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When to Invest in High Speed Rail

25

Discussion Paper 2013 • 25

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When to Invest in High-Speed Rail

Discussion Paper No. 2013-25

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1. INTRODUCTION

High speed rail (HSR) is usually regarded as services operating at 250 kmph or more, and these invariably require construction of new purpose-built lines. According to the International Union of Railways (UIC), by 2012, a total of 13 000km of such lines had been built worldwide, half in Europe and half in Asia. China had the largest network at 3 426km, whilst Japan, France and Spain all had over 2 000km. There are plans for a further major expansion, with the European Commission calling for a trebling of the kilometrage in Europe by 2030. Yet high speed rail is an enormous investment, with a typical 500km line costing 6-12Bn euros in 2004 prices (Euros 12-24 Bn per km) (de Rus and Nash, 2009). It is necessary to consider very carefully in what circumstances such an outlay is justified.

The first such line, the new Tokaido line in Japan, was clearly built with the twin aims of giving large time savings (and thus competing effectively with air transport) and relieving capacity constraints on the existing railway line. These were also clearly the motives behind the construction of the first TGV line from Paris to Lyons in France. But since then, wider motives have appeared, including reducing carbon emissions by diverting traffic from air and road, and promoting economic regeneration and growth. The first part of this paper will consider at a general level the costs and benefits of high speed rail, and evidence to date on what determines their magnitude.

We will then consider specifically evidence from the current debate in Britain. The first High Speed Rail line to be built in Britain, from London to the Channel Tunnel, opened in 2004-7. Possible benefits of regeneration in East London played a significant role in the choice of route and in the appraisal of this line (later dubbed HS1). It was not until 2001 that the Strategic Rail Authority commissioned a study of the case for high speed rail linking London with cities to the North. This formed the basis of the current proposals for a line from London to Birmingham, branching near Birmingham to form lines going on to Manchester and Leeds (HS2). The government is committed to going ahead with this line, and is just starting parliamentary processes to obtain the powers to build it. However, the project is very controversial, and consequently an enormous effort has been put into studying its effects by both proponents and opponents. The evidence from these studies will be reviewed, before we draw our conclusions.

2. COSTS AND BENEFITS OF HIGH SPEED RAIL

2.1 Introduction

The principal costs and benefit of HSR are listed in Table 2.1.

Table 2.1. HSR costs and benefits

Costs
Capital costs
Operating costs
External costs (environment, safety)
Loss of tax revenue (from traffic diverted from road to rail)
Benefits
Revenue
Time savings (beyond those recovered in higher prices)
Diversion from other routes and modes – reduced congestion, accidents and environmental costs
Generated traffic
Wider economic benefits

2.2 Costs

We have already noted the high capital costs of high speed rail. In terms of operating cost, whilst energy consumption and maintenance costs may be higher than for conventional trains, high speed means staff and rolling stock can achieve much higher utilisation rates per passenger km than conventional rail, offsetting the increased costs. Typical costs for building and operating a high speed line are shown in Table 2.2.

Table 2.2. Typical costs of a 500 km high speed line (million euros 2004 prices)

Capital costs	
Infrastructure construction	6000-12000
Rolling stock (40 units)	600
Total	6600-12600
Operating costs p.a.	
Infrastructure maintenance	32.5
Rolling stock maintenance	36.0
Energy	35.7
Labour	19.8
Total	124

Source de Rus and Nash (2009)

Of the external costs of high speed rail projects, noise, global warming and loss of amenity through land take and visual intrusion are the major issues. Noise costs and loss of amenity can be minimised at the expense of additional capital cost, ultimately by tunnelling.

Of these costs greenhouse gases has proved particularly contentious. Firstly, there is obviously carbon used in construction of the line, although in Europe, to the extent that this will mainly be undertaken by industries which are part of the European emissions trading scheme, it may be argued that the cost of offsetting any increase in carbon from this source will already be included in the capital costs of the project. The same argument may be applied to electricity for traction (and jet fuel when the ETS is fully implemented for aviation). Ignoring this argument, the greenhouse gas emissions for HSR depend very much on the source of primary energy used to generate the electricity, and as electricity generation is decarbonised this will go down. It is the source of the marginal electricity generated as a result of the increased demand for electricity generated by HSR that is of interest and this may not be the same as the average source at that point in time.

Safety is not a big issue for HSR. New high speed lines are invariably built with cab signalling and completely segregated from road and pedestrian traffic (i.e. without level crossings), and there has never been a fatal accident on a purpose built dedicated high speed line. There have been several serious accidents involving high speed rolling stock running on conventional lines, however (in Germany, China and most recently Spain).

The cost of reduced tax to the government has also been a contentious issue in the UK. The logic is that if the benefits of reduced congestion and pollution from road traffic are included as a benefit in the appraisal in full, then the loss of revenue that road transport would have paid in the form of fuel and other taxes must be seen as a cost.

2.3 Benefits

Turning to benefits, the overwhelmingly important benefit in most transport appraisals is time savings. However, it is not always appreciated that many aspects of comfort and convenience are included in the value of (generalised) time used in economic appraisal. The raw values used in current British appraisals are shown in Table 2.3. For leisure and commuting journeys, these values are based on extensive revealed and stated preference

evidence on what people are willing to pay to save time. However higher values are used for waiting time, for time standing in a crowded train, for time spent walking to access trains and for late arrivals (the evidence is that people are willing to pay something like twice as much to save time walking and waiting and three times as much to avoid being an hour late as they are to save an hour in scheduled journey time). (Wardman, 2004)

Table 2.3. **Values of time used in British rail appraisals**
(GBP per hour, 2010 prices and values)

Business	31.96
Commuting	6.81
Leisure	6.04

Source: DfT (2013)

Where passengers are travelling on business, it is assumed that the benefit of faster journeys goes to the employer, not the employee. The approach taken to this in Britain, as in the appraisal systems of most countries, is to assume that this is to be valued at the wage rate of the staff concerned, plus an allowance for the overhead cost of employing labour. In a competitive market, this will equal the value of the marginal product of labour, and thus represents the value of the additional output produced when labour is released from its current occupation. It also represents the cost saving to the existing employer, and thus is a key input into models to estimate land-use transport interactions or wider economic effects of transport investments.

Valuing rail business travel time savings in this way has been widely questioned in recent years. Firstly, it has been noted that business travellers can and do work on trains, and that improved information technology has made this easier and more productive. According to a recent survey a third of rail business passengers in Britain state that this is how they spend much of their travel time (Lyons et al, 2007). However, Batley, Mackie and Wardman (2013) point out that it is not how people spend their time on average that matters, but how this would be affected by a marginal change in travel time, and whether the time is used as productively as time spent in the office. Secondly, business journeys often start and finish in unsocial hours and it is not clear that all time saved on such journeys will be used productively. Hensher (1977) developed a method for adjusting business values of time to allow for these factors, but one which is very demanding in terms of the information needed to apply it. The Hensher approach would generally reduce the value of business travel time compared to basing it on the wage rate plus overheads.

On the other hand, empirical investigations using evidence from both revealed and stated preference studies tends to suggest a value at least as high as currently assumed, with values of time being much higher for first class travel than economy (Wardman, 2004). Possible reasons for this are that employers perceive benefits from staff not being obliged to work such long days and thus being less tired, from not having to compensate staff for unsocial hours as part of their remuneration package and from being able to fit more meetings into a day, thus saving further travel or the cost of overnight stays. (Marks, Fowkes and Nash, 1986).

The benefits of diversion from other routes or modes take the form of reductions in congestion and pollution. What is needed then is firstly an estimate of how many high speed rail travellers have diverted from each mode (including existing rail services; where there are capacity constraints this may lead to additional benefits by freeing up capacity for expansion of other services, including freight).

Once the mode from which passengers have switched is known, information is then required on the marginal social cost of the modes in question. The evidence is that, for the aviation, noise and pollution costs not fully internalised in prices, (Tables 2.4a and 2.4b), the resulting externality might provide a benefit from switching to HSR of the order of 7.5m euros at year 2000 prices for 1m passengers diverted from air. Thus it would only be if there was a very large diversion from air, probably on a route where air had previously totally dominated the market, that this would make a significant contribution to the benefits of HSR.

Table 2.4a. **Air transport externalities**
(Euro cents 2 000 per passenger km)

Flight Distance (km)	Air Pollution	Climate Change	
	Direct Emissions	Direct Emissions	Indirect Emissions
<500 km	0.21	0.62	0.71
500 – 1 000	0.12	0.46	0.53
1 000 – 1 500	0.08	0.35	0.40
1 500 – 2 000	0.06	0.33	0.38
>2 000	0.03	0.35	0.40

Note. Indirect emissions are the climate change and air pollution cost of the production and transport of fuel for air transport. Obviously there may be offsetting costs for rail which need to be included in the cost of the high speed rail project.

Table 2.4b. **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: Infrac et al (2008)

For car, the evidence of GRACE (2005) is that it is only when there is substantial congestion that marginal social cost exceeds charges (Table 2.5) for using cars in European conditions. Whilst we might now believe in a rather higher cost for global warming than applied in 2005, this would not change the conclusion. But that raises the issue that if sufficient traffic is diverted to significantly reduce road congestion, new demand will be generated to occupy some of the space. Thus accurate results can only be achieved by use of a full multi modal model. The additional road traffic would then be the benefit rather than reductions in congestion.

Benefits should also include the net benefits of diverting traffic into the capacity released on existing rail lines. This may be more substantial and include the impact of diverting freight from road (Greengauge, 2012).

Table 2.5. **Long distance car trip externalities and charges**
(Euro cents per passenger km)

Wear	Congestion	Environment	Accidents	Total Cost	Charges
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Route 1						
Peak	0.016	0.147	0.013	0.015	0.191	0.132
Off-peak	0.016	0.002	0.017	0.015	0.050	0.132
Route 2						
Peak	0.032	0.194	0.010	0.008	0.244	0.156
Off-peak	0.032	0.003	0.014	0.008	0.056	0.156
Route 3						
Peak	0.019	0.123	0.011	0.008	0.161	0.114
Off-peak	0.010	0.002	0.015	0.008	0.044	0.114
Route 4						
Peak	0.020	0.122	0.015	0.006	0.163	0.078
Off-peak	0.025	0.002	0.020	0.006	0.048	0.078

Note: Route 1 is Milan-Chiasso, route 2 Chiasso- Basel, route 3 is Basel-Duisburg and route 4 is Duisburg-Rotterdam.
Source: Grace (2005).

For generated traffic, the standard argument is that, since the person was unwilling to travel at the previous generalised cost and is willing at the new, the benefit must lie somewhere between that derived by an existing passenger and zero; assuming a linear demand curve the benefit will be half that accruing to an existing passenger. However, if new trips are generated for leisure, commuting or business, they may imply a shifting of economic activity. Whether they also may imply increased economic activity is the source of much debate. The long held position amongst most cost-benefit analysts has been that, following Mohring and Williamson (1969), in a perfectly competitive economy, there will be no benefits of transport investment over and above the direct user benefits that are measured in a standard appraisal. Whilst a transport investment may change relative prices and lead to expansion and contraction of other industries according to the degree to which transport is an input to them, as long as price equals marginal cost in those sectors, there will be no net benefits of these changes, whilst in the absence of involuntary unemployment, there will be no net benefits of job creation or removal. Transport investments may change property prices, but this will simply be a capitalisation of the benefits received by the users; it will transfer benefits from users to property owners but have no impact on the overall net benefit of the scheme. Recent arguments in Britain that there are in fact such wider economic benefits will be examined in section 4.

3. IN WHAT CIRCUMSTANCES WILL BENEFITS EXCEED COSTS?

3.1 Introduction

Empirical studies (de Rus and Nash, 2009) suggest that three elements of the appraisal of high speed rail dominate the results: construction cost, (generalised) time saving per passenger and demand. Thus the answer to this question lies in the determinants of these three factors.

3.2 Construction costs

Construction cost varies greatly from line to line (Table 3.1)

Table 3.1. **Construction cost per route km of new high speed lines**
(million euros 2005 prices)

Belgium	16.1
France	4.7 – 18.8
Germany	15.0 – 28.8
Italy	25.5
Japan	20.0-30.9
Korea	34.2
Spain	7.8 – 20.0
Taiwan	39.5

Source: Campos, J, de Rus G and Barron, I (2009)

It is heavily influenced by the nature of the terrain, the length of earthworks, viaducts and bridges and – overwhelmingly – the amount of tunnelling (SDG, 2004). A contributory factor to the low costs in France and Spain relative to Germany and Italy is said to be that these countries design their high speed lines for passenger trains only, with gradients of up to 3.5%, whereas more than 1.5% is not usually permitted on mixed traffic lines. Other things being equal, construction in flatter country will obviously be cheaper than in mountainous regions or with a lot of water crossings. But population density is also critical. Where population density is high, more bridges, viaducts and tunnels will be needed. A crucial issue is the approach to city centres. In terms of maximising patronage and time savings, access to a city centre station is critically important. If it may be made on the surface on existing right of way, as is predominantly the case in France then costs will be very much lower than if extensive tunnelling is involved (as in the case of HS1 and HS2 in Britain). One factor which may make this possible is the diversion of local services underground into a cross city tunnel as a way of improving access to city centres (as in the Paris RER network, Crossrail and Thameslink in London and many German S-Bahn schemes).

3.3 Value of time saved per passenger

The second major element is the value of the time saving per passenger. The amount of the time saving is determined by the change in the door to door journey time (i.e. amount of in vehicle time, access and egress time) compared with the previous mode. Where the previous mode was rail, this may be substantial (an hour or more for a 500km line), and it may be even greater for road, particularly where roads are congested. However, for air, the time saved may be more limited. For air journeys over the sort of distances where high speed rail makes rail competitive, a typical door to door time may be of the order of four hours. For a 500km journey by rail, it will be similar. Of course, rail will be favoured the shorter the length of the trip (as the higher speed of aircraft becomes less significant) and the more accessible the railway station is relative to the airport. So rail will be favoured in dense cities with good access (probably by public transport) to the central city. Air will do better in low density areas with good access (probably by car) to the airport.

3.4 Traffic volume

The construction costs of high speed rail are largely fixed regardless of traffic. High speed rail invariably requires a double track main line with cab signalling, and this already has a capacity of 14-18 trains per hour in each direction. Only the costs of rolling stock, stations and depots vary significantly with traffic volumes. Thus high speed rail systems are traffic hungry.

Volumes of the necessary size may be obtained by linking individual very large cities (e.g. Paris and London) or by linking a chain of large cities so that flows between different cities are aggregated together and trains remain busy throughout the route (the so called 'string of pearls'). Japan is clearly a case of the latter, with 127m people living at very high population densities mainly in large cities along the coastal strip. France also was able to benefit from this sort of geography to a degree, but by using the ability of TGVs to run at reduced speed on conventional lines to serve additional cities. For instance, trains on the original French TGV line from Paris to Lyons, went on to serve cities such as Avignon, Marseilles and Nice (since then the high speed line has been extended to serve these places directly). By contrast, Spanish cities are smaller, and arranged around Madrid in a 'hub and spoke' pattern, requiring a different line to link each city to Madrid (Table 3.2).

Obviously the difference in volumes is partly simply a question of population served. For instance, the population of Paris in 2000 was 9.7m and Lyon 1.4, whilst the TGV Sudest line went on to serve many other destinations, including Marseille (1.4m) and Nice (0.9m). By contrast, population directly served by Madrid-Seville was around half that of Paris-Lyon; Madrid-Barcelona is more comparable, but there are no further cities currently served beyond Barcelona. Beijing-Nanjing-Shanghai has a population twice that of TGV Sudest in the main three cities alone (although of course per capita inter city travel in China is way below European levels), whilst Tokyo and Osaka between them have twice as much again.

Table 3.2. Patronage (m) of HSR

Line	Traffic 1st Full Year	1 year on	5 years on
TGV Sud Est	15	17	19.2
TGV Atlantic	21.5	22	29
TGV Nord*	19	20	-
TGV Connexion	9	10	16.6
TGV Rhone-Alps	18.5	-	-
TGV Mediteranne	20.4	-	-
Madrid – Seville	2.5	2.8	3.6
Madrid – Barcelona	5.0	5.4	-
Tokyo – Osaka	35	48	80
Korean HSR	24	27	28

* Including international trains to London and Brussels as well as French domestic services

Note: some numbers have had to be estimated from graphs

Source: Paix (2010) Sanchez-Borras (2010) Hyunkyu (2010) Toshiji (2007) and RFF (2007)

As well as city size, mode share is obviously important. Table 3.3 examines the relationship between share of the rail/air market and rail station to station journey time. It is often argued that in European and Asian conditions a maximum three hour station to station journey time is required for rail to compete with air. The reasoning is that rail fares are normally competitive with air, that for most passengers getting to a city centre rail station is faster than getting to an airport and passengers spend longer at the airport going through security etc than passengers do at the rail station. With flight times themselves not varying much from around an hour as most time on short flights is taken up with take-off and landing, a penalty for air approaching two hours in terms of getting to and waiting at the airport and some other advantages of rail in terms of comfort and reliability, a three hour rail station to station journey time is competitive. Thus it is generally considered that high speed rail is most appropriate for journeys of 400-800km. Below that range, even a good quality conventional service is competitive with air, whereas above 800km even high speed rail finds it difficult to compete (SDG, 2004). (However, high speed rail may still be worthwhile at shorter distances than this in terms of competing with road traffic, although for journeys below around 150km, frequency and accessibility in terms of convenience of stops become more important than speed in terms of the comparison with road journey times).

It can be seen from Table 3.3 that there is some justification for the belief that in European and Asian conditions a 3 hour rail journey time will enable rail to compete with air, in that in every case where a three hour rail journey time is achieved rail has more than half the rail-air market, except marginally Madrid-Barcelona. Whilst 3 hours does indeed seem to be the sort of rail journey time at which rail typically gains more than half the market, it is not however a clear threshold effect. Rail gains market share rapidly as journey times come down towards 2 hours, whilst in some cases it retains nearly half the market with a journey time of around 4 hours. This diversity is to be expected; quite apart from differences in tastes amongst passengers, some passengers will have origins or destinations for which air is more convenient relative to rail, and the importance placed on reliability and comfort will vary.

Table 3.3. Rail share of rail / air market and rail station to station journey times

Corridor	Year	Travel Time	Rail Share %
Paris-Brussels	2006	1hr 25min	100
Paris-Lyons	1985	2hrs 15min	91
Madrid – Seville	2003	2hrs 20min	83
Brussels – London	2005	2hrs 20min	60
Tokyo – Osaka	2005	2hrs 30min	81
Madrid – Barcelona	2009	2hrs 38min	47
Paris – London	2005	2hrs 40min	66
Tokyo – Okayama	2005	3hrs 16min	57
Paris-Geneva	2003	3hrs 30min	35
Tokyo-Hiroshima	2005	3hrs 51min	47
Paris-Amsterdam	2004	4hrs 10min	45
Paris – Marseilles	2000	4hrs 20min	45
London–Edinburgh	1999	4hrs 25min	29
London–Edinburgh	2004	4hrs 30min	18
Tokyo – Fukuoka	2005	4hrs 59min	9

Source: Campos, J, de Rus G and Barron, I (2009), Sanchez-Borras (2010) SDG (2006)

But there is considerable variability in the rail market share for the same station to station journey time, and there is good reason for this as well. For instance, the advent of low cost airlines means that it can no longer be assumed that rail fares will be competitive, particularly where the journey is composed of legs on different operators, and the through fare is simply the sum of their individual fares. It is understood that fierce fares competition from air in one of their biggest European markets has been the reason for the comparatively low rail penetration of the Madrid-Barcelona rail-air market so far. There is a further warning in the sharp drop in the rail share of the London – Edinburgh market between the two dates recorded; this was a period of rapid growth of low cost airlines. On the other hand, high market shares have been achieved despite low cost airline competition by Eurostar and the French TGV, both of which make use of the same sort of yield management systems as the low cost airlines themselves.

Obviously, it is to be expected that where fewer passengers have city centre origins or destinations, and where more passengers use car as a feeder mode, as is likely to be the case in countries such as the US, rail will need shorter journey times than three hours to achieve high rail-air market penetration. Thus at best, the hypothesis that a three hour rail station to station journey time is sufficient and necessary for rail to compete with air, is a rough rule of thumb, needing verification by modelling competitiveness for any particular application.

3.5 Break-even volumes

De Rus and Nombela (2007) and de Rus and Nash (2009) 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 2.2). 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 3.4 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. If on average passengers travel half the length of the line, then of course the required number is doubled. 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 existed. Construction costs of 30m euros 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 euros, 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. All the breakeven volumes given assume end-to-end journeys; if some journeys only use part of the route, breakeven volumes would be proportionately higher.

Table 3.4. **Break-even 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 (%)	Break-even 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 ignore 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 wider economic benefits. If these effects are significant then HSR may be justified at lower volumes.

The economic success of HSR in France, where the early lines all opened with more than 15m passengers per year and have been found by ex post appraisal to be economically

worthwhile, compared with Spain where the traffic was 5m or less and ex post appraisal suggests that they were poor investments, tends to support the idea that there is a breakeven level of around 9m passengers per annum in cost benefit terms (de Rus and Nash, 2009). The breakeven threshold for success in purely financial terms (i.e. completely remunerating the capital cost without assistance from the government) must be very much higher. It is understood that the only two high speed lines to date to have achieved such success are the Tokaido line in Japan and the TGV Sudest in France. The Tokaido line opened with 35m passengers per annum and within 5 years was carrying 80m. Within France, ex post appraisals suggest that only the Sudest line achieved a financial rate of return in excess of 10% (with the Atlantique line achieving 7%) (RFF, 2006). TGV Sudest opened with only 15m passengers per annum (and Atlantique with 22m) but both have seen very substantial growth since, partly due to further extensions to the system, which have not themselves been financially profitable. It is therefore unclear to the current author to what extent the first two French lines can be said to be fully commercially viable at much lower volumes than those in Japan.

4. THE HIGH SPEED RAIL DEBATE IN BRITAIN

4.1 High Speed 1

Background

The Channel Tunnel Act of 1987 provided for the construction of a rail tunnel under the Channel Tunnel between Britain and France. This was to be privately funded with no government subsidy either to the tunnel or to services using it. These would comprise regular shuttle services between terminals at either end of the tunnel for cars and road goods vehicles, conventional freight trains between terminals across Britain and the continent and high speed passenger trains between London and Paris and Brussels. Whilst France and Belgium both planned new high speed lines between their capitals and the Channel Tunnel, the initial intention was that in Britain the services would use existing heavily used surface lines to a new terminal at Waterloo (Butcher, 2010). The trains were to be operated by a consortium of British, French and Belgian Railways and services started with the opening of the Channel Tunnel in 1994.

In the meantime, in July 1988, British Rail published a report suggesting that in the long term extra capacity would be required to cope with international services. Their initial choice was a route approaching London from the South. However, in 1991, the then Secretary of State for Transport, Malcolm Rifkind, announced that the government had decided on a route entering London from the East, via Stratford, with the intention of promoting regeneration of this depressed part of East London. A station called Stratford International was to be built, and indeed was and still has that name, although the operator of international services, Eurostar, has never chosen to call there. It is served by domestic high speed trains under a separate franchise agreement. Subsequent environmental pressure led to the conclusion that a long stretch of the line of some 19km at the London end should be in tunnel. The line was to be built by a private consortium, with a government contribution in respect of use of the line by domestic services. After a competition to select a private promoter, a consortium called London and Continental were chosen. As part of the agreement they received, free of debt, the British Rail share of the passenger operator (Eurostar UK) and extensive lands at Stratford and Kings Cross / St Pancras on which to develop the necessary terminals but also capable of commercial development to help finance the line.

Very early in its existence London and Continental concluded, because patronage of Eurostar was running below forecast, it could not raise the capital to finance the line without further assistance, and in 1998, the government agreed to underwrite its debt. The line opened in two stages in 2004 and 2007, with the long tunnel into central London being part of the second stage. In 2009, domestic high speed services between stations in Kent and London were added as part of the franchise agreement with the operator in that area, South East Trains.

In 2009, the government bought out London and Continental Railways, with the aim of restructuring it and selling it without further government guarantees. In 2010, it was bought by a consortium of Borealis Infrastructure and Ontario Teachers' Pension Plan. They

contract out maintenance and operations to the main British rail infrastructure company, Network Rail, and are subject to regulation by the British Office of Rail Regulation. There is now open access for any passenger or freight operator to use the line upon payment of the appropriate access charges; DB Schenker is running a small number of freight trains over it (one attraction is that it can take standard continental wagons which do not fit the loading gauge on other British tracks) and DB is intending to introduce a passenger service between Frankfurt and London using the line in due course.

The original appraisal

Because the 1998 arrangement exposed the government to some financial risk, a full appraisal of the scheme was undertaken to determine whether or not it was socially worthwhile. The results of this appraisal are shown in Table 4.1.

The transfer of Eurostar services from Waterloo to St Pancras and the introduction of domestic high speed rail services to St Pancras will have made for more convenient access for passengers from North of London than Waterloo and other domestic terminals South of Central London. However, for much of England south of London it is less convenient.

Eurostar's international services have compulsory seat reservation, so crowding takes the form of passengers being unable to get a seat at the time they want. This might have become a problem on the old route at peak times when track capacity was scarce. Transfer of the services to a dedicated high speed line segregated from slower services is understood to have brought about a major improvement in reliability. At the same time, removing these trains and some domestic traffic (by means of the domestic high speed train services) from existing lines has reduced congestion, crowding and unreliability there and enabled the system to cope with continued rapid growth of domestic traffic (80% on the system as a whole in the last 15 years).

At the time of the appraisal, standard methods for appraising reduced overcrowding and unreliability did not exist. Methods do now exist which use a higher value of time for travel in crowded conditions and for time lost in delays as opposed to schedule journey time.

Table 4.1 **1998 Appraisal of HS1**
(£m1997 NPVs)

User benefits -International Services	1 800
User benefits - Domestic Services	1 000
Road Congestion	30
Environmental benefits	90
Regeneration	500
Total Benefit	3 420
Costs to government	1 990
NPV	1 430
BCR (all benefits)	1.72
BCR (excluding regeneration benefits)	1.5

Source: National Audit Office (2001)

It will be seen that benefits to users form the majority of benefits. Benefits from reduced road congestion and reduced environmental externalities are estimated from the forecast reduction in road traffic and standard values for different types of road by time of day. The value of regeneration in the Stratford area was estimated by estimating the number of new jobs that would be created in the area, and multiplying this by the amount the government was willing to pay under other schemes to create jobs in priority areas for regeneration. This was not at the time a standard part of the appraisal process.

The costs shown in the appraisal are costs to government, including grants and interest payments. The standard benefit-cost ratio on which decisions are taken in Britain is the ratio of net benefits to others per pound of government spending.

Subsequent appraisals

By the time the National Audit Office examined the project most recently (National Audit Office, 2012) its estimate of the value of time savings had increased to £7b present value terms at current prices. The reason for this increase is largely a change in government appraisal methods, including a lower discount rate (3.5%) and a longer (60 year) assumed life, as well as rising values of time over time. However, the cost to the government had increased to £10.2b in present value terms. It made no attempt to quantify the other benefits of the line, but noted that these would have to total £8.3b for the line to have a benefit-cost ratio of 1.5, the level required for a project to be seen as offering medium value for money in the UK. The main problem was a 30% shortfall on patronage of international services compared with the estimate made at the time of the 1998 appraisal (Booz and Co, 2012). It appears that the main reason for this is not a failure of rail to take the predicted market share, but that whereas the forecast assumed continuing rapid overall market growth, in practice the market ceased to grow. The way in which the project was financed, with a lack of equity capital and the government underwriting the bonds, left the

government to pick up the cost of this shortfall (ITF, 2013). The out turn construction costs were as in Table 4.2 and were within the financial provisions made at the time of the approval of the project in 1998:

Table 4.2 **Out turn capital costs of HS1 (£M)**

Section 1 construction costs	1 919
Section 2 construction costs	3 778
Station fit-out	109
New depot	357
Total	6 163

Source: NAO (2012).

It should be noted that section 1 comprises 74km, whereas section 2 is only 39km; however, section 2 includes a 19km tunnel into Central London as well as a 2.5 km tunnel under the River Thames. Infrastructure UK (2010) compares the cost per km of building HS1 with five comparable projects elsewhere in Europe using purchasing power parity exchange rates. The mean construction cost of the other five was £19m per km, for HS1 stage 1 it was £24m and for stage 2 £94m. This gives some indication of the very high cost of section 2, which included the tunnels noted above as well as the refitting and extension of St Pancras station in London and new stations at Stratford and Ebbsfleet.

Regeneration impacts

The opening of the tunnel into central London and the St Pancras terminal has occurred simultaneously with one of the largest inner-city regeneration projects in Europe. Over a 67 acre site (27.1 hectares) some 8 million square feet (750,000 m²) of mixed use development including businesses, 1,800 homes, cultural facilities (cafes, bars, restaurants, etc.) and community (health, education, etc.) facilities is under on-going development¹. The development will end decades of blight and low quality land use in the area with all the attendant social problems.

Hedonic pricing studies have already identified uplift in property values in the vicinity of the rail terminals since the opening of the High Speed tunnel link indicating positive economic impacts. Cascetta *et al.* (2010) for example estimate house prices in the Borough of Camden increased by 13% as a result of the opening of tunnel link and St Pancras station. How much of the increase in property prices is due to the high speed rail tunnel and train station development and how much is due to the Kings Cross Central regeneration project is of course debatable. Some regeneration may have occurred anyway with just a re-modelling of Kings Cross station and St Pancras. However, the implicit linking by the government of the high speed rail tunnel alignment to the area would suggest that the improved transport accessibility and image of the high speed rail link were major contributing factors.

The regeneration effects of the tunnel and link are not just confined to London. The increased rail capacity permits fast (domestic) trains to run to Central London from Ashford in Kent. Here it is planned that 13 000 new houses and 10 300 new jobs will be created by 2016 increasing to 31 000 homes and 28,000 new jobs by 2031 (Cascetta *et al.*, 2010).

1. Kings Cross Central website: <http://www.kingscrosscentral.com/>

Such re-generation impacts do not enter the cost benefit analysis process, as the overarching guidance of cost benefit analysis in the UK (HM Treasury's Green Book) does not permit the shadow pricing of labour. That is, it is assumed that the economy is in full employment so any jobs generated will be offset by reductions in employment elsewhere. Moreover increases in property values are regarded as capitalisation of other benefits, such as time savings, and are also not allowed as additional benefits. Guidance to decision makers in the UK includes analysis of non-monetised impacts alongside cost benefit assessment. Regeneration impacts are included in the non-monetised part of the appraisal when they are potentially significant and can therefore affect the decision to build new infrastructure even though they are not part of the cost-benefit analysis.

4.2 Conclusions on HS1

The HS1 project was very expensive because of the need for a large amount of tunnelling to reach Central London in an environmentally acceptable way, particularly over the route chosen politically on grounds of regenerating a depressed area of inner London. It is not thought that this original decision was based on any detailed appraisal of the options, but an appraisal was undertaken when the government had to step in to underwrite the project's debt in order to enable it to continue. At the time it appeared that the project could be justified given the forecast growth in international rail passenger traffic, but in practice the forecast growth did not materialize, leaving a rather more marginal case. NAO (2012) concludes that, despite carrying 18.1m passengers p.a. (9.7m international and 8.4 domestic), the time savings to users were inadequate to justify the capital cost. Its value therefore depends on regeneration and wider economic benefits. In the original appraisal, quantification of the regeneration benefits of locating a high speed rail station in Stratford was based on inadequate methods; subsequent work has suggested a much greater impact (Colin Buchanan and Partners/Volterra, 2009), although its magnitude and whether it really represents a net addition to economic activity remain controversial. In addition substantial wider economic benefits were estimated. As we shall see in the following section on HS2, quantification of wider economic impacts has remained an important and controversial issue.

4.3 High Speed 2

Introduction

In 2001 the Strategic Rail Authority, the government body then responsible for rail planning, commissioned the first study of high speed rail between London and the North (Atkins, 2002). The background was steady growth in rail demand over the preceding few years which, if it continued would eventually impose capacity constraints, plus the possibility of substantial savings in travel time. The remit thus required the consultants to examine the case for high speed rail and the route it might take, bearing in mind the contribution it would make to easing capacity constraints and the amount of travel time saved. The latter objective required concentration on medium distance routes between large centres of population where existing and potential rail demand were high, whilst the former objective concerned routes that would relieve the West and East Coast main lines (the principle constraints on growth) of significant amounts of traffic. Altogether 16 high speed rail options were examined comprising different combinations of the sections of track shown in Figure 4.1. Option 1 was a minimal line from London to Birmingham; option 8 a fairly complete network with a West Coast line from London to Birmingham and Manchester, and a branch to Leeds and on to Scotland. Also considered were building a conventional line, upgrading existing lines, road widening and airport expansion (although

airport expansion was not modelled in the study. Extensive sensitivity testing was also undertaken, including examining the impact of four different long run economic scenarios, examining rail pricing policy and sensitivity to costs of other modes of transport.

Figure 4.1 Options considered by the Atkins study for HSR



Figure 4.2 Route chosen for HS2

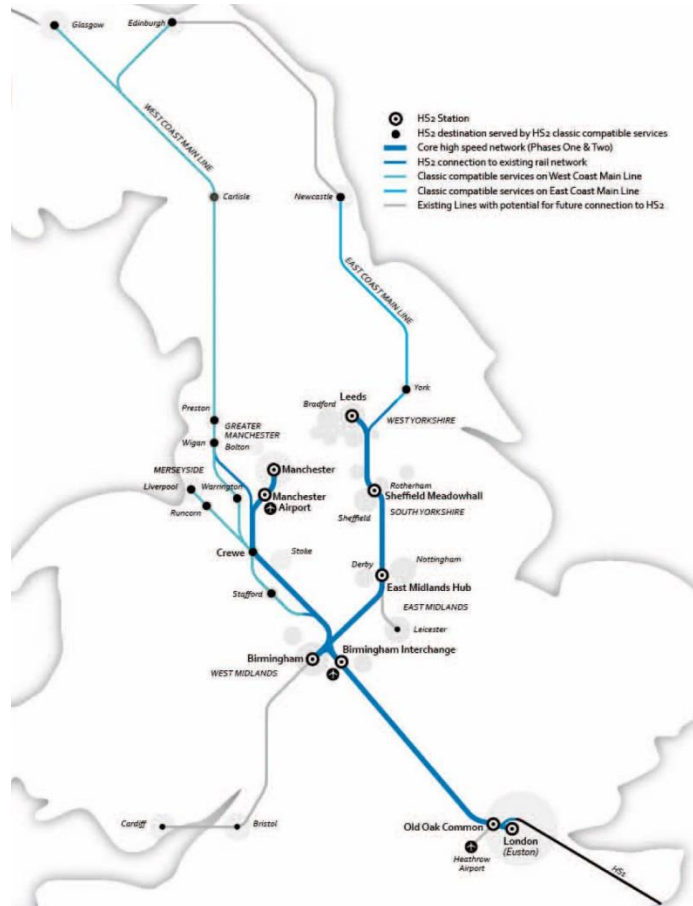


Table 4.3. Appraisal of options 1 and 8 in the Atkins study

	Option 1	Option 8
Net revenue	4.9	20.6
Non-financial benefits	22.7	64.4
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/C	2.07	2.04

Source: derived from Atkins (2003) Addendum. Table 2.1 with transcription errors corrected.

All but one of the HSR schemes gave good benefit cost ratios, with highest NPV coming from the most complete option, option 8 (Table 4.2). With a BCR close to the smallest option and above 2, this looks like the best option if it can be afforded.

A conventional line could be built for 20% less than HSR, but would lose £5b of benefits for a cost saving of less than £2b, whilst upgrading of existing lines appeared even less favourable. The road widening option appeared worthwhile but of less value than HSR. Also tested was the issue of timing; it appeared best to build the full HSR network as soon as possible (by 2016) rather than deferring it to 2021 or 2026. Charging premium fares reduced the benefits, although it was noted that the demand model did not permit testing of more differentiated pricing to target less elastic market segments (it is a common problem of rail appraisals that yield management systems are inadequately modelled, leading to an understatement of revenue or demand or both.).

Ultimately the value of a study is only as good as its forecasts, and the fact that this study foresaw the West Coast Main Line running out of capacity by 2016 suggests its forecasts were not accurate (to be fair, few foresaw the financial crisis of 2008 and subsequent recession). But in terms of what it considered, the Atkins study seems to have been a model of its kind, considering a wide range of options, including a road alternative, alternative economic scenarios and examining both fares policy and timing, which are often neglected in appraisals. Extensive sensitivity testing was undertaken.

There was no immediate follow up to this study, but in the light of continued growth in traffic, Network Rail (the infrastructure manager) undertook its own 'New Lines' study in 2009 (Network Rail, 2009). Whilst there was no necessary presumption that new lines would be high speed rail, as in the Atkins study, the study showed that in general if new lines were built for long distance rail, the extra benefits of high speed would be worth the extra costs. This study again found a good case for HSR but this time favoured the West

Coast Route to Scotland, serving Birmingham, Manchester and Liverpool but not Leeds. (the option of a line diverging to Leeds and the North East was not considered; it was argued that a separate new HSL might in due course be justified for this route). It found direct connections to Heathrow and to the high speed line to the Channel Tunnel to be uneconomic given forecast volumes of traffic.

The response of the government however was to set up a new company, HS2 Ltd, to look at the case for a high speed line from London to Birmingham as a first stage of a wider network. After reviewing the options, HS2 concluded in favour of a Y shaped network along the lines of Atkins option 8 (the extensions to Manchester and Leeds forming phase 2). Trains would continue on conventional lines to a range of cities including York, Newcastle, Liverpool, Glasgow and Edinburgh. Euston was chosen as the London terminus for the new line, but it would also call at Old Oak Common, where a high quality interchange would be provided with the new Crossrail line. This would provide an attractive way of reaching all the terminals at Heathrow (a Heathrow terminus would only provide direct access to one terminal with a bus or train ride needed for the others) with Central London, Docklands and East London. It was important because, were all passengers to arrive at Euston the station and its underground rail connections would be swamped. Subsequently, political decisions were taken to provide direct links to one Heathrow terminal (consideration of this is now postponed pending a review of airports policy) and by a single track link to a heavily used existing line for connection to the high speed line to the Channel Tunnel.

Appraisal of HS2

Essentially the British approach to appraisal consists of quantifying as many of the costs and benefits as possible in money terms; other factors are presented as quantitative or qualitative evidence to be taken into account subjectively. The aim of the appraisal is to estimate the net benefits of the project to all sectors other than the government per pound of government spending. Given constraints on government spending, the current position of DfT is that only projects giving at least £2 of net benefits per pound of government spending are considered good value for money; projects giving a lower benefit-cost ratio than this will not usually be taken forward.

Regarding wider economic benefits, for many years the British government followed the conventional wisdom that there would be no economic benefits other than the time and cost savings already included in a standard transport appraisal. The first major questioning of this position in Britain came about in the course of the appraisal of the Crossrail project, a major project to link suburban rail lines East and West of London by a major new tunnel across London, greatly increasing capacity and leading to faster journeys for many commuters (Worsley 2012). Surely, it was argued, this would both raise the productivity of existing Central London employment and permit more jobs to locate in this area of high productivity. A very influential paper was that of Venables (2007) who used the concept of agglomeration economies to show that this argument might well be correct. Firms in highly accessible locations in city centres do indeed tend to have higher productivity (they must to justify the higher costs of such a location). Investments which increase accessibility will both provide an external agglomeration benefit to firms already located there and enable jobs to relocate there from lower productivity locations (to the extent that it had previously been possible to locate there, it may be argued that if additional trips and the consumer surplus associated with them were correctly forecast then this benefit to the relocating firms will already have been taken into account in the appraisal, although there will still be agglomeration externalities accruing to other firms in both the original and the new locations). However, the increased tax revenue implied by relocation to a higher wage and

productivity location would not be valued as part of the consumer surplus as it is not received by the consumer but rather by the government.

Subsequent work, particularly that of Graham (2007), enabled these impacts to be quantified and introduced into the appraisal. A further argument has also been allowed for, in that if a degree of monopoly power is the norm, and prices are generally above marginal costs, then anything that reduces the costs of employers and thus increases their output will tend to have an additional benefit of the difference between price and marginal cost of the increased output. This provides a further argument for a multiplier to be applied to the value of business travel time savings in the appraisal. Whilst in principle these effects would apply to all modes of transport, to the extent that rail dominates commuting and business travel in large cities (in Britain, particularly London), they might particularly favour rail investment in those locations. Elsewhere, car travel dominates and the arguments might favour investment in roads.

Graham and Melo (2010) argue that investment in long distance rail cannot have a significant wider economic impact because of the small overall rail market share of journeys in the course of work and the fact that most such journeys are relatively short distance. This is essentially the position of DfT. The appraisal of HS2 therefore allows for the presence of wider economic benefits from improved commuter services using the capacity released by HS2, but not for any wider economic benefits of improved inter-city connectivity.

Table 4.4 shows the results of the 2013 update of the economic case for the line. The principal benefits would again be benefits to transport users. Wider economic benefits were forecast to exist entirely because of agglomeration benefits from the release of capacity on existing lines to improve commuter services into the main cities (in particular London) rather than because of improved inter-city connectivity. Whilst even the first phase of the line from London to Birmingham would benefit a large network of origins and destinations, since it would carry trains to major centres of population such as Manchester and Glasgow which would complete their journeys on the conventional network, the full Y shaped network actually shows a higher BCR than the first phase alone. The reason is that extending the line to Manchester and in particular connecting it to Leeds and the North East permits better use of the first phase of the network giving a better overall result.

Table 4.5 shows the breakdown of transport benefits. It will be seen that over half of the benefits are time savings, with business travel time savings being around 40% of the total. But improved reliability and reduced crowding are also estimated to be substantial sources of benefits. Tables 4.4 and 4.5 are based on the simple assumption of pricing parity between high speed trains and conventional trains.

Table 4.4 **Standard appraisal – discounted costs and benefits (over 60 years)**
(£b 2011 prices)

	Phase One <i>Oct 2013</i>	Full Network <i>Oct 2013</i>
Transport benefits (Business)	16 921	40 529
Transport benefits (Other)	7 673	19 323
Other quantifiable benefits	407	788
Indirect taxes (loss to Govt)	-1 208	-2 912
Net transport benefits	23 793	57 727
Wider economic impacts	4 341	13 293
Total costs	29 919	62 606
Revenues	13 243	31 111
Net cost to Government	16 676	31 495
Benefit cost ratio (inc WEIs)	1.7	2.3

Source: DfT (2013)

Table 4.5 **Breakdown of benefits from the proposed HS2 scheme**

(£Bn 2011 prices)	Phase One	Full Network
Time savings	17 334	45 679
Crowding benefits	4 068	7 514
Improved reliability	2 624	5 496
Car user benefits	568	1 162
Total transport user benefits	24 594	59 852
Wider economic impacts	4 341	13 293
Other impacts	407	788
Loss to Government of indirect tax	-1 208	-2 912
Total	28 134	71 020

Source: DfT (2013)

The project has been strongly criticised by opponents to the scheme, ranging from some who think the money would be better spent on roads to others who object to its environmental impacts or want the money spent on local public transport. For a systematic presentation of the arguments see Castles and Parish (2011). The most significant criticisms were of:

- The robustness of the demand forecasts

The latest version of the business case assumes growth in demand of 2.2% p.a. until 2036, and constant demand thereafter. This is considerably slower demand growth than achieved by long distance train operators in the last 20 years, despite the effects of recession. HS2 Ltd has conducted a risk analysis, which shows a very low probability of the benefit-cost

ratio falling below 1.5; if demand growth were to continue beyond 2036 then the benefit-cost ratio could rise considerably higher than the standard case estimate of 2.3. Yet it must be accepted that demand growth is uncertain. It is possible that past relationships with GDP might break down and growth stop before 2036. It is argued that, for instance, developments in information technology might lead to its substitution for much travel, although at present it seems that it is encouraging travel by rail for business and for leisure amongst younger males (Le Vine and Jones, 2012).

- The valuation of time savings

It has already been noted that the standard approach to valuation of business travel time, based on the wage rate, is argued to be inappropriate for inter-city rail travel since business travellers work on the train. Castles and Parish argue that the value of business travel time savings should be based solely on the loss of utility to the traveller as represented by the value of commuting time. However, this assumes that all time savings will be at the expense of work done on the train, that work on the train is as productive a work in the office and that there are no other benefits in terms of scheduling more meetings in a day, avoiding overnight stays and arriving at meetings more alert. We have noted above that most evidence suggests that businesses are prepared to pay at least the wage rate for time savings for business travellers.

- The degree of attention paid to alternatives.

It is argued that too little attention has been paid to optimising a set of alternative proposals to upgrade existing lines, and that a package of alternative measures (including some degree of demand management by price) exists which would meet demand at much less cost. The so-called 51M package was put forward by a group of opposing local authorities as such an alternative (Castles and Parrish, 2011).

Atkins were commissioned to appraise this package (Table 4.6). It found that the package would cost only £1.2b, and would yield a benefit-cost ratio of no less than 6. However it would not provide sufficient capacity to provide for peak demand. Given its BCR, many people argue that it is clearly a better investment than HS2. However, ranking projects on the basis of BCRs is not an appropriate way to take decisions. What matters is whether the additional cost of a more expensive alternative is justified by the extra benefits. If we look at the incremental costs and benefits of HS2, it shows an incremental benefit-cost ratio of around 2, roughly the threshold for the British government to consider a project to give high value for money. Thus the additional cost of HS2 is justified by additional benefits, according to the appraisal. But there remains concern that, at a time of constrained government spending, such a large investment will squeeze out many smaller investments that might collectively have provided better value for money.

Table 4.6 **Incremental benefits and costs over 51M package**
(£b2011PV)

	51M	Y shaped increment
Benefits	7.108	46-52
Costs to gov	1.173	25-23
BCR	6.06	1.6-2.3

Source: derived from Atkins (2012)

The latest strategic case published by DfT includes a much more thorough examination of alternative rail schemes (diversion of traffic to road or air is dismissed as incompatible with government policy). Several different packages of schemes, including duplicating sections of main line and improving junctions and existing stations were put together. Table 4.7 shows the appraisal of the packages of schemes most comparable to HS2. Neither package provides nearly as much capacity as HS2. Both provide higher BCRs than HS2, but the incremental BCR from the much greater investment in HS2 remains above 2.

Table 4.7 **Capital costs and benefits of alternatives**

	HS2 Phase One	Phase One Alternative	HS2 Both Phases	Phase One and Two Alternative
Capital costs (£bn)	19.4	2.5	38.4	19.2
Benefit-cost ratio	1.7	2.0	2.3	3.1
Benefits £bn	28.1	8.5	71.0	30.7

Source: DfT (2013)

Wider economic benefit

It was noted above that the DfT appraisal contains no wider economic benefits from improved inter-city connectivity, although this – and the idea that HS2 will help reduce the North-South divide in terms of British prosperity – have been influential arguments politically. The DfT position has been challenged in work recently undertaken by KPMG (2013) for HS2. The first step of their methodology is to calculate the impact of HS2 on labour and business connectivity by location. They do this by looking at journey times weighted by the distribution of existing journey lengths for the purpose in question (the so-called distance decay function). As seen in Table 4.8, most areas gain, even when not directly served by HS2 (long distance journeys may still use HS2 for part of their route, whilst other places gain from improved services using the capacity released on the existing network), although it is the Midlands and South Yorkshire that enjoy the greatest gains (they gain for journeys to London but also to other cities in the Midlands and North).

Table 4.8 **Average change in connectivity by region in 2037 after investment in HS2**

City regions	Change in labour connectivity by rail	Change in business connectivity by rail
Derby-Nottingham	14.7%	23.2%
Greater Manchester	1.4%	18.8%
Greater London	6.9%	8.8%
South Yorkshire	31.8%	22.5%
West Midlands	15.7%	21.1%
West Yorkshire	9.1%	19.7%
Rest of Great Britain	5.3%	11.3%

Source: KPMG (2013)

They then regress labour productivity on rail connectivity and similar measures of connectivity by road. The difficulty faced is that these indicators of connectivity are all highly correlated (and may be correlated with other benefits of a city centre location). The result is that only one measure of connectivity can be included in a single regression. They therefore run separate regressions of labour productivity on rail connectivity and on road connectivity. They scale down the parameter value on rail connectivity by assuming that rail connectivity is responsible for a proportion of the benefits equal to the ratio of the parameter values on rail connectivity and road connectivity in the separate regressions. This leads to an estimate that HS2 could add £15Bn p.a. to GDP. Whilst this is not entirely additional to the current appraisal benefits, it must represent a substantial uplift. However, there is no theoretical justification for the assumption by which the rail share of the effect is estimated, and a sensitivity test using mode share data to perform this allocation gives a much lower value. Moreover, it has been argued that inadequate attention has been paid to the issue of labour quality. Thus the wider productivity impact of HS2 remains very uncertain.

Conclusions on HS2

HS2 represents something of an extreme in terms of HSR. Its costs are exceptionally high (although they contain a large contingency in view of past experience with projects overrunning on cost). But its traffic forecasts (more than 40m trips per annum at opening of phase 2) are also very high. The high level of traffic is the result of British geography, which if not quite the Japanese string of pearls, enables many of the main cities of Britain (London, Birmingham, Manchester, Leeds) to be served by a single line splitting into two in the Midlands. Moreover, trains can then continue on conventional lines to serve a large number of other cities including Liverpool, Newcastle, Glasgow and Edinburgh. The result is a high estimated benefit cost ratio.

Of the uncertainties surrounding this ratio, the greatest concerns growth in demand. If growth in demand slowed or ceased, it would have a substantial effect on the BCR, although the BCR would be very unlikely to fall below 1. If demand continued to grow long term (in the current forecast growth in demand is capped at its 2036 value) the BCR would be still higher.

The question of whether the improvements in inter-city connectivity would bring greater economic benefits than are included in the official CBA remains uncertain and controversial.

OVERALL CONCLUSIONS

From the number of studies undertaken and the experience of high speed lines around the world, it is possible to reach some general conclusions on the circumstances in which high speed rail will be worthwhile. Of course, the decision is a trade-off between costs and benefits; factors which make for higher costs may be outweighed by other factors making for higher benefits. The dominant factors are construction costs, value of time savings per passenger and the volume of passengers.

Firstly, high speed line construction costs vary greatly, but a major factor is the amount of tunnelling. If routes can be found which allow access to city centre stations without tunnelling the savings will be large. This might be achieved by placing suburban services underground; this may be a lower cost solution and have other benefits if it enables suburban services to penetrate and cross the city centre.

Secondly, the value of time savings per passenger will vary with the quality of the alternative and the incomes (and therefore value of time) of passengers. HSR will bring greater time savings per passenger where it is substituting for conventional rail or car than where it depends for most of its traffic on a marginal time saving compared with air. Of course other benefits – environmental and reduced congestion at airports – may be greater where it is predominantly diverting from air, but it is unlikely that these will compensate for the smaller time savings in the appraisal.

Thirdly, serving a large population is crucial. High speed rail requires either to link very large cities, or to serve a string of large cities, possibly by running on conventional lines past the end of the high speed line. High density cities with strong public transport networks will favour HSR over car and air. HSR journey times of around 3 hours are required to compete effectively with air, however, so HSR will be most effective for routes of up to 800 km. For shorter journeys HSR may be worthwhile in terms of time savings to existing rail users and diversion from car, but below around 150km, the high speed of HSR will be irrelevant because of the shortness of the journey).

Fourthly, congestion on existing rail, road and air systems will favour HSR by providing a case for more capacity. However, there are always numerous ways of providing more capacity; a policy which favours rail over road and air on environmental grounds will obviously favour the case for HSR.

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