Journal of Rail Transport Planning & Management 5 (2015) 12–22

Contents lists available at ScienceDirect

Journal of Rail Transport Planning & Management

journal homepage: www.elsevier.com/locate/jrtpm

When to invest in high speed rail

Chris Nash

Institute for Transport Studies, University of Leeds, United Kingdom

A R T I C L E I N F O

Article history:
Received 10 June 2014
Revised 15 February 2015
Accepted 16 February 2015
Available online 12 March 2015

Keywords:
High speed rail
Investment
Appraisal

A B S T R A C T

This paper starts by a general review of the costs and benefits of high speed rail, of how they are measured in cost–benefit analysis and of the circumstances in which benefits may be expected to exceed costs. Two approaches are taken to the latter; first, examining models in which values of key parameters are varied to see in what circumstances benefits exceed costs, and secondly looking at the limited evidence from ex post studies, mainly for France and Spain. We then turn to British experience of the appraisal of HS2 – the proposed line linking London to Birmingham, Manchester and Leeds. It is concluded that the main factors determining economic success for high speed rail projects are construction costs, value of time saving per passenger and traffic volume and degree of congestion of existing transport networks. The biggest uncertainty regarding the case for high speed rail surrounds the possibility of wider economic benefits.

Contents

1. Introduction

High speed rail (HSR) is usually regarded as comprising services operating at 250 kmph or more, and these speeds invariably require construction of new purpose built lines, although high speed trains may run at up to 200–225 kmph on upgraded existing lines. According to UIC, by 2013, a total of 21,472 km of new high speed lines had been built worldwide. China had the largest network at 9867 km, whilst Japan, France and Spain all had over 2000 km. There are plans for a further major expansion, with the

http://dx.doi.org/10.1016/j.jrtpm.2015.02.001
2210-9706/

European Commission calling for a trebling of the kilometres of high speed line in Europe by 2030. Yet high speed rail is an enormous investment, and 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 then examine evidence on the circumstances in which benefits will exceed cost, drawing both on theoretical modelling exercises and on ex post studies of actual schemes.

We will then consider specifically the current debate on high speed rail in Britain. The large volumes of existing rail traffic, and the ability to serve many of the main cities of Britain with a single line splitting into two branches, appear to make Britain an ideal country for high speed rail. However, the proposed line from London to the North, HS2, has proved very controversial. The final section of this paper draws conclusions.

2. Costs and benefits of high speed rail

2.1. Introduction

The principal costs and benefit of HSR are listed in Table 1. Section 2.2 discusses costs, Section 2.3 patronage and revenue, Section 2.4 time savings, Section 2.5 rail capacity benefits, Section 2.6 diversions from other modes and Section 2.7 wider economic benefits.

2.2. Costs

Table 2 summarises construction costs of high speed rail in Europe and Asia. It will be seen that there is a considerable range both within and between countries. Obviously there are many factors influencing this including differing labour and land costs, whether the line is designed for both freight and passenger trains or passenger only and whether the line uses slabtrack or traditional ballasted track. But particularly significant factors are the degree to which new stations have to be constructed and the length of tunnelling needed (either because of the terrain or to alleviate environmental problems (SDG, 2004). For instance of the estimated construction cost of HS2 Phase 1 in Britain, over 40% comprises station and tunnelling costs (HS2, 2012). This is because a substantial amount of tunnelling is planned, particularly in order to get into central London, and either new or substantially extended stations are required. By contrast, in many European cities (such as Paris) high speed trains have generally been accommodated in existing stations without major extensions and accessed these on the surface. One reason for this is that suburban trains have been redirected into underground routes across city centres releasing surface capacity for high speed rail.

Table 1
HSR costs and benefits.

Costs	Benefits
Capital costs	Revenue
Operating costs	Time savings (beyond those recovered in higher prices)
External costs	Release of capacity on existing rail routes
Loss of tax revenue (from traffic diverted from road to rail)	Diversion from other modes – reduced congestion, accidents and environmental costs
Opportunity cost of public sector funds	Induced traffic
	Wider economic benefits

Table 2
Construction costs of high speed rail (2005 prices).

	Euros m per route km
China	5.7–18.8
Belgium	16.1
France	4.7–18.8
Germany	15–28.8
Italy	25.5
Japan	20–30.9
Korea	34.2
Spain	7.8–20
Taiwan	39.5

Source: Derived from Campos et al. (2009) Graph 1.3, except China, which is from Wu et al. (2014).

Given these high costs, it is obviously sensible to ask whether the costs may be reduced by using upgraded conventional tracks for all or part of the network. Much will depend on what already exists and whether it has spare capacity. For instance, in Japan the existing lines were metre gauge with many curves and gradients and not easily upgraded for high speed operation. In Spain, existing lines were broad gauge and difficult to upgrade for high speeds, but the decision to build a new network of standard gauge lines has limited through running to the conventional network to trains capable of changing gauge. Even in parts of Europe, where the existing lines were much more suitable, upgraded lines are not usually used for more than 200 kmph (although 225 kmph might be feasible with new cab signalling). A further consideration is capacity; if lines upgraded for higher speeds have to accommodate existing trains at lower speeds (e.g. freight or regional passenger trains), the increased spread of speeds will actually lower capacity.

What is more common is to build new lines where demand is strongest and capacity most scarce but to use existing lines elsewhere. The French TGV network has been developed along these lines, with new tracks being built for the trunk haul into Paris but trains proceeding to a host of destinations on the old network (some of these destinations are now on extensions of the high speed network). The German ICE network uses upgraded conventional lines for much of its distance with new lines largely confined to overcoming bottlenecks.

In terms of operating cost, it appears that high speed trains are no more expensive than conventional trains when the capital cost of the vehicles is taken into account. Whilst energy consumption and maintenance costs are higher than for conventional trains, high speed means staff and rolling stock can achieve much higher utilisation rates than conventional rail, offsetting the increased costs (Civity, 2013).

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. Other things being equal, energy consumption rises rapidly with speed, particularly at speeds above 300 kmph, so high speed trains may be more energy intensive than conventional trains. Moreover the higher speeds will induce additional traffic that has not simply diverted from other modes. Offsetting this is the fact that high speed trains typically run at much higher load factors than conventional trains as a result of long nonstop runs between major cities and the use of yield management systems; load factors as high as 70% have been claimed for the Eurostar trains between London and Paris and Brussels, and for the French TGV network, as opposed to 40% for conventional trains. The result of these differences in load factor is that the carbon cost per passenger km for a Eurostar train, for instance, is very similar to that for a 200 kmph pendolino (CILT, 2011).

As well as the carbon produced by train operation, 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 emissions trading scheme is fully implemented for aviation).

Putting this argument aside, the greenhouse gas emissions for HSR operation 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.

The safety record of rail overall is very good, but for high speed trains it is particularly good. New high speed lines are invariably built with cab signalling and completely segregated from road and pedestrian traffic (i.e. without level crossings). The only fatal accident to date on a newly built high speed line was on the 250 kmph Ningbo–Taizhou–Wenzhou line in China, when two trains collided at low speed due to human error following a signal failure. There have been several serious accidents involving high speed rolling stock running on conventional lines, however, notably in Germany and most recently Spain.

The majority of high speed lines in the world have not been commercially viable, and have needed government grants towards construction costs (and sometimes operating costs as well). The major exceptions seem to have been the first French and Japanese lines (see Crozet, 2014 and Kurosaki, 2014). Added to this is the fact that they actually cost the government tax revenue if they divert trips from heavily taxed road transport to more lightly or untaxed rail. (Of course, one reason for the heavier taxation of road transport is its greater external costs, but these are best taken into account in the cost–benefit analysis directly, rather than by assuming that the level of taxation correctly reflects them). The treatment of the cost of reduced tax to the government as one of the costs of rail schemes has 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.

Given that taxation typically involves the deadweight loss of distortions, (and indeed that for macro economic or political reasons there may be overall budget constraints on the public sector) the call on public funds may have an opportunity cost in excess of the simple cash flow. For many years this opportunity cost was allowed for in the discount rate applied to public sector projects, which was based on the rate of return such funds could achieve in the private sector. More recently, discount rates for public sector projects have typically been much lower (for instance 3.5% in Britain, reducing to 3% after 30 years). This strongly favours projects with high capital costs and long lives, by increasing the present value of the benefits more than the costs. However, it raises the issue of how to allow for this opportunity cost. Some countries (e.g. Sweden) shadow price public sector funds by multiplying them by a shadow price greater than one (often 1.3). Others such as Britain require a ratio of net benefits to public sector funding greatly in excess of one – in Britain typically at least 1.5 – to allow for the opportunity cost of funds.

A further possible reason for a higher discount rate is to allow for risk, but this is a crude way of doing so. Generally the favoured approach now is by means of a quantified risk assessment, which considers the probability distributions for all the elements contributing to cost and uses these to build up a probability distribution of the cost of the project in total. The decision taker may then choose if they wish to be cautious and take a cost figure higher than the 50th percentile of the distribution in the appraisal.

2.3. Traffic and revenue

The construction costs of high speed rail are largely fixed regardless of traffic. High speed rail almost invariably requires a double track main line with cab signalling. If all trains are identical in performance and leave the main line at high speed turnouts before slowing down to stop at any intermediate stations, then in principle operation at 3 min headways is feasible, offering 20 trains per hour. Some margin to recover from delays is necessary, but already France runs 13 trains per hour in the peak between Paris and Lyons and Japan 15 between Tokyo and Osaka. Britain plans a peak service of 18 trains per hour on HS2. France is already operating trains with pairs of double deck units offering around 1000 seats. Only the costs of rolling stock, stations and depots vary significantly with traffic volumes. Thus high speed rail systems have very high fixed costs which can only be justified by high traffic volumes.

The world's first high speed line, from Tokyo to Osaka, carried 39 m passengers in its first full year of operation (1965) and this had grown to 149 m by 2008 (Albalate and Bel, 2012) with the help of extensions to the line. Paris–Lyon opened with 19.2 m passengers in 1985, whilst the following Atlantic, North, Connection, Rhone-Alpes and Mediterranean lines all opened with similar numbers (Paix, 2010). However not all lines have attracted traffic in these sorts of volumes. At the other extreme, the Madrid–Seville line opened with as few as 2.5 m passengers, and Madrid–Barcelona with only 5.0 m (Sanchez-Borras, 2010).

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 127 m people living at very high population densities mainly in large cities along the coastal strip. France also is able to benefit from this sort of geography to a degree, partly 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.

Clearly the volume attracted is not simply a matter of the population but also its propensity to travel and the competitiveness of rail with other modes. An upgraded conventional rail system may achieve a commercial speed of the order of 160 kmph, whilst for high speed rail designed for 300 kmph, 240 kmph may be feasible. The journey time for each in terms of hours for certain distances is shown in Table 3. However, competitiveness in terms of door to door journey time also depends on access to the station and frequency of service. Car provides door to door service with no waiting time or schedule delay. For a door to door journey largely on motorway, a 100 kmph average may be feasible. If rail involves an additional 2 h in terms of access, egress and waiting time then

Table 3
Comparative journey times for upgraded conventional and high speed rail.

Distance (km)	Hours at 160 kmph	Hours at 240 kmph
200	1.25	0.83
300	1.875	1.25
400	2.5	1.67
500	3.125	2.083
600	3.75	2.5
700	4.375	2.917

even high speed rail will only be faster than car for journeys of well over 300 km. If part or all of the road journey is on congested or low speed roads, then rail may be competitive over much shorter distances, and even with upgraded conventional lines. Indeed for shorter journeys, a frequent service calling at easily accessible stops may be preferable to a high speed service calling only at the very busiest stations and made up of high capacity less frequent trains, with other passengers having to change into the trains at these stops.

In comparison with air, it has been argued that – because for most passengers it involves less access, egress and waiting time – rail can compete with air provided the station to station rail journey is not more than 3 h. Table 4 shows that indeed rail generally has more traffic than air in these circumstances. (The exception is Madrid–Barcelona, where in 2009 airlines had retained slightly more than 50% of the market partly by offering a shuttle service on which passengers may take the next available flight without reservations. On the other hand, there are cases such as Paris–Brussels, where air has completely withdrawn from the market and books its passengers into a special seating area in the trains.) Thus whilst upgraded conventional rail may be able to compete at up to 450 km high speed rail pushes this up to at least 700.

However Table 4 reveals a diversity of rail share for the same rail journey time. A major factor here is the geography of the catchment areas. In a dense city with high quality public transport focussed on the city centre and frequent inter city services, access, egress and waiting time for rail may typically add less than 2 h to the door to door journey time, whilst for a more remote airport, including time spent at the airport, for air it may be at least three. In a low density city, with weaker public transport, the advantage of rail in access and egress may be much lower.

But competitiveness does not solely depend on journey times. Rail may also have the edge over other modes on comfort and on board facilities (for instance, the ease of use of devices such as laptops, tablets and mobile phones). Whether fares will be competitive depends on the pricing policy, but with increasing use of yield management high speed rail fares start to look much more like airline ones. Whether rail is competitive with car on price obviously depends on factors such as the price of fuel, the presence and level of road tolls and how many people are travelling together.

Table 4
Rail share of rail/air market and rail station to station journey times.

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

Source: Compiled by the author from Campos et al. (2009), Sanchez-Borras (2010) and SDG (2006).

2.4. Time savings

Table 3 in the previous section shows that substantial time savings may be made by passengers previously using even upgraded conventional trains. For car or air, the time saving depends very much on the length of journey; if the journey is close to the break-even point between the modes then the time saving may be much smaller. However, it is not always appreciated that many aspects of comfort and convenience may also be included in the value of (generalised) time used in economic appraisal. The raw values used in current British appraisals are shown in Table 5. 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). Around half of the benefits to rail users from HS2 is estimated to come from reduced crowding, improved reliability, reduced walking and waiting times and improved access and interchange, as opposed to simple reductions in in-vehicle time (DfT, 2013).

Of course in lower income countries such as China it must be expected that the willingness to pay to save time, will also be lower, and it will be more difficult to justify high speed rail. Wu et al. (2014) conclude that in China it is only the busiest high speed lines on the prosperous East Coast that are justified; many of the other lines would be better built as conventional mixed traffic railways.

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 et al. (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

Table 5
Values of time used in British rail appraisals (£ per hour, 2010 prices and values).

Business	31.96
Commuting	6.81
Leisure	6.04

Source: DfT (2013).

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; depending on the precise assumptions, Batley et al. found cases where it might be as low as 32% of the existing valuation.

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 et al., 1986).

2.5. Release of capacity on existing routes

Building a high speed line which will divert a substantial volume of traffic from an existing route not only creates a huge capacity for high speed traffic itself; it may also permit growth of other types of traffic on the existing line. Removing all the fastest services from a route will reduce the spread of speeds and thus release more capacity than simply the number of paths formerly taken by the diverted trains. In Europe, a major incentive for the construction of high speed lines has been to release capacity for more freight trains on paths that involve less time in loops waiting for faster trains to pass. If the new line is built into the centre of the cities it serves, then it will also release capacity sufficient for an expansion of commuter and other regional passenger services.

Of course, building a high speed line is not the only way of achieving this. Building a new mixed traffic or freight dedicated line (as is underway in India) will also create capacity for other services. More limited upgrading (for instance grade separated junctions, longer passing loops, etc.) will create some extra capacity, whilst a decision may be taken simply to price the peaks in traffic off rail. But if a new line is to be built on routes with a lot of passenger traffic, in many cases in wealthier countries it has been found that it is better to build a high speed passenger line as the increase in cost involved (20% in the case of HS2 in Britain) is less than the benefit it brings. As noted above, this does not necessary apply to lower income countries such as China.

2.6. Diversion from other modes

The benefits of diversion from other modes take the form of reductions in externalities – congestion, accidents and emissions. Against these must be set any excess of mode specific taxes and charges over and above marginal cost of infrastructure provision and maintenance. What is needed then is firstly an estimate of how many high speed rail travellers have diverted from each mode. Once the mode from which passengers have switched is known, information is then required on the marginal social cost of the modes in question. Based on the evidence cited in Table 6, reduced noise and pollution costs from air transport might provide a benefit from switching to HSR of the order of 9 m euros at year 2000 prices for 1 m passengers diverted from air in 200 seater aircraft on an 800 km route. 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.

For car, the evidence of GRACE (2005) is that it is only when there is substantial congestion that marginal social cost exceeds charges (Table 7) 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 include commuter journeys into large cities and heavy freight. Since these are both types of traffic where the evidence is that external cost typically exceeds charges, the benefits may be more substantial (Greengauge, 2012).

2.7. Induced traffic and wider economic benefits

For induced 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

Table 6
Air transport externalities.

		Air pollution	Climate change	
Flight distance (km)		Direct emissions	Direct emissions	Indirect emissions
(a) Externalities air (eurocents 2000 per passenger km)				
<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
	40 seater	100 seater	200 seater	400 seater
(b) Noise costs per landing or take off at Schiphol (euros 2000)				
Fleet average	180	300	600	1200
State-of-art	90	150	300	600

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.
Source: Infras et al. (2008).

Table 7
Long distance car trip externalities and charges (1998 euros per vehicle km).

	Wear	Congestion	Environment	Accidents	Total cost	Charges
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	0.156	0.056
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 is Chiasso-Basel, Route 3 is Basel-Duisburg and Route 4 is Duisburg-Rotterdam.
Source: GRACE (2005).

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.

More recently the shortcomings of this position have been exposed to greater scrutiny. Firstly, it is clear that perfect competition is not the norm. If transport improvements lower the cost of production and thus encourage output to expand, to the extent that price exceeds marginal cost for the good in question, there is an additional benefit to take into account. Secondly, if improved transport induces people to enter the labour market or to work longer hours, whilst the benefit to themselves may be reflected in their willingness to pay in the transport market, there is an additional benefit to government in terms of the extra tax they pay. Thirdly is the issue of agglomeration externalities. It appears that there is a direct link between accessibility and labour productivity, perhaps because in a larger labour market workers are better fitted to the jobs they do, innovations spread more quickly and there are economies of scale leading to better supply of business services.

These issues were introduced into the debate on rail investment regarding the Crossrail project in London (Venables, 2007) and the empirical work to quantify them was led by Graham (2007). However, work by Graham and Melo (2010) for the HS2 project in Britain concluded that whilst these impacts might be important for conurbations, they were unlikely to be significant for intercity passenger rail transport, because they are a small proportion of total work trips and rail has a small market share. However, the fact that intercity rail is heavily used by managerial and professional people may mean that the market share understates its importance, as these are exactly the sort of people for whom agglomeration effects are most likely to be significant.

More recently, further work undertaken by Rosewell and Venables (2013) for HS2 concluded that there might be a significant benefit to the economy from increased specialisation as a result of better connectivity. Moreover, to the extent that high speed rail tends to centralise economic activity in large cities, there may also be increased agglomeration benefits from land use changes.

The only attempt to quantify these benefits for HS2 was undertaken by KPMG (2013). 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 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 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 £15b p.a. to GDP. Whilst this is not entirely additional to the current appraisal benefits, it must represent a substantial uplift. However, as Overman (2013) points out, 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.

3. In what circumstances will benefits exceed costs?

3.1. Introduction

There are essentially two approaches to answering this question. The first is to construct a model and explore the values of variables for which benefits exceed costs. Evidence from such studies is summarised in the next section. The second is to examine actual ex post case studies. The following sections do that.

3.2. The modelling approach

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). 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 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. 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 3 m trips per annum, but it is doubtful whether such a favourable combination of circumstances has ever existed. Construction costs of 30 m euros per km will carry this up to 7 m, and a reduction of the value of time savings to a more typical level to 4.5 m; lower benefit growth and levels of generated traffic will take the result to 4.3 m. An increase in the rate of discount to 5% would take the value to 4.4 m. 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 19.2 m trips per annum, and even worse scenarios can of course be identified. On the other hand a more modest increase of capital costs to 20 m 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 9 m. 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 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 passengers)
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

Source: Derived by the author from de Rus and Nash (2009).

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.

3.3. Ex post evaluations

The number of ex post evaluations to be found in the literature is rather limited, and of course none are truly ex post inasmuch as they were generally undertaken something like 5 years after opening of a very long lived asset. So these appraisals still involve forecasting, but forecasting from the position of knowing what the construction cost turned out to be and having data for the first few years of quality of service, traffic, revenue and operating cost.

In France it is a legal requirement that all major government funded projects are subject to an independent ex post evaluation, to check that they have provided value for money and to learn lessons from any problems that are found. Table 10 provides the results of ex post appraisals of the first six French high speed lines.

Ex post financial and socio economic returns are generally somewhat below forecast, in some cases due to cost overruns and in others due to shortfalls of traffic, but the only really large error was in the case of TGV Nord, which carries traffic to Lille, Brussels and London, and where traffic through the Channel Tunnel to London was only a third of that forecast. Although the only line which might be considered to yield a truly commercial rate of return is the first one, Paris–Lyon, the returns on all of them are acceptable in socio economic terms (though only just in the case of TGV Nord; at the time the French government sought a minimum return of 5% in cost benefit terms on its investments). It should be noted that these returns are based on traditional cost–benefit analysis; that is to say they make no allowance for any wider economic benefits.

By contrast the experience of Spain has been less satisfactory. Traditional cost–benefit analysis of the two busiest Spanish lines,

Table 10
Ex post appraisal of French high speed line construction.

		Sud Est	Atlantique	Nord	Inter connection	Rhone Alpes	Mediterranean
Length (km)		419	291	346	104	115	259
Infrastructure cost (m euros 2003)	Ex ante	1662*	2118	2666	1204	1037	4334
	Ex post	1676	2630	3334	1397	1261	4272
	% change	+1	+24	+25	+16	+22	−1
Traffic at opening (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	6.1	4.1
Social return (%)	Ex ante	28	23.6	20.3	18.5	15.4	12.2
	Ex post	30	12	5	13.8	10.6	8.1

Source: Conseil Général des Pont et Chaussées (2006) Annex 1. Ex post results for the last two lines are taken from Crozet (2014).

Madrid–Seville and Madrid–Barcelona, shows benefits considerably below costs. (Table 11). The discount rate used was 5%, but a sensitivity test with 3% gave the same conclusion. It is clear that the main reason for these disappointing results is the much lower level of traffic than in France – only 5.5 m passenger trips p.a. in the first full year on Madrid–Barcelona and 2.8 m. on Madrid–Seville.

Our final example of an (incomplete) ex post evaluation is the line from London to the Channel Tunnel in Britain. Originally it was intended that this line would be built privately on a commercial basis, but when it became clear that rail traffic through the Channel Tunnel on Eurostar trains between London and Paris and Brussels was only reaching around a third of the level forecast, the private company concerned approached the government for assistance. At that stage a full cost–benefit analysis was undertaken (Table 12).

It will be seen that benefits to users form the majority of benefits. Whilst the biggest share of these were to international traffic, there were also expected to be substantial benefits to domestic passengers on commuter services serving a number of south east towns which would join the high speed line for the run to London (these operate at 225 kmph on the high speed line rather than the full 300 kmph of the Eurostar trains). 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 government spending.

The (partial) ex post appraisal was undertaken by the National Audit Office (National Audit Office, 2012). It should be said that this followed the current approach to appraisal, which is not consistent with that used in 1998, and included a lower discount rate and a longer (60 years) assumed life, as well as rising values of time over time. By this time, on this basis the present value of time savings had increased to £7b. 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 between London and Paris and Brussels, but that whereas the forecast assumed continuing rapid overall market growth, in practice the market ceased to grow. Also, the rise of low cost airlines had prevented rail from taking the predicted market share for longer journeys from other British cities and/or to cities in Europe beyond Paris and Brussels, for which rail was not competitive in journey time or fare.

The out-turn construction costs were as in Table 13 and were within the financial provisions made at the time of the approval of the project in 1998.

It should be noted that Section 1 comprises 74 km, whereas Section 2 is only 39 km; however, Section 2 includes a 19 km 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 £19 m per km, for HS1 stage 1 it was £24 m and for stage 2 £94 m. 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.

NAO (2012) concludes that, despite carrying 18.1 m passengers p.a. (9.7 m 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.

4. High speed 2

4.1. Introduction

High speed 2 is the proposed high speed line from London to Birmingham, with branches to Manchester and Leeds and connecting to the existing main lines to Glasgow and Edinburgh. It is worth examining in some detail because it has been subject to what is probably the most extensive and controversial appraisal process of any high speed line.

The first study of the possibility of building a high speed line from London to the North was undertaken by Atkins for the Strategic Rail Authority, the government body then responsible

Table 11
Cost benefit analysis of the Madrid–Seville and Madrid–Barcelona HSR.

CBA of high-speed rail in Spain (billions of 2010 euros)	Madrid–Seville	Madrid–Barcelona
Costs	6.8	12.4
Benefits	4.5	7.2
Of which time savings	1.6	2.8
Generated traffic	0.8	1.1
Costs saved on other modes	1.9	2.9
External costs saved	0.2	0.4
Net present value	−2.3	−5.3

Source: de Rus (2012).

Table 12
1998 Appraisal of HS1 (£m 1997 NPVs).

User benefits – international services	1800
User benefits – domestic services	1000
Road congestion	30
Environmental benefits	90
Regeneration	500
Total benefit	3420
Costs to government	1990
Net present value	1430
Benefit cost ratio (all benefits)	1.72
Benefit cost ratio (excluding regeneration benefits)	1.5

Source: National Audit Office (2001).
Note: At the current exchange rate (January, 2015) £1 equals 1.3344 euros.

Table 13
Out-turn capital costs of HS1 (£m).

Section 1 construction costs	1919
Section 2 construction costs	3778
Station fit-out	109
New depot	357
Total	6163

Source: NAO (2012).

for rail planning (Atkins, 2002). The objective was to examine whether there was a case for a high speed line, and if so what route it should follow, in the light of two main objectives – providing capacity for the rapid growth in rail traffic underway and expected to continue, and maximising the sum of time savings. Some 16 high speed rail options were examined comprising different combinations of the sections of track. Obviously these concentrated on routes linking the largest cities and relieving the overcrowded East and West Coast main lines. Also considered were building a conventional line, upgrading existing lines, road widening and airport expansion. 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.

Table 14 shows the results of the appraisal of two of the options. Option 1 was a simple London to Birmingham line; Option 8 extended this to Edinburgh and Glasgow via Leeds with a separate branch to Manchester. Both show an adequate benefit cost ratio, with the incremental benefit cost ratio on the substantial extra spending on the larger option also being above 2.

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).

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) confirming the case for high speed rail. 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.

Table 14
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.

4.2. Appraisal of HS2

Table 15 shows the results of the 2013 update of the economic case for the line. With more than 40 m passengers per annum forecast to use busiest section of HS2 from 2043, it is not surprising that the benefits are forecast to greatly exceed the costs.

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 16 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. Since 69% of the users are estimated to divert from existing rail lines, benefits to other types of traffic from the release of capacity on them are substantial. On the other hand 26% of traffic is estimated to be induced and only 4% diverted from car and 1% from air (DfT, 2013). So any benefits in terms of reduced externalities on these modes are thought to be small. The reason for such a low level of diversion is that rail already plays a very important role between most of the cities served by HS2, and with rail journey times from London to Manchester and Leeds already little more than 2 h, air has lost most of its market to rail already. This is a marked contrast to Spain, where previous rail services were very slow compared to HSR and rail held a small market

Table 15
Appraisal of HS2: present value of costs and benefits over 60 years (£b 2011 prices).

	Phase 1 Oct 2013	Full network Oct 2013
Transport benefits (business)	16,921	40,529
Transport benefits (other)	7673	19,323
Other quantifiable benefits	407	788
Indirect taxes (loss to govt)	−1208	−2912
Net transport benefits	23,793	57,727
Wider economic impacts	4341	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 16
Breakdown of benefits from the proposed HS2 scheme (£b 2011 prices).

	Phase 1	Full network
Time savings	17,334	45,679
Crowding benefits	4068	7514
Improved reliability	2624	5496
Car user benefits	568	1162
Total transport user benefits	24,594	59,852
Wider economic impacts	4341	13,293
Other impacts	407	788
Loss to government of indirect tax	−1208	−2912
Total	28,134	71,020

Source: DfT (2013).

share. On the Madrid–Seville and Madrid–Barcelona lines nearly half of the traffic has come from air (de Rus, 2012).

Unlike in the earlier study, no appraisal has been undertaken of alternative timings for construction of the line. Phase 1 (to Birmingham) has been planned for completion in 2026 and phase to in 2033. The reason for this timetable was primarily dictated by funding and availability of physical resources – the plan was to follow directly on from completion of the major Crossrail project in London. However, consideration is now being given to an accelerated timetable.

The project has been strongly criticised by opponents to the scheme on a number of grounds. Some argued that the original appraisal was guilty of extreme optimism in terms both of costs and demand forecasts (Castles and Parish, 2011). As against that, it may be argued that the cost estimates were based on experience elsewhere (HS2, 2012) and that for schemes at an early stage of development in Britain a large margin for optimism bias (67%) is now added to the estimates. On the demand side, the case for the project rests on a continued substantial demand growth until completion of Phase 2 in 2033. It has been argued that improvements to telecommunications will reduce the demand for long distance travel, although to date it seems these may have increased demand for rail relative to other modes because of the greater possibility to use them whilst travelling compared with road and air (Le Vine and Jones, 2012). The British government also takes a cautious approach in assuming that demand growth will cease in 2036, which is only 3 years after opening of the complete scheme; if growth continued the benefit cost ratio would be greater than shown in Table 15. In the latest appraisal, an extensive risk analysis has been undertaken, demonstrating a low probability of the benefit cost ratio being less than 1.5 (DfT, 2013). Criticisms of the value of business travel time and of the wider economic benefits predicted for the scheme have been discussed above (it should be noted that the KPMG (2013) estimate of an increase in GDP of £15b p.a. is not included in the official appraisal in Table 15, where the much lower value of wider economic benefits relates only to the improvement of commuter services in the conurbations).

Secondly, there has been much criticism of the detail of the route and of its impact on the existing rail network. At the London end, it has been argued that it would be better to bring it into St Pancras and connect directly with the high speed line to the Channel Tunnel. The station locations at Nottingham/Derby and Sheffield are not at the city centres, whilst because of lack of spare capacity at existing stations and difficulties in extending them, new stations will be built at Birmingham and Leeds, leading to less than ideal interchange with existing rail services and the consequent need for investment in local transport, including light rail, to improve local connectivity. Wellings (2013) argues that the cost of these measures should be regarded as part of the cost of HS2, although presumably they add benefits as well. There are also fears that some cities on the existing main line and not served by HS2 will incur a worsening of services, although others will gain from use of the capacity released on those lines. Optimal design of the route requires numerous options regarding all of these issues to be examined, and indeed the siting of the Nottingham/Derby and Leeds stations is being reviewed.

Thirdly has been the claim that other cheaper alternatives to HS2 have not been adequately examined. In particular, a group of local authorities opposed to the line (the 51 M group) put forward a much cheaper package of alternatives to increase capacity at the London end of the line, costing only £1.2b (Castles and Parish, 2011). However, it would not provide sufficient capacity to meet peak demand, some of which would have to be dealt with by other measures such as large increases in peak fares. Atkins were commissioned to appraise this package (Table 17) and found that the package would yield a benefit–cost ratio of no less than 6. However, 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.

Table 17
Incremental benefits and costs over the 51 M alternative package (£b 2011PV).

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

Source: Derived from Atkins (2013).

Table 18
Capital costs and benefits of alternatives.

	HS2 Phase 1	Phase 1 alternative	HS2 both phases	Phase 1 and 2 alternative
Capital costs (£b)	19.4	2.5	38.4	19.2
Benefit–cost ratio	1.7	2.0	2.3	3.1
Benefits (£b)	28.1	8.5	71.0	30.7

Source: DfT (2013).

The latest strategic case published by DfT (2013) 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 18 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.

Thus the case for HS2 has been subjected to much more extensive scrutiny than many transport projects, with extensive examination of alternatives. Nevertheless, such is the scale and complexity of the project that arguments continue as to whether all the options and their implications for the network as a whole and in terms of local transport connectivity have been adequately examined.

5. 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 h are required to compete effectively with air, however, so HSR will be most effective for routes of up to 700 km. For shorter journeys HSR may be worthwhile in terms of time savings to existing rail users and diversion from car, but below around 150 km, the high speed of HSR will be of less importance 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, not just for fast intercity trains but also for commuter and regional passenger trains and freight, either on the high speed line (as with commuter trains on HS1) or in the capacity released on existing lines. However, as demonstrated by the British example, there are always numerous ways of providing more capacity or of using demand management to remove the need for it; fitting a new high speed line into an intensely used existing network is a complex matter requiring many options to be examined (including timing). A policy which favours rail over road and air in terms of adding capacity on environmental grounds will obviously favour the case for HSR.

Finally the most controversial and unresolved issue is the extent to which high speed rail will produce wider economic benefits. Were such benefits to be firmly identified they might reduce the level of traffic needed to justify the investment by a substantial amount.

Acknowledgements

An earlier version of this paper was produced as Christopher Nash (2013) When to Invest in High-Speed Rail. International Transport Forum Discussion Paper No. 2013-25 December. OECD, Paris.

I am grateful to ITF for permission to reuse material from that paper, and to participants in the round table on High Speed Rail in New Delhi, December 2013 for comments on the earlier draft.

References

Albalate, D., Bel, G., 2012. The Economics and Politics of High Speed Rail. Lexington Books, Maryland.
Atkins, 2002. High Speed Line Study, HSL Business Case. Atkins, London.
Atkins, 2003. High Speed Line Study, Summary Report. Atkins, London.
Atkins, 2013. HS2 Strategic Alternatives, Final Report. DfT, London.
Batley, Richard, Mackie, Peter, Wardman, Mark, 2013. Review of the Value of Time Assumptions for Business Travellers on HS2 DfT, London.
Booz, Co, 2012. Review of HS1 Demand Forecasts, Report to HS2 Ltd. HS2 Ltd., London.
Castles, C., Parish, D., 2011. Economic Evaluation: London – West Midlands Link. RAC Foundation, London.
Colin Buchanan and Partners/Volterra, 2009. Economic Impact of High Speed 1, Final Report. London & Continental Railways, London.
Campos, J., de Rus, G., Barron, I., 2009. A review of HSR experiences around the world. In: de Rus, G. (Ed.), Economic Analysis of High Speed Rail in Europe. Fundacion BBVA, Bilbao (Chapter 1).
Chartered Institute of Logistics and Transport, 2011. Transport Use of Carbon. CILT, London.
Civity, 2013. Further Development of the European High Speed Rail Network System Economic Evaluation of Development Options, Summary Report. Study commissioned by Alstom and SNCF, Paris/Hamburg.
Crozet, Y., 2014. High-Speed Rail Performance in France. From Appraisal Methodologies to Ex-post Evaluation. International Transport Forum Discussion Paper No 2013-26 OECD, Paris.
de Rus, Nash, C.A., 2009. In what circumstances is investment in HSR worthwhile? In: de Rus, G. et al. (Eds.), Economic Analysis of High Speed Rail in Europe. Fundacion BBVA, Bilbao, chapter 3.
de Rus, G., Nombela, G., 2007. Is investment in high speed rail socially profitable? J. Transp. Econ. Policy 41 (1), 3–23.
de Rus, G., 2012. Economic Evaluation of the High Speed Rail, undertaken for The Expert Group on Environmental Studies. Ministry of Finance, Sweden, <http://www.ems.expertgrupp.se/Default.aspx?pageID=3>.
Department for Transport, 2013. HS2 Strategic Case. DfT, London.
GRACE, 2005. Generalisation of Research on Accounts and Cost Estimation, European Commission project under the Transport RTD of the 7th Framework Programme, Deliverable D7. University of Leeds, Institute for Transport Studies.
Graham, D.J., 2007. Agglomeration, productivity and transport investment. J. Transport Econ. Policy 41 (3), 317–343.
Graham, D.J., Melo, P., 2010. Advice on the Assessment of Wider Economic Impacts: a Report for HS2. HS2 Ltd., London.
Greengauge, 2012, The Carbon Impacts of HS2. London.
Hensher, D.A., 1977. Value of Business Travel Time. Pergamon Press, Oxford.
HS2 Ltd, 2012. Cost and Risk Model. HS2 Ltd., London.
INFRAS, CE Delft, Fraunhofer Gesellschaft ISI, University of Gdansk, 2008. Handbook on Estimation of External Cost in the Transport Sector, produced within the study Internalisation Measures and Policies for All External Costs of Transport (IMPACT). CE Delft, Delft.
Infrastructure UK, 2010. Infrastructure Cost Review. London.
KPMG, 2013. High Speed Rail: Consequences for employment and economic growth, Technical Report. HS2 Ltd., London.
Kurosaki, F., 2014. Shinkansen Investment before and after JNR Reform, International Transport Forum Discussion Paper No. 2013–2027. OECD, Paris.
Le Vine, S., Jones, P., 2012. On the Move: Making Sense of Car and Train Travel Trends in Britain. University College London, London.
Lyons, G., Jain, J., Holley, D., 2007. The use of travel time by rail passengers in Great Britain. Transp. Res. Part A 41, 107–120.
Marks P., Fowkes A.S., Nash C.A., 1986. Valuing Long Distance Business Travel Time Savings for Evaluation: A Methodological Review and Application. PTRC Summer Annual Meeting.
Mohring, H., Williamson, H.F., 1969. Scale and "industrial reorganisation" economies of transport investments. J. Transport Econ. Policy 3 (3), 251–271.
National Audit Office, 2001. Department of the Environment, Transport and the Regions: The Channel Tunnel Rail Link. HMSO, London.
National Audit Office, 2012. Department for Transport: The Completion and Sale of High Speed 1. London.
Network Rail, 2009. New Lines Programme. Strategic Business Case, London.
Overman, H., 2013. Treasury Committee, Oral evidence: Economics of HS2, HC 788 Tuesday 5 November 2013.
Paix, J.-F., 2010. Feedback on High Speed Rail in France, Proceedings of the 7th World Congress on High Speed Rail, Beijing, UIC.
Bridget Rosewell, Tony Venables, 2013. High Speed Rail, Transport Investment and Economic Impact. Paper written for HS2 Ltd., London.
Sanchez-Borras, M., 2010. High Speed Rail in Spain, presentation at the first TEMPO Conference on Sustainable Transport, Oslo.
SDG, 2004. High Speed Rail: International Comparisons, Final Report. Commission for Integrated Transport, London.
SDG, 2006. Air and Rail Competition and Complementarity, Final Report. European Commission, DGTREN, London.
Venables, A.J., 2007. Evaluating urban transport improvements: cost–benefit analysis in the presence of agglomeration and income taxation. J. Transport Econ. Policy 41 (2), 173–188.
Wardman, M., 2004. Public transport values of time. Trans. Policy 11, 363–377.
Wellings, R., 2013. The High-Speed Gravy Train, IEA Current Controversies Paper No. 46, London.
Wu, Jianhong, Nash, Chris, Wang, Dong, 2014. Is high speed rail an appropriate solution to China's rail capacity problems? J. Transp. Geogr. 40 (2014), 100–111.