Royal Automobile Club Foundation for Motoring

The Case for High Speed Rail: A review of recent evidence

Prepared by:

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October 2009

Report number 09/128

RAC
Foundation

The Royal Automobile Club Foundation has commissioned a number of external experts to write a series of think pieces and occasional papers throughout the course of 2009/10. This paper is about The Case for High Speed Rail and is report number 09/128.

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Biographical Note

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Abstract

This paper examines recent reports on high speed rail (HSR) with specific reference to recent evidence on the economic benefits and costs. These reports indicate that although the capital costs of HSR are high, and are particularly so in Britain, there are also substantial benefits. As a result recent studies have put forward HSR schemes for Britain with Benefit Cost Ratios between 1.8 and 3.5. The dominant benefits are time savings to HSR users and the net revenue to the rail industry.

Other benefits, such as reduced overcrowding, the benefits of released capacity on the classic rail network and on parallel roads, and of reduced emissions of greenhouse gases are much smaller but are positive. The main benefits of HSR are thus transport benefits with the main beneficiaries being existing and future rail users.

Many of the benefits of HSR are thus predicated on there being strong demand growth for passenger rail services. There may be some wider economic benefits as a result of the greater scope for long-range commuting and business travel offered by HSR but these are unlikely to radically alter the economic case for HSR. Although recent studies have shown that HSR in Britain could cover its operating and maintenance costs, it could only contribute to a fraction of its capital costs, with public support of between £17 billion and £27 billion required.

It will therefore be important to ensure that an investment of this magnitude represents value for money, both within the transport sector and across Government departments. The limited reviews of high speed rail projects elsewhere in Europe indicate that they have been affected by appraisal optimism and that out-turn results suggest Benefit Cost Ratios much lower than those being forecast in Britain.

Moreover, the analysis so far in Britain has been largely uni-modal and future analysis will need to be multi-modal so as to assess HSR against rival and complementary investments, particularly in the air and road sectors, whilst further work may also be required to analyse the inter-relationships with the classic rail sector and to test the robustness of modelling results.

These questions will need to be addressed before the more detailed planning can begin.

1. Introduction

This paper was commissioned by the RAC Foundation in August 2009 to provide a rapid review of emerging evidence on the case for High Speed Rail (HSR). The background includes the creation by Government of High Speed 2 (HS2) Limited in January 2009 to examine the case for HSR, with a report to ministers expected later in the year (DfT, 2009). HS2 follows on the perceived success of HS1 (formerly known as the Channel Tunnel Rail Link - CTRL), opened on time and to budget in November 2007.

In addition, in April 2009 a suite of seven papers on the Department for Transport's New Line Capacity Study, undertaken in July 2007, was released, albeit with some sections heavily redacted.[1] Furthermore, Professor Gines de Rus and colleagues published a review of recent European evidence in May (de Rus, 2009). Moreover, following the commission of this work by the RAC Foundation, further relevant reports have come into the public domain. In late August, Network Rail published the findings of its New Lines Programme, a 20,000 man-hours, 12-months study running to over 1,500 pages of research, modelling and analysis (Network Rail, 2009). In mid September, Greengauge 21 published its views of an HSR strategy for Britain along with a parallel report by the Northern Way (Greengauge 21, 2009[2], Northern Way, 2009).

In the light of this and other evidence, this review will examine the following issues with particular reference to HSR in the UK in operation around 2025:

1. the role of HSR in other countries
2. the economic benefits and costs
3. the financial liability for the public purse
4. net carbon savings
5. planning issues

These issues will be dealt with in subsequent sections. However, before tackling these issues, it is worth making some introductory comments. High Speed Rail is defined by the Union Internationale des Chemins de fer (UIC - the International Union of Railways)[3] as services with a maximum speed of at least 250 kilometres per hour (kph) (155 miles per hour – mph) if operating on purpose built new lines or 200 kph (124 mph) if operating on existing lines. These definitions are enshrined in EC Directive 96/48/EC. By this definition the UK only has 112 km (70 miles) of high speed lines, with HS1 operating at speeds of up to 300 kph (186 mph). Some of the UK's conventional rail services are on the fringes of the high speed definition. For example, services on the upgraded West Coast Main Line (WCML) reach operating speeds of 201 kph (125 mph).

High speed rail can be seen as covering a spectrum of technologies and of configurations between track and vehicles. Givoni (2006) classifies technologies on the basis of compatibility with conventional rail, operating speed and construction costs. – see Figure 1. In the bottom left of this figure are tilting trains such as the

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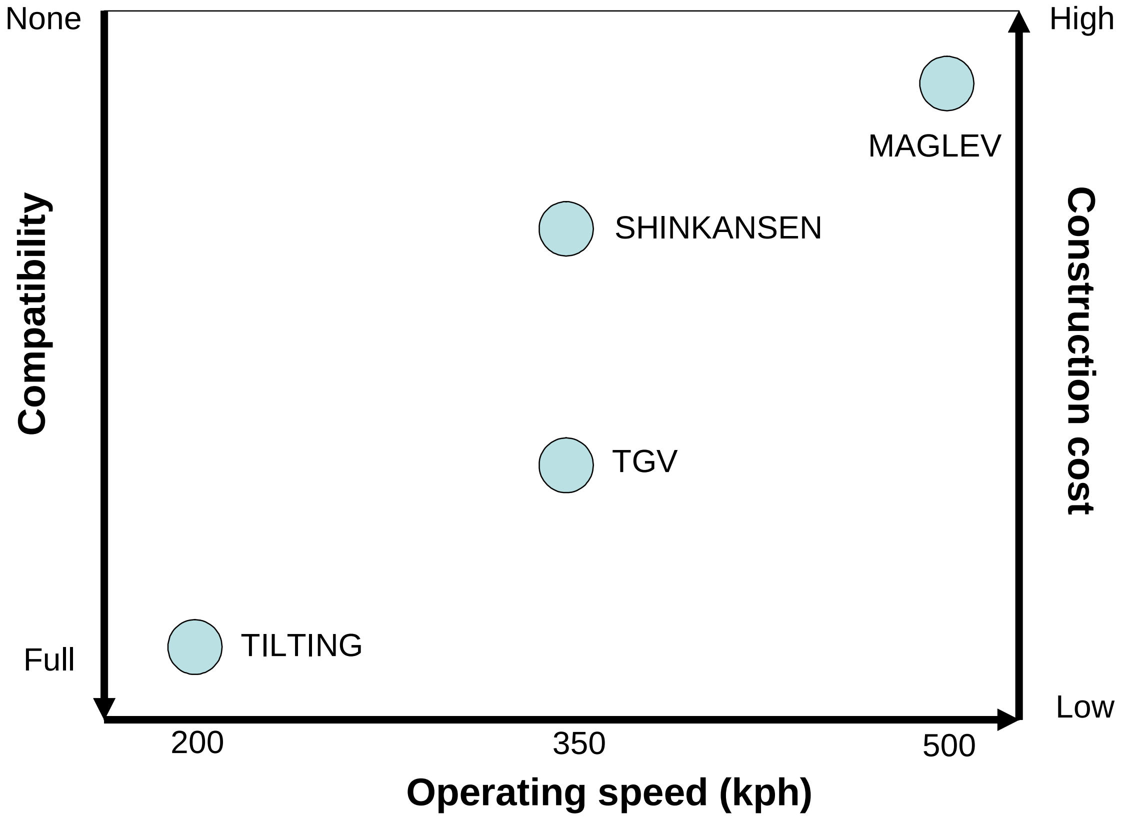
[1] http://www.dft.gov.uk/pgr/rail/researchtech/research/newline/

[2] See also www.greengauge21.net/hsr-development-programme.html

[3] http://www.uic.org/spip.php?article971

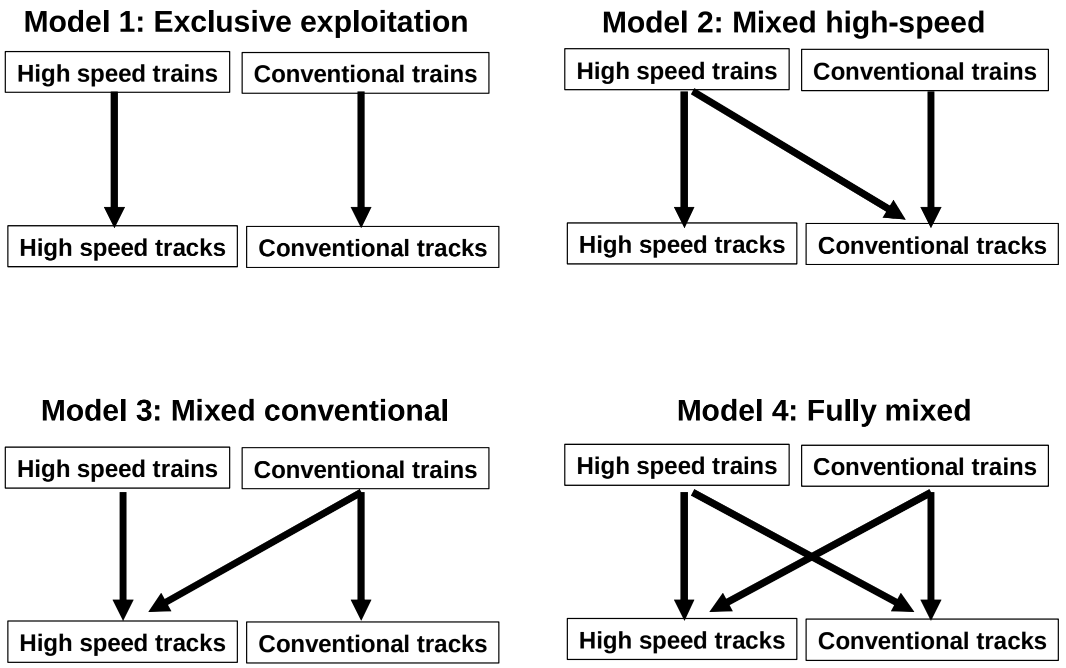
Pendolinos operating on the WCML that have full compatibility with conventional rail and the infrastructure package has relatively low construction costs (although the WCML upgrade cost £9 billion) but such tilting trains also have relatively low operating speeds. At the other extreme, in the top right of the figure are the Maglev systems, with no compatibility with conventional rail and high construction costs but also very high operating speeds. In between are the two dominant high speed rail systems – the Japanese Shinkansen and the French TGV (Train à Grande Vitesse). The discussions in the UK seem to be focusing on the use of TGV technology – either through the use of TGV Duplex in the Department of Transport's 2007 study and the more recent Greengauge 21 (2009) study or the next generation AGV (Automotrice à Grande Vitesse) considered in Network Rail's 2009 report.

Figure 1: Classification of High Speed Rail (Source: Givoni, 2006).



An alternative classification is provided by Campos and de Rus (2009) – see Figure 2. This examines the relationships between high speed and conventional trains and tracks. The Japanese Shinkansen system is largely based on exclusive exploitation, whilst the French TGV system can be classed as mixed high speed, as high speed trains use conventional tracks to access city centres. The Spanish AVE system (Alta Velocidad Española) is classified as mixed conventional as conventional trains use the high speed tracks to access some destinations. The German ICE (Inter City Express) system may be classed as fully mixed. It seems that the discussions in Britain concerning HSR to date are mainly focusing on the exclusive exploitation model but given the likely difficulties in securing a segregated right of way, it is possible that mixed models will need to be considered, a point recognised by the Greengauge 21 (2009) study.

Figure 2: Classification of High Speed Trains and Tracks (Source: Campos and de Rus, 2009)



2. The Role of HSR in Other Countries

The early development of HSR is detailed in Whitelegg (1993), with the key dates being the opening of the Tokaido Shinkansen between Tokyo and Osaka in 1964 and the TGV Sud-Est between Lyon and Paris in 1981. The perceived success of these schemes has led to a roll out of HSR in these countries, with Japan having 6 Shinkansen lines and 2 min-Shinkansens and France having 5 main LGVs (Lignes à grande vitesse), [4] as well as the Interconnexion. HSR has taken off elsewhere, particularly in Europe (e.g. Germany, Spain) and Asia (e.g. Korea, Taiwan). Even the US is getting interested with the Federal Government committing $12 billion[5] to HSR studies and Californian voters approving proposition 1A in November 2008 authorising $9.95 billion for the planning of HSR between Sacramento and San Diego.

In Europe in 2008, there were 3,480 miles of high speed lines in operation, a further 2,160 under construction and another 5,280 planned. By contrast, there are currently only 70 miles in the UK (HS1), with none planned (Department for Transport, 2009, p11). Similarly, Network Rail (2009), using UIC data, reports that by 2025 China will have 5,678 miles of high speed line in place or planned, followed by Spain (4,415),

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[4] Temple, 2007, Appendix 5 and 9.

[5] See Ed Glaeser in the New York Times 28 July, 2009. http://economix.blogs.nytimes.com/2009/07/28/is-high-speed-rail-a-good-public-investment/

France (4,135), Japan (3,774) and Germany (2,237). At 70 miles, the UK total would lag behind countries such as Morocco (422) and Saudi Arabia (342).

The main impact of HSR results from the reduced journey times compared to conventional rail as a result of both increased speeds and more direct routings. For example, the AVE between Madrid and Seville, introduced in April 1992, reduced rail journey times between Madrid and Seville from 6½ to 2½ hours. The recent Greengauge 21 (2009) proposal is based on typical London to Manchester journey times reducing from 2 hours 10 minutes to 1 hour 15 minutes and London to Glasgow reducing from 4 ½ hours to 2 hours 40 minutes[6]. HSR services also tend to have higher reliability than conventional rail services, as a result of the dedicated infrastructure and greater homogeneity of services. For example, the punctuality of Eurostar services has increased from 79% to 92% following the opening of HS1 (Greengauge 21, 2009). Compared to air, HSR has advantages in terms of the central location of most stations (resulting in lower access and egress times) and reduced check-in time. HSR services may also have greater reliability than competing air services. Other advantages of HSR, particularly over car, are the levels of comfort, which are particularly conducive to the productive use of travel time (around 70% of business travellers work while on train journeys of over one hour according to Fickling et al., 2008) and the high levels of safety, although these may not be perceived by users.

One way of measuring these impacts is through assessing the impact on accessibility – which measures the ease of reaching destinations. There have been numerous studies that have examined changes in rail accessibility as a result of the introduction of HSR, particularly at the European scale. However, the results of these studies depend on the nature of the accessibility measure used, the nature of the high speed rail implementation and the area of study (Martín et al., 2004; Martín and Reggiani, 2007; Vickerman, 2007). It has been estimated that the implementation of a European network of high speed trains could reduce weighted travel times between major European cites by as much as 50% (Gutiérrez et al., 1996). Implementation of a single international line would have a much smaller effect across Europe – reducing weighted travel costs by 5% or increasing a market potential measure of accessibility by 2% (Gutiérrez, 2001). If the study is done at a national scale, a new high speed line might reduce rail travel times by 10% or lead to a broadly similar increase in market potential measures (López et al., 2008).

An implementation of a network at a European sub-regional scale can increase network efficiency by between 17% and 35% by providing more direct and faster routes (López et al., 2009), whilst at the national scale a high speed line can increase cumulative opportunities by between 24% and 34% (Gutiérrez, 2001; Martín et al., 2004). Further development of these partial modal accessibilities allows analyses of a range of more sophisticated estimates of modal and multi-modal accessibility changes (Spiekermann and Wegener, 1994; Vickerman et al., 1999; Spiekermann et al., 2001; Spiekermann and Wegener, 2006).

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[6] The Network Rail (2009) proposals involve slightly faster journey times of 1 hour between London and Manchester and 2½ hours between London and Glasgow.

The reductions in journey times and resultant increases in accessibility will result in increased demand. Brown (2007) notes that rail demand on the Paris – Marseille corridor increased three fold between 1999 and 2005, with market share increasing from 22% to 61%, as a result of the introduction of TGV. Similarly between 1991 and 1997 the AVE grew rail demand between Madrid and Seville 2.8 fold, with market share increasing from 19% to 53%, whilst Thalys increased rail demand between Paris and Brussels 2.2 fold between 1994 and 2005, with market share increasing from 24% to 52%. Campos and Gagnepain (2009, Table 4.2) quote similar data. For example, rail's market share on Paris – Lyon is estimated to have increased from 40% to 73% between 1980 and 1997, whilst the share on Madrid – Seville increased from 16% to 62% between 1991 and 2002 and the share on Hamburg - Frankfurt increased from 23% to 51% between 1985 and 2000.

Layram (2009) has analysed the change in demand for Eurostar service from the UK North of London as a result of High Speed One and finds an elasticity of demand with respect to accessibility of around 2.85. Given fixed land use, this can be interpreted as being equivalent to a journey time elasticity (with an appropriate sign change). This value may be on the high side. Nash (2009) notes that in the phased introduction of TGV Sud Est, the opening of the northern section led to a journey time reduction of 30% and a journey time elasticity of -1.6. The opening of the southern section led to a further reduction of 25% but only a journey time elasticity of -1.1. This was because the transfer from air had largely been completed in the first phase, as rail journey times had gone below a key threshold.

An important issue is where this additional demand comes from. Some evidence is presented in Table 1.

Table 1: Diversion Factors resulting from introduction of HSR

Route	Paris-Lyons[1] 430 km	Madrid-Seville[2] 471 km	Madrid-Barc'a[3] 630 km	Thalys[4]	Eurostar[4]
% HST traffic generated from:	1980 to 1985	1991 to 1996 forecast	'Before HSR' to 'After HSR'	Range not given	Range not given
Induced	29	50	20	11	20
Road	11	6	10	34	19
Conventional rail	40*	20	10	47	12
Air	20	24	60	8	49

Note: * All Paris-Lyons 'after' rail travel is presumed to be by HST (i.e. no conventional rail following introduction of HST), since alternative journey time is ~5 hours compared to ~2 hours by HST.

Sources: [1]Bonnafous, 1987. [2]de Rus and Inglada 1997. [3]Coto-Millán et al., 2007. [4] Segal, 2006.

The variations shown in these figures are due to the route-specific nature of the modal split. For instance, according to Coto-Millán et al. (2007), around 70% of journeys on the Madrid-Barcelona route were undertaken by air prior to the introduction of HSR compared to only 25% of journeys from Madrid to Seville. The level of induced journeys seems to be around 10-30% with the main exception of Madrid-Seville. Givoni (2006) suggests that some of this induced traffic may in fact be due to external growth and this may have been a particular factor on the Madrid – Seville line. On average, for these five schemes 32% of demand is abstracted from air, 26% is abstracted from classic rail, 16% is abstracted from road and 26% is induced.

Greengauge 21 (2009) estimate that a full network of HSR services in Britain would carry 178 million passengers in 2055, of which 57% would come from classic rail, 19% would be generated, 17% would be abstracted from air and only 7% (12.6 million) abstracted from car. The average trip length is expected to be 300 km. This suggests that the impact of HSR on the British road network is expected to be modest. Compared to the average results in Table 1, HSR in Britain seems more dependent on abstraction from classic rail and less reliant on abstraction from air and road and on generated traffic.

3. The Economic Benefits and Costs of HSR

Evidence on the economics of HSR in Britain is emerging and this is reviewed in three sections. In section 3.1, costs are examined, then in section 3.2 benefits are examined before in section 3.3 the interplay of costs and benefits is considered.

3.1 Costs

Evidence is emerging at a global scale on the costs of HSR, particularly from Campos and de Rus (2009) and Campos et al. (2009). From a sample of 24 projects in operation, they find infrastructure and superstructure construction costs vary between €9 and €39 million per km (2005 prices), with a mean of €18 million. These figures exclude planning and land costs which they believe may add an additional 10%. When the database is also extended to projects under construction, the total number of observations increases to 45, and the range increases to be between €6 and €45 million, with a mean of €17.5 million. They note that there is no evidence of economies of experience – that unit construction costs reduce as more lines are built. Indeed the evidence suggests diseconomies. In both Japan and France the most recent lines have had unit costs around three times or more than the initial lines. However, this may reflect that the first lines were built where there were established rights of way and/or when there were lower environmental standards. They note that costs in Northern Europe and Asia (excluding China) tend to be higher than those in Southern Europe due in part to both higher population densities and more difficult terrain

Another source of construction cost estimates comes from Booz Allen Hamilton (2007). In Table 2.1 (p 8), they provide data for some 17 schemes on out-turn costs between 2001 and 2007. They find a range of £9 to £50 million per kilometre, with an average of £22.6 million. However, tellingly they find CTRL to be the most expensive high speed line, with costs of around £50 million per km. This is partly because 25% of the route is in tunnel (around 28 km out of 113 km). As a result the costs of phase 1 (at £26 million per km) were substantially below those of phase 2 (at £85 million per km) which included the tunnelled approaches to London.

Booz Allen Hamilton (op cit.) also use a bottom-up engineering approach to estimate the construction costs of a 1,240 km high speed network. They estimate that this might cost around £31.5 million per km, compared to £27.5 million per km for conventional rail. These costs include a 66% uplift for appraisal optimism, based on past evidence of cost over-runs, although there is a danger that this approach to cost risks becomes a self-fulfilling prophecy.

Network Rail (2009b) similarly uses a bottom-up engineering approach to derive some strategic costs options. For their preferred option (MB1.4.1) which is 773 route km, they compute a unit infrastructure cost of £44 million per km (including a 66% appraisal optimism uplift). A feature of these estimates is that non-construction costs are equivalent to 35% of construction costs. Non-construction costs include surveys, design, programme development, planning costs and project management.

Greengauge 21 (2009) estimates the capital costs of the first phase of High Speed North West, a 337 km line which runs to Manchester and has connections to HS1, Heathrow Airport, the West Coast Main Line and Midland Main Line, at approximately £19 billion in 2008 prices. The unit cost is thus around £50 million per route km. A full network of over 1,500 kms of high speed lines in which High Speed North West is extended to Scotland, a High Speed North East runs through Cambridge, Nottingham, Sheffield, Leeds, Newcastle and Edinburgh and a High Speed Wales and West upgrades services to Bristol and Cardiff, is costed at £69 billion. This network also includes upgraded Transpennine services between Manchester and Sheffield/Leeds and an Edinburgh-Glasgow link. The unit construction costs of the full network, at £45 million per route km, are slightly lower than for the single route as the costs of constructing terminus stations, particularly in London, are spread across more route kms.

Campos et al. (2009) indicate that the costs of maintaining a high speed line ranges from €28,000 to €33,000 per kilometre of single track (2002 prices). Similarly they estimate that the average train operating and maintenance costs range from €0.0826 per seat km for TGV Duplex (with 510 seats) to €0.186 per seat km for an ICE2 (with 368 seats) (both again 2002 prices). They also indicate that the acquisition costs of rolling stock ranges from €33,000 per seat for the TGV Réseau to €65,000 per seat for ICE-1.

Booz Allen Hamilton (2007, Table 2.3) indicate that the AVE trains for the Madrid Barcelona route have capital costs of £1.1 million per car (for 384 cars) and with a maintenance cost of £71,000 per car per year. They also note that the infrastructure maintenance contract for CTRL equates to a cost of £120,000 per route km per annum. Network Rail (2009b, p40) report that the annual operating and maintenance costs of HS1 equates to around £20 million, or approximately £90,000 per route km per annum. It is also indicated that the operating and maintenance costs of European high speed routes average €70,000 per single track km.

Campos et al. (2009, p48-50) undertake some calculations to determine the split between fixed and variable costs and how this varies with respect to initial demand, commercial speed and train capacity. For their reference case, they estimate that fixed costs will account for between 55% and 77% of total costs. Network Rail (2009, Table 4.8, p47) estimate the 60 year NPV of operating a new line for option MB1.4.1 is £10.4 billion (with a possible £0.7 billion reduction on classic line services). The capital costs for this option are estimated at £34 billion (Table 4.2, p39). This suggests that capital costs comprise almost 77% of total costs. For Greengauge 21's full network, HSR maintenance and operations cost have an estimated net present value of £27.5 billion (2002 prices). By contrast capital costs are given as £31.7 billion – representing 54% of total HSR costs. Costs on the classic rail network are forecast to reduce by £11.1 billion.

3.2 Benefits

The main benefits from HSR schemes are the time savings and related benefits that accrue to users. These in turn are related to mean journey length, relative door to door speeds and the value placed on travel time savings. Travel time savings tend to be much higher for business journeys than commuting or leisure journeys[7], so the proportion of HSR travellers that are business users is an important variable as is the premium given to business travellers' time. Generated travellers will have, on average, only half the user benefits of travellers diverted from other modes, so the proportion of trips that are generated is also an important variable. A technical issue relates to how these time savings are estimated. For example, the Planet Strategic Model (PSM) that underpins the forecasting work of Atkins (see section 3.3 below) assumes an alternative specific constant in favour of HSR. This means all other things being equal a traveller would be expected to choose HSR with a benefit equivalent to the alternative specific constant. Recent work by SDG for Network Rail (2009e) was unable to find support for such alternative specific constants, but found evidence that the value of time for HSR was substantially below that of other modes – which was assumed to occur because of the more comfortable and productive travel conditions. This has the effect of amplifying the benefits of travel time savings. Another important benefit of HSR in the UK context is overcrowding relief. Forecasts indicate that the major intercity routes into London be will operating at or beyond capacity when HSR comes on line and passengers will benefit from greater seat availability.

Other benefits include net revenue, benefits from the released capacity on the classic rail system, as well as environmental benefits and non user benefits as a result of reduced congestion on competing road and air transport. In the UK context – where the user pays principle is at least partly enacted – net revenue can form an important component of benefits. On the continent, where HSR fares are lower than those that might be expected in the UK – in part because of 'a democratisation of speed' (Nash, 2009) – net revenues tend to be less important. Two issues are worthy of mention here. The first is that inter-modal competition may place limits on HSR demand levels and fares (Campos and Gagnepain, 2009). Such competition has been an enduring feature of cross Channel services and explains in part the failure of Eurostar to meet its demand forecasts. The second is that the level of track access charges will affect HSR usage and the pattern of benefits. UIC (2008) finds that such charges account for between 25% and 45% of the revenue of high speed operators. This in turn affects the profitability of HSR services and the ability to compete with other modes (Adler et al., 2007).

3.3 Interplay of Costs and Benefits

There are three source of evidence on the interplay of cost and benefits in the case of HSR. The first is theoretical models. The second is ex-post evaluation. The third is ex-ante appraisal. These will be discussed in turn.

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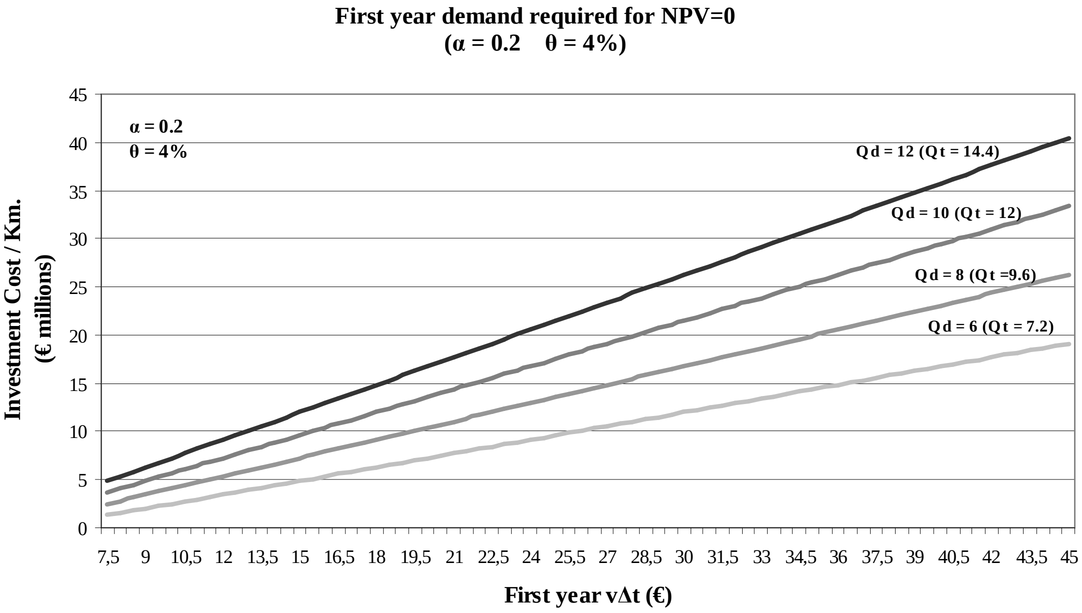
[7] For example, WebTAG Unit 3.5.6 gives values for business of £39.96 per hour compared to £5.04 for commuting and £4.46 per hour for leisure (2002 market prices).

3.3.1 Theoretical Models

In a number of papers, theoretical models have been developed to examine social break-even traffic levels for HSR investments (de Rus and Nash, 2006, de Rus and Nombelo, 2007, de Rus and Nash, 2009). As shown in Figure 3, this work determines the combinations of investment costs per kilometre, demand levels (both deviated (abstracted) from other modes and generated) and the mean value of travel time savings at which HSR schemes just break even in social terms. These break-even lines are referred to as isoquants. As with all economic models, the results depend on the input assumptions. Assumptions include the interest rate (say 3%), the project life (say 30 years), the proportion of traffic that is generated (say a 20% uplift, implying that around 17% of demand is generated), the annual growth of net benefits (e.g. 4%), the construction costs per km (say €10 million) and the mean value of travel time savings (say €25), based on an average time saving of 50 minutes (from SDG, 2004). Under these assumptions, for a 500 km route, it can be estimated from Figure 3 that the break-even first year demand is around 6 million passengers per annum – a relatively high figure.

With higher construction costs and lower time savings (which are both arguably more realistic assumptions), a total first year demand of at least 9 million trips per annum may be needed (de Rus and Nash, 2009, page 66). As a result, de Rus and Nash believe that the economic case for high speed rail is restricted to a relatively few city pairs. Recent evidence from Network Rail (2009c) indicates that the largest point to point intercity rail flows in Britain are between London and Birmingham (2.1 million journeys per annum), Manchester (2 million) and Leeds (1.5 million). These flows increase if wider catchment areas are included (e.g. London – Birmingham 4.4 million, London – Manchester 3.5 million) but still fall somewhat short of the threshold demand levels indicated by de Rus and Nash’s analysis

Figure 3: Social Break-Even Isoquants for HSR. (Source: de Rus and Nash, 2006)



Qd: deviated demand
Qt: total demand $Qt=Qd(1+\alpha)$
α: proportion of generated traffic
θ: annual growth of net benefits
v: average value of time
Δt: average time saving per passenger

This somewhat sceptical approach was also broadly the view taken by Eddington (2006) with its distaste for 'grand projets' and its view that the economic geography of Britain was not conducive to HSR, that the competitive domestic aviation market also limits the role for HSR and that inter city business travel 'is surprisingly low and too small to form the bedrock of an economic case for high speed rail'. Given the very large costs involved in constructing and operating a high speed line and the risks involved, it was believed that 'Government will find it difficult to ensure that it (HSR) offered better value for money in meeting economic, environmental and other policy objectives than alternative ways of spending that money' (Mann, 2006).

3.3.2 Ex post evaluation

There has been surprisingly little ex post evaluation of HSR schemes. The best known example is the work of de Rus and Inglada (1997) on the AVE services between Madrid and Seville, opened in 1992. This scheme had capital costs of some 238 billion pesetas (1987 prices), but a simple financial analysis suggested a loss of 314 billion pesetas (1987 prices, 30 year project life, 6% discount rate, 2.5% GDP growth), indicating that the scheme does not even cover its operating costs. A social cost benefit analysis indicates a negative net present value (NPV) of 258 billion pesetas, suggesting a benefit cost ratio (BCR) of only 0.18. With regards to benefits, some 44% were estimated as accruing to generated travellers, with 23% accruing to abstracted travellers in terms of time savings, 28% accruing to other transport operators in terms of reduced operating costs (assuming perfectly competitive readjustments) and some 5% related to congestion and accidents. Given the theoretical models outlined above, the results are explained by the relatively low levels of traffic on this corridor – with less than 3 million passengers in the second year of operation and only 5 million passengers some ten years after opening.

Another source of ex post evaluation is for the LGV schemes in France (Conseil General des Ponts et Chaussees, 2006). This indicated that out-turn costs were generally higher than forecast, ranging from 1% greater for LGV Sud Est to 25% greater for LGV Nord. Similarly, although out-turn traffic for LGV Sud Est was 7.5% greater than forecast, it has been lower than forecast for all other lines and 50% lower than forecast for LGV Nord. As a result, although LGV Sud Est had out-turn social returns greater than those forecast (30%[8] compared to 28%), for other lines the out-turn returns have been less then those forecast – 12% compared to 24% for LGV Atlantique, 5% compared to 20% for LGV Nord and 14% compared to 19% for LGV Interconnexion. These returns appear relatively low compared to returns sought for UK investments, although a relatively short project life (20 years) and high discount rate (8%). However, the French experience does suggest that appraisal optimism is a potential problem.

3.3.3 Ex ante appraisal

The application of cost-benefit analysis to HSR schemes before they are opened is rather more common. A number of UK examples might suffice. The National Audit Office (2001, page 36) estimated a BCR for the CTRL of only 1.35, including regeneration benefits of £500 million. HS1 may have been perceived as a success operationally but its cost-benefit performance seems to be more mooted, particularly as usage has been affected by the economic downturn.

Atkins (2003, as reported by de Rus and Nash, 2009, Table 3.4) undertook an analysis of HSR options in the UK and found a BCR of 2.07 for option 1 (London – West Midlands) and 2.04 for option 8 - a full network covering both East and West Coast routes[9]. Nearly 50 million passengers a year were forecast to use option 8, with around two-thirds diverted from classic rail and the rest split between diversion from other modes and generated journeys. Most of the forecast diversion came from car, reflecting the relatively modest role of air in the UK. For option 1, the break-down of benefits was 17% net revenue, 77% non financial benefits and 7% released capacity. For option 8, the breakdown is 23%, 72% and 5% respectively (de Rus and Nash, 2009, Table 3.4). For option 1, the non financial benefits can be broken down as reduced journey time/overcrowding 94%, accident savings 2% and non user benefits (due to reduced journey times and/or vehicle operating costs) 4% (de Rus and Nash, Table 3.5). These appraisals were based on the assumption that the HSR operator charged a 30% premium on classic rail fares.

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[8] This can be interpreted as being equivalent to a BCR of 1.3.

[9] Table 6.1 of Atkins (2003) suggests a BCR for option 1 of 1.41, whilst Figure 6.1 suggests a BCR for option 8 of 1.32. Adjustments to the classic rail service and lower fare levels (than the 30-50% premium originally assumed) could improve the BCR to around 2. Atkins (2008, p4) indicates that their 2003 study showed that 'HSR is capable of delivering substantial economic benefits to the UK of between 1.9 and 2.8 to 1'. The calculations in Table 6.1 used a social cost basis. If costs to the public purse are used instead the BCR becomes 1.55.

Atkins' original work was based on a 30 year project life and a discount rate of 6%, but the subsequent publication of the revised HM Treasury Green Book (which became operational in April 2003) subsequently modified the practice to a project life of 60 years and an initial interest rate of 3.5%, declining to 3% after 30 years. Ordinarily this would strengthen the case for rail investment, but this was offset by provisions for appraisal optimism. Atkins (2008) updated its appraisal, indicating a BCR for a West Coast route of 1.7 (slightly down on the 2003 estimate of 2.0, attributed to the impact of the West Coast modernisation), a BCR for the East Coast route of 2.5 (up from the 2003 estimate of 2.0, reflecting strong interim demand growth without corresponding increases in supply) and an overall network BCR of 2.0 (largely unchanged from the 2003 analysis).

Preston et al. (2009) examine the case for HSR services between Edinburgh and Glasgow, a distance of only 70km, with some 2.5 million passengers per year. Assuming strong economic growth and high capital costs, they find a BCR of 1.64, for a scheme with a notional start date of 2022. These benefits were additional to improvements to the classic rail services.

Network Rail (2009b) present detailed appraisal results for various high speed options. The stage 1 options involve various service configurations serving London, Birmingham and Manchester (options MB1.0a to MB2.0c). The BCRs are in the range 0.6 to 0.9, suggesting that none of these schemes are worth taking forward on social grounds. For the best performing scheme (MB1.0a), the Present Value (PV) of costs is £15.7 billion (2002 prices), whilst the PV of revenue transfer is £7.5 billion and the PV of benefits is £7.7 billion, resulting in a Net Present Value (NPV) of -£0.6 billion.

The benefits mainly accrue to new line users (76%), but with some benefits due to service improvements for classic line users (4%), reductions in car externalities due to reduced congestion, accidents and carbon emissions (18%) and to private sector impacts (1%).

Network Rail's Stage 2 assessments included extensions to Liverpool (MB1.0) with a BCR of 0.9 and to Edinburgh and Glasgow (MB1.1 to MB1.6) with BCRs in the range of 1.3 to 1.9. This suggests that HSR options are only worthwhile if they serve a number of destinations. This might be seen as a form of network economy, largely stemming from economies of density. For example, it is estimated that in 2030 stage 1 option MB1.0a (serving London, Birmingham and Manchester) carries 21 million passengers per annum (with base 2030 rail demand almost double that in 2007). By contrast, stage 2, option 1.4.1, additionally serves Warrington, Liverpool, Preston, Glasgow and Edinburgh and is forecast to carry 43.7 million journeys in 2030.

For the preferred stage 2 option (MB1.4.1) the PV of costs is £41.3 billion, the PV of revenue transfers is £23.4 billion and the PV of benefits is £31.4 billion, resulting in an NPV of £13.5 billion. Excluding private sector impacts, the breakdown of benefits is that 78% accrue to new line users, 7% to classic line rail passengers and 2% to rail freight, whilst 13% is due to reductions in car externalities.

The Network Rail study also examined options to serve Heathrow, partly in response to Arup's Heathrow Hub proposal. Option 3.4.1 in which all services are run via

Heathrow had an NPV of £10.8 billion, some £2.7 billion less than option 1.4.1 (or £ 3.2 billion if traffic accessing Heathrow is added to option 1.4.1), with a BCR of 1.5 (compared to 1.8 for option 1.4.1). This is because the vast majority of passengers would be travelling to central London and an additional 15 minute diversion to Heathrow would reduce time savings benefits for the many to increase them for the few. Option 1.7.1 instead involves a spur to Heathrow with an NPV of £12 billion and a BCR of 1.6. Although Network Rail believes this delivers a good business case, an incremental analysis indicates that this incurs £3 billion additional costs for only £0.9 billion additional benefits.

Further evidence is provided by Greengauge 21 (2009). For the full network, benefits of £111.4 billion have been estimated (present value 2002 prices). The break down is a follows: time savings 62%, net revenue 20%, crowding relief 9%, capacity benefits 6%, reductions in greenhouse gases 2% and highway decongestion 2%. Overall a BCR of 3.48 was estimated, along with a NPV of £63.3 billion. This study also includes the incremental BCRs and NPVs of a phased implementation of the full network. High Speed North West phase 1 has a BCR of 2.9 and an NPV of £24 billion. This includes extensions to Heathrow and HS1 which are stated to have incremental BCRs in excess of 5 (page 48). In addition, this first phase includes connections to the West Coast Main Line and the Midland Main Line.

The extension of High Speed North West to Glasgow and Edinburgh has an incremental BCR of 7.6 and NPV of £23 billion. The first phase of High Speed North East from London to Newcastle has a BCR of 2.0 and NPV of £15 billion, but the second phase to Edinburgh only has an incremental BCR of 1 (and hence a NPV close to 0). High Speed Trans-Pennine is estimated as having a BCR of 1.3 and NPV of £1 billion, whilst High Speed Wales and West is estimated as having a BCR of 2.8 and NPV of £3 billion.

It should be noted that the Greengauge 21 analysis is not based on fare premia and this might partly explain the higher BCRs. Sensitivity analysis examines a 20% fare premium which is found to reduce HSR demand by 19% and total benefits by 13%.

4. The Financial Liability for the Public Purse

We have seen that Spanish economists believe that the Madrid – Seville AVE represents a significant drain on the public exchequer. By contrast, the Conseil General des Ponts et Chaussees (2006) estimates ex post financial returns in the range 2.9% (LGV Nord) to 15% (LGV Sud Est), although with the exception of LGV Sud Est these returns are substantially lower than the ex ante forecasts. However, it is not clear how capital grants from local and central Government are treated but they may be treated as windfall gains. However, it is worth noting that TGV services are expected to operate commercially.

Network Rail (2009b) gives some indications of the financial liability of HSR options in the UK. For stage 1, option MB1.0a, the net revenue PV is £7.5 billion, whilst the costs PV is £15.7 billion, of which £10.6 billion is infrastructure capital costs (68% of total costs). This suggests an exposure to the public purse of some £8.2 billion, or 77% of infrastructure capital costs.

For stage 2, option MB1.4.1, the net revenue PV is £23.4 billion, whilst the PV of costs is £41.3 billion, of which infrastructure capital costs are £24.1 billion (58%). This suggests an exposure to the public purse of £17.9 billion, or 74% of infrastructure capital costs. These calculations are assuming that the procurement mechanism does not impose additional costs on the public purse.

Similarly Greengauge 21 (2009) gives some indication of the exposure to the public purse. HSR revenue is estimated as exceeding HSR operating costs by around £23.4 billion (present value 2002 prices) but the reduction in classic rail revenue is estimated to exceed the reduction in costs by £17.2 billion. Overall rail revenue exceeds rail operating costs by around £6.2 billion – only around 19% of capital costs. The total cost to the public purse is estimated at £26.5 billion.

It is assumed that the design development/consent stage of work for High Speed North West phase one and the preliminary development of future stages are likely to run from 2011 to 2015 and entail projected expenditure of around £100 million per annum. By 2025, Government is expected to incur £10 billion in project costs, with a further £16.5 billion incurred between 2026 and 2053.

5. Net Carbon Savings

Electrically powered trains are almost free of local pollutants at the point of use, with the main exception being particulate matter from braking. Hence the main environmental impacts relate to energy consumption and the emission of pollutants at the source of electric power generation, although visual intrusion, noise and vibration are other important impacts. The conventional wisdom is that HSR has less environmental impacts than competing modes. For example, INFRAS/IWW (2000) estimate external costs (in € per thousand passenger kms) for the high speed rail served Paris – Brussels corridor as 43.6 for car, 47.5 for air and 10.4 for rail. By contrast, for the longer Paris-Vienna corridor, the figures are 40.2 for car, 11.7 for (classic) rail and 28.7 for air. The superior performance of high speed rail compared to classic rail is mainly related to high load factors, whilst the improved performance of air on the longer corridor occurs because much of the environmental costs of air are associated with take-off and landing.

Work by CE Delft (2003) gives a slightly different picture, as shown by Table 2. Even with a superior load factor, high speed rail has higher energy consumption per passenger km than classic rail, and a broadly similar performance to the best performing cars but appears to have an environmental advantage compared to air. A key determinant is load factor. Reservation based systems such as TGV and Eurostar have relatively high load factors of around 70%, whilst the turn up and go ICE system in Germany has load factors of around 50% (see Network Rail, 2009d, Tables 2.12 and 2.13). In Network Rail’s new lines study the average load factor for HSR services is 42%, compared to 33% for conventional services. It is worth noting that improvements in mobile information technology may make book-ahead services more acceptable in the future.

Table 2 Energy Consumption by Mode 2010

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

*At 70% load factor

Source: CE Delft (2003), reported in Nash (2009).

More recently there have been concerns about the life cycle costs of rail. Most studies have focused on point of use emissions and have ignored vehicle production, infrastructure provision and fuel production. Chester and Horvath (2009) estimate that total life cycle energy inputs and greenhouse gas emissions contribute an additional 63% for road, 155% for rail (urban heavy and light rail) and 31% for air over point of use emissions.

There have been two recent studies that have investigated aspects of the life cycle costs of HSR in the UK. Booz Allen and Hamilton (2007b) estimate that taking into account construction adds around 35% to the CO_2 emissions that result from operation. Network Rail (2009d, Figure 3.1) estimate that the greenhouse gas emissions (measured in CO_2eq per seat-km) can in 2007 be attributed 80% to train operations, 18% to infrastructure and only 1% to train production (reflecting relatively long asset lives and intense utilisation), based on a Eurostar Class 373. However, given the proposed rates of decarbonisation of electricity generation over the period 2025 to 2055 and the adoption of the AGV, the carbon footprint of operations will reduce dramatically. In such a situation, 70% of greenhouse gas emissions can be attributed to infrastructure, 28% to train operations and 2% to train production. An important challenge is therefore to reduce the carbon footprint of rail construction materials.

Overall, Network Rail (2007d), using research by AEA Technology, concludes that per seat-km, high speed rail will emit around 9% more greenhouse gas emissions than conventional rail in 2025. There are two components of energy consumption of a train: kinetic energy to accelerate the train and energy to overcome resistance to motion in order to maintain speeds (Davies and Thompson, 2009). Kinetic energy is proportional to the mass of the train and square of velocity. It is also related to the number of stops – which are limited on HSR services. The Davis formula suggests that the resistance to motion is dominated by aerodynamic resistance which increases with the square of speed. The expectation is that, all other things being equal, rail energy consumption would broadly increase with the square of speed. Some calculations of this type were in the Eddington Study and the 2007 Rail White Paper (Davies and Thompson, op cit. p5). It was estimated that reductions in journey times of 25% (and hence implied speed increases of 33%) led to increases in energy consumption of 90%. However, use of lightweight materials and aerodynamic designs seems to result in a broadly linear relationship between train speed and energy use per seat km (RSSB, 2007) However, because of higher load factors, high speed rail is estimated to produce around 15% less greenhouse gas emissions than conventional rail in 2025. When modal shift and demand creation are take into account this differential increases to 17.4%, with high speed rail emitting 26.4g CO_2eq/pkm and conventional rail emitting 32.0g CO_2eq/pkm.

This analysis thus suggests that the carbon impacts of HSR can be positive but relatively modest. This is supported by Capita Symonds (2007) who re-work the Atkins HSR demand forecasts to suggest carbon savings of 0.24MtC in 2016, rising to 0.84 MtC in 2031. Even using a high value of carbon (£238 per tonne, as recommended by Stern) and high estimate of carbon saved, results in an estimated benefit of £12 billion compared to financial costs of £33 billion suggesting that 'carbon savings, even under optimistic assumptions, are unlikely to be a significant part of the business case'. This work assumes savings of 20 to 30 g of carbon per passenger km transferred from air and road. The assumption made was that diversion from air was between 18% and 24% of demand, and diversion from road was around 18% so that the overall reduction is something like 10 g of carbon per passenger km whilst the AEA Technology work is suggesting something much more modest, such as 5.60g CO_2eq/pkm (or 1.5g of carbon). In addition, Capita Symonds were assuming a radiative forcing factor of 4 for air emissions which may be on the high side.

Greengauge 21 (2009), using data from ATOC, estimate that HSR carbon emissions per passenger km are 29.5g in 2008, declining to 2.1g in 2040 and 1.3g in 2055. The corresponding figures for car are 105.3g in 2008, 38g in 2040 and 4g in 2055, whilst for air they are 119.6g in 2008, 59.8g in 2040 and 51.4g in 2055. The headline figure is that a full HSR network would result in an annual reduction in CO_2 emissions of one million tonnes by 2055. However, this is estimated to only lead to climate change benefits of around £1.8 billion (present value, 2002 prices). Moreover, these calculations only consider operations even though over the life time of the project the infrastructure carbon costs will constitute 70% of total carbon costs and hence there is a 'need to develop less carbon-intensive methods of construction'.

Whilst carbon emissions are the main environmental impact of HSR, noise and vibration are also significant. At conventional speeds (160-200 km/h) noise is mainly caused by rolling noise (wheel-rail contact). Above 200 km/h, aero-acoustic noise (due to turbulence) starts to contribute (Mellet et al., 2006). De Coensela et al. (2007) found no difference in noise annoyance from conventional and high speed trains, whilst Vos (2004) found the noise annoyance from conventional rail to be less than that of road, partly due to its more intermittent nature. Janic (2003) note that due to the lack of harmonised indicators it is not possible to compare the noise levels from passenger air services and HSR. However, HSR can adopt mitigation measures that are not available to air services, including low speed approaches to/from major stops, acoustic screens and bunds and tunnelling. Tunnelling can have the problem of 'tunnel booms' as trains enter and exit, but this can be reduced by aerodynamic design and the use of air shafts (Ricco et al., 2007). Another factor is land-take. Greengauge 21 (2009) estimate that a two track high-speed railway that can carry over 16,000 passengers an hour requires 40% less land than a three lane motorway.

The importance of environmental impacts might be judged from Temple (2007b) who estimate mitigation costs of £4.3 billion (given appraisal optimism) or around 11% of total costs for a North – South HSR route in the UK. This same study indicated that between 0.5 and 1.1 million people could be affected by HSR noise and between 26,500 and 37,500 could be affected by vibration.

6. Planning issues

HSR has been advocated as a tool in spatial planning. Harman (2006) notes that HSR led to substantial development around Eurolille and Lyon-Part Dieu, strengthening these regional centres. However, HSR by-passed other towns such as Arras and Dijon, although subsequently these towns have seen improvements in service through the strengthening of regional express services using the released capacity on the classic lines. Moreover, there is the problem of the two way road – with the possibility that some economic activity may shift from regional centres to the central capital. For example, Vickerman and Uliad (2009) note that Tours, a little over 1 hour from Paris by the TGV Atlantique suffered reductions in business activity.

HSR has also promoted some long distance commuting – for example between Ciudad Real and Madrid (Garmendia et al., 2008). It is anticipated that Ashford will exhibit similar growth with the introduction of domestic high speed services in December 2009 (Preston and Wall, 2008).

Even if HSR does strengthen regional centres, these economic impacts may be redistributive rather than generative. However, there are arguments that HSR has wider economic benefits, as do other transport interventions. In particular, HSR can lead to agglomeration benefits by extending labour catchment areas and by bringing new land sites into development (as, for example, at Ebbsfleet). By extending market areas, HSR may also make service industries more competitive. As a result of these factors, the economy becomes more productive. Studies have suggested an elasticity of productivity with respect to accessibility of between 0.12 (Rice et al. 2006) and 0.29 (Prud'homme and Lee 1999). Accessibility in these studies is described in terms of average speed within a city, and hence reduced journey times. Hence based on the figures given for the introduction of the HSR network in Spain, which indicated an average reduction in travel time of around 10% between cities (López et al. 2008), this would imply an increase in productivity of between 1% and 3% for inter urban economic activities. Atkins (2008) suggest that the development a network of HSR services on the East Coast (London to Edinburgh) and West Coast (London to Glasgow) corridors could, over a 60 year appraisal period, lead to transport benefits of £63 billion and wider economic benefits of £44 billion for a cost of £31 billion. These figures suggest wider economic benefits of around £1.75 billion for the first year, which represents a growth of 0.13% in GDP.

These wider economic benefits may also be expressed in terms of a multiplier on existing transport benefits. For example, the work by Atkins described above suggests a multiplier of 70%. Similarly, Oosterhaven and Elhorst (2003) have examined high speed projects in the Netherlands and find a wider economic benefit multiplier of 20% for urban connections within the Randstad and an 80% multiplier for an inter urban connection between Randstad and Groningen. Docherty et al. (2009) investigate the wider economic benefits of HSR between Glasgow and

Edinburgh. Using Transport Scotland’s Agglomeration Productivity Aggregate Response Calculator (APARC), they estimate a multiplier of 26%.

Most recently Greengauge 21 (2009) estimate that wider economic benefits of their full network are worth almost £14 billion (present value 2002 prices) representing a multiplier of 13% on other benefits. This study also maps out the regional economic benefits of a full network based on journey time savings, agglomeration benefits and benefits from reducing imperfect competition. The regions with the biggest shares of these benefits are London (31%), Scotland (25%) and the North West (14%) – which illustrates the two-way nature of the economic impact of transport interventions.

Other important planning issues relate to accommodating housing and employment growth. Of most relevance here is the Milton Keynes/South Midlands Growth Area for which 223,400 houses and 191,190 jobs are planned between 2001 and 2021. Although no HSR stops are currently planned for this sub-region, it should benefit from the release of capacity on classic lines (Department for Transport, 2009).

The last issue is the planning process itself. Eddington (2006) illustrated that for major schemes such as the M6 Toll Road the public inquiry process could take up to three years and in the case of Heathrow Terminal 5 this process took six years. Recommendations were made as to how the process and associated timescales could be compressed. The Barker report made the case for an independent Planning Commission, in part to assist in the delivery of major projects. The 2008 Planning Act created an Infrastructure Planning Commission and high speed rail would provide a major test of its effectiveness. The timing of high speed rail would also need to fit into the HLOS and Control Period framework. As an indication of the timelines involved SNCF began detailed planning for the TGV Sud Est in 1966, with construction beginning in 1976 and completion in 1981 – a period of 15 years. Given that the French planning system is more streamlined than that in the UK this might be thought of as a minimum. Greengauge 21 (2009) assumes planning starts in 2011, construction in 2015 and operations in 2021, with a 38 year concession beginning in 2015. The funding structure would be based on a Design, Build, Finance and Transfer contract.

7. Conclusions

HSR is an expensive technology and appears particularly so in the UK, due to the country’s built-up nature, the resultant high land costs and high environmental and other regulatory standards. The capital costs of construction are likely to be the most important cost category. There is a high degree of uncertainty about these capital costs but the current approach of an appraisal optimism uplift may be less effective in controlling costs than more proactive forms of risk management. With a 60 year life, mid life refurbishment and replacement costs may be significant but difficult to estimate, given changes in technology and a possible 15 year lead in time. Non construction costs related to planning, design and project management can be substantial and processes are required to ensure that these are kept in check. It will be important to develop a procurement model that minimises capital costs for a given standard of service.

The main benefits of HSR are the generalised cost savings that accrue to existing rail passengers, passengers that have been abstracted from air and road and generated passengers. These benefits will be mainly in the form of time savings but may also be related to improved levels of comfort. Important issues relate to the growth of demand and the growth in the value for time. There are great uncertainties in forecasting demand over a 60 year period whilst there are problems with assuming the value of time will increase with income indefinitely. For example, in a recent study of HSR between Edinburgh and Glasgow, Preston et al. (2009) found that in year 1 user benefits were 57% greater than increases in revenue. By year 60, user benefits were over nine times greater than the increased revenue (assuming that fares were fixed in real terms). It would be sensible to cap the value of time so as to limit this growth in user benefits and there are provisions in WebTAG for this. These demand uncertainties have been brought into focus by the current recession which has led to lower levels of rail demand growth than would otherwise be expected and may have put the case for HSR back a number of years in some cases. For example, sensitivity analysis undertaken by Greengauge 21 (2009) indicate that reducing GDP growth by 0.5% a year results in 22% lower HSR demand in 2055 and reduces lifetime benefits by 21%.

There will be benefits for users of classic lines, as capacity is released but these benefits are likely to represent less than 10% of gross benefits, although detailed modelling has yet to be undertaken. An important source of benefits will be net revenue. Implementation of the users pay principle would improve financial performance but at the expense of social performance. A 30% premium on standard anytime return fares in excess of £200 would clearly deter some passengers. An important issue is how revenue yield techniques might work on HSR services and the extent to which they attract users from across the social spectrum.

Another issue is the extent to which there will be price competition from rival conventional train services and how that might affect the financial performance of HSR and of the franchised classic rail system. Such competition has not been a feature in the regulated systems outside the UK. Related issues include the track access charging regime that will be applied and the extent of competition from other modes, particularly air and coach. There seems a lot of work still to do to establish appropriate prices for HSR.

The evidence suggests that HSR can grow the rail market by a factor of two or more. Substantial abstraction from air is possible with head-on competing air services often limited to the inter-lining market after the introduction of HSR. However, air can compete by offering alternative destinations. Abstraction from car is more limited and any benefits on the road network may be diluted by re-congestion. It should be noted that in the Network Rail study rail demand is assumed broadly to double between 2007 and 2030. For London – Birmingham HSR grows the rail market by 30% but for London – Edinburgh it nearly trebles it. There must be some concern about market saturation. With HSR these forecasts are suggesting rail travel between London and Edinburgh could increase six fold when according to National Travel Survey data (2002-6) rail already has a 24% share of London – Scotland travel.

Theoretical work suggests that given the likely high construction costs for HSR, high levels of demand would be needed. This is confirmed by the Network Rail study that suggests that HSR to Birmingham and Manchester, although attracting a combined usage of 21 million passengers per annum in 2030, would not be socially viable and that such viability can only be achieved by extending northwards to Scotland. It could be argued that some benefits are missing from the analysis. The most important of these are wider economic benefits. Theoretical studies indicate that this could lead to anything between a 20% to an 80% increase in benefits, but there are no practical studies that have measured generative benefits of this magnitude. There is also the issue of whether wider economic benefits would be best achieved by linking, say, Leeds with Manchester and Edinburgh with Glasgow to develop city regions that could compete with London, rather than linking these cities to London. Another issue is the extent to which a system of national road user charging would strengthen the case for HSR.

Although there is a need for continuing work, the evidence to date suggests that the environmental case for HSR is positive but small. Given the planned decarbonisation of electricity generation, emphasis may switch to how the infrastructure itself can be decarbonised. Substantial mitigation measures that may equate to over 10% of construction costs will be required to minimise adverse environmental impacts, particularly due to noise and vibration.

Despite the detailed recent work undertaken by Network Rail there are a number of unresolved issues. Although a case for a West Coast route has been made, other routes were screened out at a strategic level based on a demand/capacity analysis. However, the base scenarios against which HSR is tested will be different across routes. The West Coast has had a recent upgrade and the base scenario may approximate to a do nothing scenario. The East Coast line has had little investment since electrification was completed in 1990 and the base scenario here might involve substantial expenditure on various upgrades. Atkins (2008) argued that this was one of the reasons why in their later work the East Coast route exhibited a higher BCR than the West Coast route. The extent to which there are network benefits that could justify a number of routes also needs to be further investigated further, although some of these issues have been examined by Greengauge 21 (2009).

Table 3 summarises some of the recent ex ante appraisals of HSR in Britain, although it should be borne in mind that these results are sensitive to the underlying assumptions and in some cases there may be comparability problems. Nonetheless, it can be seen that all the network studies have BCRs in excess of 1.5, the Department for Transport’s medium value for money threshold. However, only the Greengauge 21 study has a BCR comfortably in excess of 2, the high value for money threshold. With the exception of the Atkins 2003 study the network benefits exceed the benefits of individual lines. However, only the Network Rail study reports a BCR below one for a major route, whilst as noted above there is also some inconsistency about the relative merits of an East Coast and a West Coast route. It should also be noted that higher BCRs may be achieved by alternative investments. For example, Dodgson (2009) reports that a sample of 48 local road schemes had a mean BCR of over 4.2, whilst 93 Highways Agency projects had a mean BCR of over 4.6.

Table 3: Reported Benefit Cost Ratios (BCRs) of Recent HSR studies in Britain

	Source	Description	BCR
Full Networks	Atkins, 2003		2.0
	Atkins, 2008		2.0
	Network Rail, 2009	Option 1.4.1	1.8
	Greengauge 21, 2009		3.5
Individual Lines	Atkins, 2003[1]	London-West Mids	2.1
	Atkins, 2008	East Coast	2.5
		West Coast	1.5
	Network Rail, 2009	London-Manchester	0.9
	Greengauge 21, 2009	HS NW Phase 1[2]	2.9
		HS NE Phase 1[3]	2.0

[1] As reported by de Rus and Nash (2009), [2] London – Manchester, [3] London – Newcastle

An important issue is the extent to which the different results in Table 3 are an artefact of the forecasting models used. Jansson and Lang (2009) compare the Sampers and VIPS models in appraising HSR options in Sweden (Stockholm-Gothenburg and Stockholm-Copenhagen-Hamburg) and find that Sampers gives a BCR of 1.2 whilst VIPS produces a BCR of 1.8. It should be noted that the kernel of the Sampers model is the EMME/2 assignment model that also forms the basis of the British rail model PLANET.

Both the Network Rail and the Greengauge 21 studies forecast that although the revenue from HSR schemes can cover operating and maintenance costs (which also seems to be the case for the TGV services in France), the net revenue only makes a small contribution to the capital costs. For example, the preferred Network Rail scheme would require public support of almost £18 billion, equivalent to 74% of the capital costs. The more extensive Greengauge 21 network would require public support of almost £27 billion, equivalent to 81% of capital costs. This is major public expenditure which will put railways in competition with other major areas of expenditure such as health, education and defence.

There are also issues about the need to consider alternative uses of any proposed HSR alignment, either for alternative technology such as Maglev, or for conventional rail (either passenger and freight) that have so far only been examined by a fairly crude form of multi-criteria analysis. A West Coast HSR may pass a given BCR threshold but there is a possible concern that alternative transport investments could give better returns.

Given that a London to Scotland HSR line will attract a lot of air traffic, there will be a marked reduction in domestic flights. An important issue will be the second round benefits of the freed up capacity and how that might be utilised. At its extreme, this boils down to whether serving Heathrow by HSR may act a substitute for a third runway. There is the related question of whether improved links to HS1 could reduce short haul flights from regional airports such as Birmingham to the near continent.

The big unknown at this stage is what will be the precise route taken and whether there is any scope for the rights of way established to be multi-modal or multi-functional (for example also providing for the super grid or for water supply). A particular issue is the location of stations. If the exclusive model is to be pursued these would probably need to be located at edge of town locations. In such cases, connections with the classic rail network might be problematic and access/egress by car would be greater than it might otherwise be, with knock-on environmental impacts. It will be important to investigate mixed exploitation models that permit the use of existing central city stations and for multi-modal links at these stations to be improved. Work to date on HSR has been largely uni-modal, for understandable reasons, but a more multi-modal approach will be required to ensure that HSR is the most appropriate transport intervention. It is hoped that the on-going HS2 study will help resolve some of these issues.

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