emphasise the network effects of this line, which as well as serving the Paris-Lyons market carried trains for a large number of destinations beyond Lyons. From this beginning plans were developed for a network of lines with the justification being largely in transport cost-benefit analysis terms although hopes were also raised for wide regional economic impacts (Polino, in Whitelegg et al 1993). The idea that high speed trains should be open to everyone, at reasonable fares (democratisation of speed) was an important part of the philosophy and helped the popularity of TGV with the general public. Subsequent developments have seen extensions to Marseille and Nice, the TGV Atlantique Paris-Bordeaux, Paris-Lille-London/Brussels and most recently Paris-Strasbourg.

The background to the introduction of high speed rail in Germany was somewhat similar; a perceived shortage of capacity in the face of growing demand, accentuated by particular bottlenecks on north-south routes which had become more important following partition. Again the growing threat of air and car competition also led to a perceived need for high speed to satisfy the marketing requirement of ‘twice as fast as car; half as fast as plane’. (Aberle, in Whitelegg et al 1993). However, the geography of Germany did not lend itself to development of a single key route, but rather of new sections of track where particular bottlenecks occurred. These were designed for both freight and passenger traffic, although their use by freight has been small. Although construction started in 1973, it was held up by environmental protests. Not until 1985 was a new design of high speed train (the ICE) introduced. Gradually these trains were extended to cover the principal inter city routes throughout Germany, with long stretches of running on conventional track upgraded for 200 km p h. Thus the marketing of the ICE is very different from that of the French TGV; a lot of shorter journeys are made on it, reservations are not compulsory and load factors averaging 50% as opposed to the French 70% are tolerated.

The geography in Spain is more like that of France, with long distances between the major cities and even less intermediate population. Given the relatively low quality of the inherited infrastructure, Spanish Railways were rapidly losing market share to air and car. High speed was seen as a way of enabling rail to compete, as well as promoting regional economic development (Gomez-Mendosa, in Whitelegg et al 1993). Whilst construction of the first line, Madrid-Seville, was hastened to serve the International Exhibition in Seville in 1992, construction of a whole network of lines was encouraged by Keynesian policies of relieving large scale unemployment by a major public works programme. The aim is to link Seville—Madrid—Barcelona to the French TGV system, and for that reason the network is being built to standard gauge even though other main lines on the Iberian peninsula are broad gauge.

Italy took its first steps towards construction of dedicated high speed lines early with the Rome-Florence Direttissima, work on which started in 1966 and the first section of which opened in 1976 (Giuntini, in Whitelegg et al 1993) but it was not until 1985 that a team was set up explicitly to study high speed rail, leading ultimately to plans for a network of lines.

The early development of high speed rail in Europe was entirely at the national level, using domestically produced technology (France, Germany and Italy each produced their own high speed rolling stock using national manufacturers). However, the advantages of linking lines into a European inter-operable network were realised, and the concept emerged of a 15,000 km network of high speed routes emerged, linking all the major cities of Europe (CER, 1989).. The 1993 Treaty of Maastricht called for a network of Trans-European lines, linking the existing high speed lines. Of major strategic importance were the new line between Brussels and Cologne, the extension of TGV Sud-Est to the Spanish border, the planned Alpine crossing between Lyon and Turin and links between the French and German networks (TGV Est). Recognition that such lines would benefit not just the countries in which they were built but the European Union more generally led to their designation as part of the Trans European Network, and a large share of the limited European funds made available for transport infrastructure has been directed towards them. Peripheral countries have also received substantial funding for high speed rail from regional and cohesion funds, designed to reduce economic and social inequality within Europe.

By 2006, high speed trains in Europe were carrying 84b passenger km per annum, of which more than half was in France (UIC, 2008a). In the meantime, high speed rail has been extended to more countries in Asia, including Korea, Taiwan and China.

3. Impact on mode split

This section will briefly consider impacts on rail market share. Detailed results on market shares are available for the early impact on mode split of the Paris-Lyon and Madrid-Seville lines. TGV Sud-Est between Paris and Lyon was opened in two stages between 1981 and 1983. The train journey time was first reduced by around 30%, after the opening of the Northern section, and the implied journey time elasticity was around –1.6. However, the time elasticity was around –1.1 for a journey time reduction of around 25% on the opening of the Southern section of the route. The cause of this lower elasticity was because the transfer from air had been largely completed in the first phase when rail was fast enough to provide effective competition. The Spanish AVE service introduced in April 1992 reduced rail journey times between Madrid and Seville from around 6½ hours to 2½ hours, making what was a very unattractive service into one which competes effectively with air.

Table 1 indicates the market shares of plane, train and road before and after the introduction of high speed rail on these two routes. The impact on rail market share is very large, particularly in Spain where the improvement in rail journey time was larger. Much more traffic is extracted from air than road. It should be noted that the figures will have been influenced by a significant amount of newly generated traffic. Wilken (2000) reports that surveys of AVE passengers indicated that 15% of the additional rail traffic was newly generated, whilst according to Bonnafous (1987) no less than 49% of the additional traffic on Paris Lyons in the first four years was generated traffic. In other words, whilst there was indeed a substantial transfer from air, the reduction in road mode share was largely caused by the generation of rail traffic, rather than direct transfer.

Table 1: Before and After High Speed Market Shares

	TGV Sud-Est		AVE Madrid-Seville	
	Before	After	Before	After
Plane	31%	7%	40%	13%
Train	40%	72%	16%	51%
Car and Bus	29%	21%	44%	36%

Source: COST318 (1996).

More up-to-date figures are quoted by SDG (2006) and Campos and Gagnepain (2007) for the air-rail mode split, showing that where rail journey times are reduced below 4 hours, rail share of the rail-air market increases rapidly with further journey time reductions, and rail tends to have a market share of at least 60% and sometimes effectively drives air out of the market when rail journey times are below three hours. Future trends are found to depend on a wide variety of factors including the introduction of environmental charges on air transport and trends in air and rail costs.

It should be stressed that this evidence is from countries where for most people a city centre rail station is more convenient than an airport: where development is low density with weak city centres and poor public transport this may not be the case.

Kroes (2000) points out that the available evidence concerning modal shift relates to traffic that is not transferring at the airport to another plane. There is very little evidence on the transfer market. However, the increasing integration of rail with air with high speed rail stations at airports such as Paris, Brussels, Frankfurt and Amsterdam offers the prospect of much greater rail penetration into this market, especially if ticketing and baggage handling is better integrated.

4. Appraisal of HSR

The process of appraisal requires comparison of a base case with a series of options. It is necessary to be clear what the base case is and to ensure that a realistic range of options is examined. A base case that literally assumes a 'do-nothing' situation may be very unfavourable, particularly in the face of growing traffic, and thus exaggerate the case for undertaking a particular option; on the other hand the base case should not be padded out with unnecessary investments, as that may have the same effect. In general the base case should be a 'do minimum' and other likely investments should be examined as alternative 'do something' options. These alternatives should be compared on an incremental basis to see whether the additional cost of moving to a more expensive option is justified, and the phasing and timing of options should also be examined. The fact that a particular option is better than the base case is thus not in itself evidence that it is desirable.

In the case of high speed rail, the base case should therefore include such investment as is necessary to keep the existing service running, and consideration should be given to how to deal with any exogenous growth in traffic. This might mean investing in additional rolling stock or revising fares structures and levels. More major changes should be considered as alternative do something options. These might include upgrading existing infrastructure, purchase of a fleet of new tilting trains or indeed construction of additional road or airport capacity. There will also be options regarding high speed rail – how far to extend the new line; to which alternative points to run the new trains, what service frequency and pricing policy to adopt. It is essential to examine sufficient alternatives to be confident that the best alternative has been identified. The range of potential options makes appraisal of high speed rail a difficult task.

It is also necessary to consider the timing of investment. High speed rail might turn out to have the highest net present value, but if the demand for HSR and the other benefits from it are forecast to grow then it might still be better to postpone the investment.

HSR involves construction of new lines, stations, etc. and purchase of new rolling stock, and additional train operating costs and externalities (mainly noise, air pollution and global warming effects). The principal benefits from, HSR are:

- time savings
- additional capacity
- reduced externalities from other modes
- generated traffic
- wider economic benefits

Time savings are generally split into business, commuter and leisure. A relatively high proportion of HSR traffic is likely to be travelling on business, although questions have been raised on whether the full business value of time should be applied in this case on two grounds:

- many long distance business trips start and end outside normal working hours
- when travelling by train it is possible to work on the way (Hensher, 1977)

However, research has shown that firms are willing to pay something like the full business value of time even in these circumstances, presumably because of the benefits they perceive in shortening long working days and having staff less tired (Marks, Fowkes and Nash, 1986)

Additional capacity is obviously only of value if demand is exceeding the capacity of the existing route. But in those circumstances additional capacity may be of value not just in allowing for growth between the cities served by the high speed line, but also, by relieving existing lines of traffic, for other types of service such as regional passenger or freight. Of course, this raises the further option of building new capacity not for high speed passenger but for regional passenger or freight traffic. If new capacity is to be built anyway, then it is the incremental benefit of high speed versus the incremental cost that has to be considered, a comparison which is likely to make high speed look much more attractive than if the entire cost of new lines has to be justified on the basis of higher speeds. There is also clear evidence (Gibson et al. 2002) that running rail infrastructure less close to capacity benefits reliability; it may also lead to less overcrowding on trains. Both of these features are highly valued by rail travellers and especially business travellers (Wardman 2001).

Typically as illustrated in the previous section a substantial proportion, but not all, of the new traffic attracted to rail will be diverted from other modes – mainly car and air. To the extent that infrastructure charging on these modes does not cover the marginal social cost of the traffic concerned there will be benefits from such diversion. It is frequently argued that high speed rail has substantial environmental advantages since it diverts traffic from road and – particularly – air, where greenhouse gas emissions are much greater. On the other hand, as noted above, a substantial proportion of the traffic is typically newly generated or diverted from conventional rail, where given lower speeds, one might expect energy consumption to be lower. Of course high speed rail is invariably electrically powered, which gives the possibility of using a carbon free source of energy, whereas inter urban road and air transport are currently tied to oil. Electrically powered trains are also free from local air pollution, except for small particulate matter from braking, at the point of use, although the visual intrusion and noise from a new high speed line are often the subject of controversy.

One of the few studies to break down emissions in detail by type of train, as well as type of air and car transport is C E Delft (2003). They produce the following results:

Table 2 Energy Consumption by Mode 2010

	Intercity train	High speed train	Air (500km)	Diesel car on motorway
Seating capacity	434	377	99	5
Load factor	44%	49%	70%	0.36
Primary energy (MJ per seat km)	0.22	0.53	1.8	0.34
(MJ per passenger km)	0.5	1.08 (0.76*)	2.57	0.94

*At 70% load factor

Source: CE Delft (2003)

In other words, high speed rail has a substantial advantage over air transport, is similar to car and very much worse than conventional rail. Recent unpublished work for Network Rail suggests that on a heavily used new high speed line from London to Manchester, energy embodied in the infrastructure might add some 15% to these figures; obviously for a less well used line the increase could be substantially more. However. whilst the load factor given for high speed rail of 0.49 may be typical of Germany, where high speed trains spend a lot of their time running at conventional speeds on traditional track, and seat reservations are not compulsory, both the French TGV and Eurostar, with long non stop runs, compulsory seat reservations and sophisticated yield management systems, claim load factors similar to the 70% shown for air. A load factor of 70% reinforces the advantage over air and brings HSR below car, but it is still 50% higher than conventional rail. Given the sort of combination of mode switching and generation found above, the savings and costs tend to cancel out and the introduction of high speed rail cannot lead to a substantial energy saving; where there is little diversion from air, it will undoubtedly lead to an increase. So the claim of HSR to reduce greenhouse gases must rest on a non fossil fuel source of electricity generation, as is currently the case in some countries (e.g. France, with a high share of nuclear and Switzerland with a lot of hydro) but not others such as Britain.

Diverting traffic from road does not simply affect greenhouse gases, but also reduces road noise, accidents, local air pollution and congestion. The following table (Table 3) presents the unit values for these costs for a petroleum car, as estimated for a major European corridor in the European research project GRACE (GRACE, 2005 Deliverable 7). Whilst the off peak costs are quite similar between routes, the peak costs are much larger and more variable, being dominated by congestion costs which vary greatly from route to route.

Table 3 Marginal social cost and prices for long distance car transport

Car
Petrol
Milano-Chiasso

Interurban petrol GRACE car petrol EV

	Peak	Off-Peak	Night
Noise	0.007	0.011	0.035
Congestion	0.147	0.002	0.001
Accident	0.015	0.015	0.015
Air pollution	0.001	0.001	0.001
Climate change	0.005	0.005	0.005
W&T	0.016	0.016	0.016
	0.191	**0.050**	**0.073**

Chiasso-Basilea
Interurban petrol GRACE car petrol EV

	Peak	Off-Peak	Night
Noise	0.004	0.007	0.021
Congestion	0.194	0.003	0.001
Accident	0.008	0.008	0.008
Air pollution	0.001	0.001	0.001
Climate change	0.005	0.005	0.005
W&T	0.032	0.032	0.032
	0.244	**0.056**	**0.068**

Basel-Duisburg

Interurban petrol GRACE car petrol EV

	Peak	Off-Peak	Night
Noise	0.005	0.009	0.027
Congestion	0.123	0.002	0.001
Accident	0.008	0.008	0.008
Air pollution	0.001	0.001	0.001
Climate change	0.005	0.005	0.005
W&T	0.019	0.019	0.019
	0.161	**0.044**	**0.061**

Duisburg-Rotterdam
Interurban petrol GRACE car petrol EV

	Peak	Off-Peak	Night
Noise	0.009	0.014	0.043
Congestion	0.122	0.002	0.001
Accident	0.006	0.006	0.006
Air pollution	0.001	0.001	0.001
Climate change	0.005	0.005	0.005
W&T	0.020	0.020	0.020
	0.163	**0.048**	**0.076**

Table 4 shows what motorists pay for these routes (it is doubtful whether vehicle excise duty should be included here, as it is a fixed cost of car ownership and is unlikely to influence the decision to drive on a particular journey). It is found that in the peak there is a significant benefit of up to 10 eurocents per kilometre from removing cars from untolled roads, whilst in the off peak cars pay around their marginal social cost on untolled roads and more than that where a toll is payable. Of course, a higher shadow price of carbon would affect this comparison but as is seen greenhouse gas costs are not a large part of the total. In other words for road transport, the biggest issue concerns congestion. But it is unlikely that there will be a large net benefit from relief of road congestion unless the road is congested in the off peak as well as the peak.

Table 4 Road transport prices

Road Transport

Corridor segment	Km	Car Passenger Toll * €km	Fuel tax gasoline €km	Vehicle excise duty per km car gasoline	Total price
A8-A-9 Milano-Chiasso (I)	50	0.055	0.064	0.013	0.132
E35 Chiasso-Basilea (CH)	279	0.093	0.053	0.010	0.156
A5-E35 Basel-Duisburg (D)	584	0.046	0.056	0.012	0.114
E35-A25 Duisburg-Rotterdam (NL)	204	- -	0.058	0.020	0.078

Source: GRACE D7.

Table 5 shows similar estimates for social costs of air transport, taken from the IMPACT study. In the case of air, the absence of fuel tax means that there is normally no charge for environmental externalities, although this is crudely allowed for in some countries (including Britain) by a departure tax. In the absence of a departure tax there is an uncovered cost of perhaps 1.5 eurocents per passenger km on a 500km flight, or a total of 7.5 euros. In other words, diversion of 1 million passengers from air might give a benefit of 7.5m euros. It will be seen in the next section that this is not a very great contribution to the costs of HSR.

The other key issue for air is charging for slots at congested airports. The allocation of slots by grandfather rights, and charging structures based on average costs of running the airport (or less) means that charges may not reflect the opportunity cost of slots or the costs of expanding capacity. Where shortage of capacity is acute and the cost and difficulty of expanding capacity high, as at Heathrow, this may be a significant factor.

Table 5 Externalities air (eurocents 2000 per passenger km)

	Air Pollution	Climate Change	
Flight Distance (km)	**Direct Emissions**	**Direct Emissions**	**Indirect Emissions**
<500 km	0.21	0.62	0.71
500 – 1000	0.12	0.46	0.53
1000 – 1500	0.08	0.35	0.40
1500 – 2000	0.06	0.33	0.38
>2000	0.03	0.35	0.40

Noise costs per landing or take off (Schiphol)

	40 seater	100 seater	200 seater	400 seater
Fleet average	180	300	600	1200
State of Art	90	150	300	600

Source: IMPACT 2008 Handbook.

In other words, the biggest external benefits of HSR are likely to come where road or air are highly congested and expansion on those modes difficult and expensive, including in terms of environmental costs. Of course, HSR construction has its own external costs in terms of noise, land take and visual intrusion which must be set against these benefits. External costs for air are much higher for the shorter route due to their concentration on take-offs and landings.

Generated traffic leads directly to benefits to users, which are generally valued at half the benefit to existing users using a linear approximation to the demand curve. But there has been much debate as to whether these generated trips reflect wider economic benefits that are not captured in a traditional cost benefit analysis. Leisure trips may benefit the destination by bringing in tourist spending, commuter and business trips reflect expansion or relocation of jobs or homes or additional economic activity. The debate on these issues centres on whether these changes really are additional economic activity or whether it is simply relocated. In a perfectly competitive economy with no involuntary unemployment, theory tells us that there would be no net benefit. In practice, there are reasons why there may be additional benefits. For instance, if the investment relocated jobs to depressed areas, it may reduce involuntary unemployment. However, it is common for high speed rail to favour central locations, and if the depressed areas are at the periphery, this is the opposite of what is desired.

It is generally accepted that reducing transport costs may lead to benefits or costs that are not reflected in a standard cost-benefit analysis, due to market imperfections such as uncompetitive labour markets or agglomeration externalities (Graham, 2005). SACTRA (1999) suggested that wider economic benefits of schemes would not generally exceed 10-20% of measured benefits, whilst a specific study of the TENS network suggested that it would not change regional GDP by more than 2% (Brocker, 2004). On the other hand there may be specific cases where effects are much larger. The impact of HSR on Lille (with its uniquely favourable location) is often cited, whilst a study of a proposed high speed route in the Netherlands found wider economic benefits to add 40% to direct benefits. (Oosterhaven and Elhorst, 2003). Vickerman (2006) concludes that whilst high speed rail may have major wider economic benefits, the impact varies greatly from case to case and is difficult to predict.

5. Actual Case Studies

There are relatively few published ex post cost-benefit analyses of specific high speed rail projects, One of the few published studies, for Madrid-Seville, which opened with less than 3m trips per annum and is still carrying only of the order of 5m trips p.a., found the project not to be justified. (de Rus and Inglada, 1997). A summary of the appraisal is given in Table 6. In this case, it appears that the social benefits of the line do not even cover the costs of operation, so that having built it, it would have been better to have left it unused, initially at least! Neither shadow pricing labour to allow for relief of unemployment, nor a general increase in costs on all modes of transport change this unfavourable result significantly. It will be seen that no value is given for environmental benefits, although we have seen above that this is not likely to be large. There is also no benefit given for the capacity released on conventional rail or at airports; perhaps in the circumstances of Spain, this has little alternative use, although that is not always the case, as will be seen below.

Table 6 Cost benefit analysis of the Madrid-Seville HSR

	Social benefit of HST*	GDP growth rate (3%)	Project life (40 years)	Shadow prices for labour	Increase of 25% in generalized costs of car, train and bus
Costs					
Infrastructure	-237.761	-237.761	-237.761	-200.575	-237.761
Residual value	17.636	18.546	5.816	17.636	17.636
Trains	-58.128	-61.003	-61.700	-58.128	-58.128
Maintenance	-41.410	-41.410	-45.022	-41.410	-41.410
Operation	-135.265	-140.575	-155.516	-135.265	-135.265
Time savings					
deviated traffic:					
– Conventional train	37.665	39.950	44.582	37.665	55.119
– Car	4.617	4.898	5.469	4.617	9.779
– Bus	1.958	2.079	2.321	1.958	2.867
– Air transport	0	0	0	0	0
Generated traffic	86.718	92.080	102.951	86.718	92.703
Costs savings					
– Conventional train	18.505	19.629	21.906	18.505	18.505
– Air transport	19.020	20.157	22.460	19.020	19.020
– Bus	1.680	1.783	1.990	1.680	1.680
– Car operating costs	17.412	18.471	20.618	17.412	17.412
– Congestion	4.896	6.284	7.486	4.896	4.896
– Accidents	4.128	4.363	4.867	4.128	4.128
Net present value of HST	-258.329	-252.509	-259.533	-221.143	-228.819

* Project life (30 years), GDP growth (2.5%), social discount rate (6%)

Source: de Rus and Inglada (1997)

As commented above, France is one of the countries with the most experience of HSR, and it is also a country which is systematic in conducting cost benefit analyses of all transport projects. More recently, an ex post evaluation of French HSR projects has been undertaken and compared with the ex ante appraisals (Table 7). It will be seen that all the lines considered were expected to have acceptable financial and social rates of return, and to carry at least 15m passengers per annum. In practice, the out turn rates of return are generally lower, mainly because of higher infrastructure costs and lower traffic levels than forecast in some cases. However, the only line for which the social case turned out to be marginal was the TGV Nord, where the major shortfall in traffic was mainly due to extreme over estimation of Eurostar traffic through the Channel Tunnel.

Table 7 Ex post appraisal of French high speed line construction

		Sud Est	Atlantique	Nord	Inter Connection	Rhone Alpes	Mediter-ranean
Length (km)		**419**	**291**	**346**	**104**	**259**	
Infrastructure cost	**Ex ante**	**1662***	**2118**	**2666**	**1204**	**1037**	**4334**
(m euros 2003)	**Ex post**	**1676**	**2630**	**3334**	**1397**	**1261**	**4272**
	% change	**+1**	**+24**	**+25**	**+16**	**+22**	**-1**
Traffic (m pass)	**Ex ante**	**14.7**	**30.3**	**38.7**	**25.3**	**19.3**	**21.7**
	Ex post	**15.8**	**26.7**	**19.2**	**16.6**	**18.6**	**19.2**
	% change	**+7.5**	**-12**	**-50**	**-34**	**-4**	**-11.5**
Financial return (%)	**Ex ante**	**15**	**12**	**12.9**	**10.8**	**10.4**	**8**
	Ex post	**15**	**7**	**2,9**	**6.5**	**n.a.**	**n.a**
Social return (%)	**Ex ante**	**28**	**23.6**	**20.3**	**18.5**	**15.4**	**12.2**
	Ex post	**30**	**12**	**5**	**13.8**	**n.a.**	**n.a.**

Source: Conseil Général des Pont et Chaussées (2006), Annex 1.

6. Key parameters influencing the case for HSR

De Rus and Nombela(2007) and de Rus and Nash (2007) have explored the key parameters determining the social viability of high speed rail, and in particular the breakeven volume of traffic under alternative scenarios. They built a simple model to compute capital costs, operating costs and value of time savings for a new self contained 500 km line at different traffic volumes. Typical costs were estimated using the database compiled by UIC (Table 8). A range of time savings from half an hour to one and a half hours was taken, and a range of average values of time from 15 to 30 euros per hour. Other key assumptions are the proportion of traffic that is generated, and the rate of traffic growth.

Table 8. Estimated costs of a 500 km HSR line in Europe (2004)

	Cost per unit (€ thousand)	*Units*	*Total cost (€ million)*
Capital costs			
Infrastructure construction[1] (Km.)	12,000-40,000	500	6,000-20,000
Rolling stock (trains)	15000 600.0	40	600.0
Running costs (p.a.)			
Infrastructure maintenance (Km.)	65	500	32.5
Rolling stock maintenance (Trains)	900	40	36.0
Energy (Trains)	892	40	35.7
Labour (Employees)	36	550	19.8

Source: de Rus and Nash (2007).

Table 9 shows the breakeven volume in terms of millions of passengers per annum in the first year, assuming all travel the full length of the line, under a variety of assumptions about the other factors. Note that benefit growth may occur because of rising real values of time as incomes rise, as well as traffic growth. With exceptionally cheap construction, a low discount rate of 3 %, very valuable time savings and high values both for the proportion of generated traffic and for benefit growth, it is possible to find a breakeven volume as low as 3m trips per annum, but it is doubtful whether such a favourable combination of circumstances has ever been found. Construction costs of 30m per km will carry this up to 7m, and a reduction of the value of time savings to a more typical level to 4.5m.; lower benefit growth and levels of generated traffic will take the result to 4.3m. An increase in the rate of discount to 5% would take the value to 4.4m. In other words, it appears to be the construction cost that is the key determinant of the breakeven volume of traffic; all the other adjustments considered have a similar smaller impact. All of these adjustments together would raise the breakeven volume to 19.2m trips per annum, and even worse scenarios can of course be identified. On the other hand a more modest increase of capital costs to £20m, with a high value of time savings but a discount rate of 5%, 30% generated traffic and a 3% annual growth in benefits leads to a breakeven volume of 9m. This represents a realistic breakeven volume for a completely new self contained high speed line in favourable circumstances.

Table 9. **Breakeven demand volumes in the first year (m passengers) under varying assumptions**

Construction cost (£k per km)	Rate of interest (%)	Value of time saved (euros)	% generated traffic (%)	Rate of benefit growth (%)	Breakeven Volume (m pass)
12	3	45	50	4	3
12	3	30	50	4	4.5
30	3	45	50	4	7.1
12	3	45	30	3	4.3
12	5	45	50	4	4.4
30	5	30	30	3	19.2
20	5	45	30	3	8.8

These representative breakeven volumes ignoring any net environmental benefits, but we have given reasons above to expect these to be small. What they also ignore is any network benefits in terms of reduced congestion on road and air, and also within the rail sector, and that issue will be considered further in the next section.

Construction costs vary enormously from case to case, as can be seen from Table 8, with Spain having the lowest costs and Britain the highest (Steer, Davis and Gleave, 2004). Some of these cost differences are inevitable, as a result for instance of land prices, although these do not usually account for more than around 5% of the costs of an HSR project. A very major contributor to costs is the amount of tunnelling involved, and generally the costs of entering large cities are high. The British high speed link to the Channel Tunnel is the most expensive high speed line ever built, largely because of the lengthy tunnelling at the approach to the London terminal to avoid environmental objections. If these costs can be avoided, for instance by using existing under or unutilised rail infrastructure, then the case can be considerably improved, even if this means a compromise regarding speeds (Whilst it may be thought unlikely that such infrastructure exists in the neighbourhood of large cities, this is not necessarily so; for instance British cities do often have such infrastructure as a result of rationalisation of rival lines built by competing companies in the early days of development of the rail system).

7. Network effects

Laird, Mackie and Nellthorp (2005) demonstrate how network effects may take place within the transport sector, leading to costs and benefits beyond the project being considered, as a result of the presence of one or more of the properties of economies of scale, scope or density, congestibility and consumption externalities. How far do such benefits improve the case for high speed rail?

We have already considered network effects on road and air infrastructure, but are there also network effects within the rail sector? Essentially the argument is that once one stretch of high speed rail has been built, extending it further will add to traffic on the existing stretch, reducing unit costs and increasing unit revenues and benefits. At the same time, by relieving conventional lines of fast passenger trains, capacity may be released which enables other services, passenger or freight, to be improved, although their finance may be seriously weakened by taking away their most profitable traffic.

The point may be illustrated with a study for Britain which examined a whole range of alternative routes, from a short new line from London to Birmingham (under 200km), with trains continuing to other destinations over conventional lines, to a route continuing via Leeds and Newcastle to Edinburgh and Glasgow (around 750km).

Britain only first began considering HSR, except for the link to the Channel Tunnel, in 2002, with a study undertaken by Atkins for the Strategic Rail Authority (Atkins, 2003). The Atkins study took place in a context of rapid growth in both passenger and freight traffic in recent years, leading to forecasts of severe overcrowding on both long distance services and London commuter services, and a lack of capacity for further growth in freight. Thus a major objective of the scheme was to relieve existing routes, as well as providing faster more competitive services between the major cities. This rather general remit led to the need to generate and study a wide range of options. Altogether some fourteen options were studied in depth, the main issues being whether to have a single route north from London which might split further north to serve cities up the east and west sides of the country, or two have two separate routes, and how far north to go. The obvious starting point would be a new route from London to the heavily populated West Midlands (the initial section of route would carry no fewer than 12 trains per hour in each direction in 2016 for much of the day). The further north the line was extended, the less heavily used the new sections would be, but this effect might be offset by the fact that these extensions attract additional traffic on to the core part of the network. It is a feature of British geography that most of the main cities in Britain could be served by a single line or a short branch off it.

It was forecast that the new line if built to its extremities would attract nearly 50m passenger trips per year in 2015, although most of these would only use part of the route. This high figure reflects the high population density of Great Britain and the large number of origin-destination pairs that the line would serve. Of these passengers around two thirds would be diverted from existing rail routes and the remainder split almost equally between diversion from other modes and newly generated trips. Most of the forecast diversion occurred from car – the forecast of diversion from air was surprisingly low given experience of the impact of HSR on air traffic elsewhere.

Results of the appraisal of two options are shown in Table 11. Option 1 is the line from London to the West Midlands. which is the obvious first phase of any high speed rail programme in Great Britain, and is seen to be well justified in its own right. But option 8, the extension through to both Manchester on the West Coast and right through to Scotland via the East Coast are also shown to be justified. It is obviously important, however, to examine the issue of timing and phasing. The study showed that, if feasible, immediate construction of the whole line was the best option.

Although net revenue more or less covers operating costs for both options, the capital cost can only be justified by non financial benefits and released capacity. Some 75% of the non financial benefits take the form of time savings or reduced overcrowding with the remainder mainly taking the form of reduced road congestion and accidents. On balance it was thought that the non quantified environmental benefits were slight. It is an interesting question whether more of the user benefits could be captured as revenue by more sophisticated yield management techniques than the simple fare structure modelled. Such yield management methods are already in use on other high speed services, including Eurostar services between London, Paris and Brussels.

Table 11 Appraisal of Options 1 and 8 (£bn PV)

	Option 1	**Option 8**
Net revenue	4.9	20.6
Non financial benefits	22.7	64.6
Released capacity	2.0	4.8
Total benefits	**29.6**	**89.8**
Capital costs	8.6	27.7
Net operating costs	5.7	16.3
Total costs	**14.4**	**44.0**
NPV	15.3	45.7
B/a	2.07	2.04

Source: Atkins 2003) Summary report, addendum Table 2.1 with errors corrected.

Table 12 compares unit costs and unit incremental revenues. The capital cost per train km of the larger option is somewhat higher than for option 1, for the obvious reason that the density of trains on the route diminishes once the junction with the branch to Birmingham is reached (train km per route km would fall from around 300 per day to nearer 200 when we move from option 1 to option 8). However, the incremental revenue per train km also rises quite substantially, even though on average the additional route is less intensively used than the initial stretch. The reason for this is clearly that the longer route attracts more traffic raising both mean fares and load factors on the first section of the route. Thus the more extensive network covers a much greater share of its costs from incremental revenue than the more limited network.

Table 11 also shows the estimated value of the improvements in services and increased traffic that could be carried on existing lines as a result of the construction of the new HSR line. These improvements would mainly affect London commuter services and freight traffic, where, in the absence of new capacity, severe constraints on capacity would apply.

Naturally, these benefits are assessed to cover a much greater share of the capital cost of option 1, which duplicates the heavily used West Coast Main Line into London, than further north.

Table 12 Unit costs and revenues

Option	HSR train km(2016)	Capital cost per train km	Net revenue per train km
1	55474	2.58	1.47
8	162067	2.85	2.12

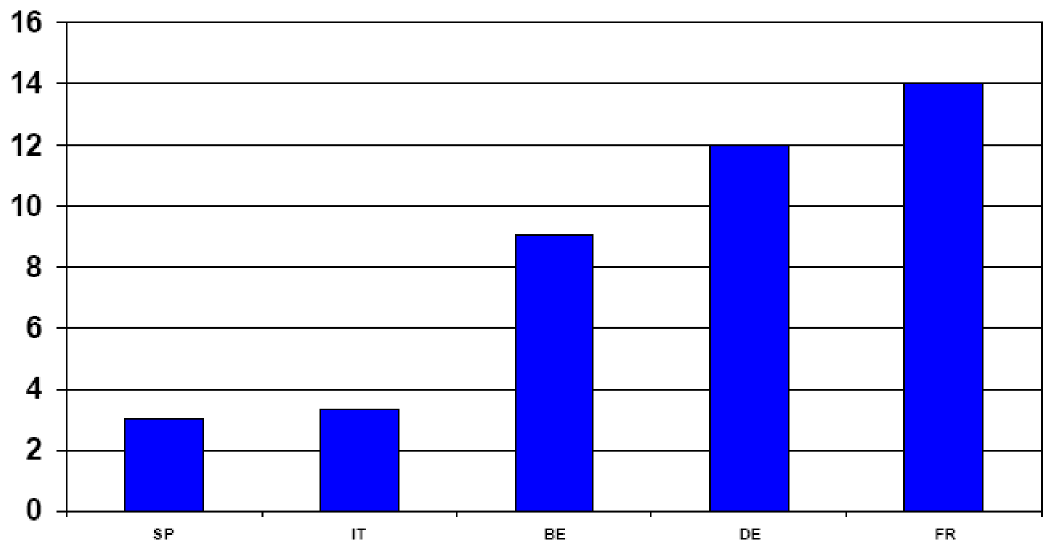
8. Pricing policy

To the extent that HSR is built with government funding, the opportunity cost of that funding should be taken into account by use of a shadow price of public funds, or by requiring a benefit-cost ratio well in access of one. Where private financing is involved, this will need to be serviced, and the most obvious source of income for this is via track access charges.

The method of financing high speed rail can also be significant in determining the outcome. UIC (2008) find that the access charges levied on train operators vary substantially, but absorb between 25 and 45% of the revenue of high speed rail operators. As such, they significantly affect the competitive position of rail as opposed to other modes.

Some typical track access charges for HSR are illustrated in Fig 1

Fig 1 Typical Access Charges for high speed passenger trains € per train-km in 2008



Source: ITF (2008), based on the approach of ECMT (2005)

In Britain, variable track access charges are based on estimated short run marginal wear and tear cost, and for a class 390 pendolino tilting train, running at 200km p h on conventional track, the current charge is around 14p per vehicle mile. This amounts to roughly 1 euro per train km or 2 euros per 1000 gross tonne km. This figure is based on a cost allocation model resting on engineering judgement. The only econometric study of rail infrastructure costs which produces separate figures for high speed passenger services is the .Quinet and Gaudry work for France (Gaudry and Quinet, 2003). They find a value of around 2 euros per train km for high speed and other inter city services, and of 3 euros per train km for other passenger trains. To this must be added a small amount of external cost; where track capacity is scarce, a more substantial scarcity charge may be justified. Nevertheless, it therefore appears that charges in Belgium, Germany and particularly France (as well as through the Channel Tunnel and to London) may substantially exceed marginal cost, even if environmental costs are charged for.

Of course, marginal social cost pricing in the rail sector is only optimal to the extent that it is adopted on competing modes as well. To the extent that air transport is not charged appropriately for scarce runway capacity and for environmental costs, there may be a case for charging rail below marginal cost on routes that are competitive with air.

The impact of high track access charges may be minimised by means of Ramsey-Boiteux pricing (Ramsey, 1927; Boiteux, 1956). Essentially this means pricing up more in those market segments which are least sensitive to price. This is permitted under the EU Directive on track access charges (2001/14), provided there is no discrimination between different operators competing for the same market segment.

Crozet (2007) calculates the value of the optimum mark up, assuming that the shadow price of public funds is 1.3 (Crozet, 2007). For the French high speed network, the optimal mark up would range between 3.2 and not more than twice the marginal cost, for elasticities of 0.7 (Paris-Lyon) and 1.5 (Paris-Nice), respectively. That is, even allowing for the opportunity cost of government funds, infrastructure charges for high speed lines should not be higher than 6.4 €/train-km taking 2 €/train-km as an upper limit to the marginal infrastructure cost per train km for high speed rail and a price elasticity of 0.7 and if there is no environmental charge (which arguably should be the case given the general absence of environmental charges in air transport). As seen from Fig 1, the typical mark ups for access to high speed lines in France greatly exceed these levels. The impact of high track access charges on the new route could be even more problematic if open access competition is permitted on the existing lines at much lower charges.

Adler, Pels and Nash (2008) modelled competition between rail and air on a number of Trans European Network corridors where investment in high speed rail is either underway or proposed, using a game theory model to compute Nash equilibria. They assumed competition between low cost and conventional airlines but no within mode competition on rail.

Where high speed rail was introduced with a low track access charge of 2 euros per train km, they found high speed rail to be socially worthwhile, even though a profit maximising monopoly rail operator would use much of the benefit to raise price rather than increase market share (although, as noted above, a sophisticated yield management system might be able to achieve both of these aims simultaneously). However, when access charges were raised to 10 euros per train km, services ceased to be profitable and would not operate without subsidy. In general, a high access charge will limit the frequency of service offered below the optimal level, and thus also limit the benefits.

On the other hand, a fixed charge as part of a two part tariff could make a major contribution towards the costs of building the network. However, such a charge is problematic if open access competition is to be introduced. What contribution should new entrants make to the fixed charge? The answer provided by the literature is that the new entrant should pay for the reduction in profitability of the existing operator (Baumol, 1983), but such a system is hard to administer. On the other hand, a franchising system – including a cap on the fares to be charged – can reconcile the desire to make a contribution to fixed costs with a wish to charge for track access at marginal cost; in this case the contribution could come from the willingness of the franchisee to pay for the franchise

9. Conclusions

Most successful applications of high speed rail seem to arise when there is both a need for more rail capacity and a commercial need for higher speeds. It seems difficult to justify building a new line solely for purposes of increased speed unless traffic volumes are very large, but when a new line is to be built, the marginal cost of higher speed may be justified; conversely the benefits of higher speed may help to make the case for more capacity. It follows from the above that appraisal of HSR will need to include assessment of the released capacity benefits for freight, local and regional passenger services and the changes in service levels on the conventional lines. It also follows that the case for HSR is heavily dependent both on future economic growth and on the assumption that demand for long distance passenger and freight transport will continue to increase. If long run economic recession, or environmental constraints prevent this from occurring then far less new HSR will be justified than in a 'business as usual' scenario. Already the current recession will have at least delayed the case for some new lines, although increased government spending to reflate the economy may have the opposite effect.

High speed rail is more successful at competing with air than car, and there is evidence for the widely quoted 3 hour rail journey time threshold (although this evidence predates the increased security and congestion at airports which is believed to have increased this threshold). Where rail journey times can be brought close to or below 3 hours HSR can be expected to take a major share of origin-destination aviation markets.

Of the measured indirect benefits of HSR investment, congestion is the most significant. Relief of road congestion is, however, unlikely to be a major part of the case for high speed rail except where chronic congestion is spread throughout the day along much of the route. Relief of airport capacity through transfer of domestic legs from air to rail is potentially more important where capacity is scarce and expansion is difficult, costly and has a serious environmental impact, as in the case of Heathrow.

Environmental benefits are unlikely to be a significant part of the case for high speed rail when all relevant factors are considered, but nor are they a strong argument against it provided that high load factors can be achieved and the infrastructure itself can be accommodated without excessive environmental damage. A key factor here is the approach to cities, where the choice may be between use of conventional tracks at reduced speed or expensive tunnelling.

The issue of wider economic benefits remains one of the hardest to tackle; such benefits could be significant, but vary significantly from case to case, so an in depth study of each case is required.

The breakeven volume of passengers to justify a new high speed line is very variable, ranging from 3m to 17m in the first year of operation under possible assumptions examined, but typically even under favourable conditions at least 9m passengers per annum will be needed. Whilst it appears that all the French high speed lines comfortably exceeded this volume, it is clear that some proposals are being developed where traffic is very much less dense (the Madrid-Seville line, for instance, carried less than 3m passengers in its second year of operation and is still only at around the 5m level). The most important variable in determining the breakeven volume is the construction cost, which varies enormously according to circumstances.

It is important to consider network effects. The benefits of a high speed line may be maximised by locating it where it may carry traffic to a wide number of destinations using existing tracks beyond the end of the high speed line, whilst extensions to an existing network lead to greater benefits than isolated new lines by attracting increased traffic to the network as a whole. Obviously this implies technical compatibility between HSR and existing rail as a prime requirement.

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