High-Speed Rail Development Programme 2008/9

Principal Consultant

Strategic Choices

Final Report for Workstream 2

Contents

Executive Summary

The purpose of this Workstream 2 report is to explore the strategic choices to be made in defining a high-speed rail network in Great Britain.

We discuss national priorities and the way in which high-speed rail may be able to meet the recently published objectives set by the Secretary of State for Transport and the Scottish Government and identify some of the emerging themes expressed during the consultation that Greengauge 21 has initiated.

These objectives are discussed in detail along with the potential UK market for high-speed rail travel. We also reflect on relevant international experience of high-speed rail design, development and operation in order to inform the preliminary design of a future high-speed network for the UK. We then make a preliminary assessment of the traffic demand to inform an emerging network design, which will be discussed further in later workstreams.

We consider constraints that are imposed by Britain's topography, spatial structure (in particular that of cities), and the general constraints on infrastructure development in the UK, including economic and regulatory. Specific railway design constraints are also reviewed, as are potential future transport projects and technological changes that might have an influence on the design.

Conclusions are drawn, together with their implications for the corridor-level studies to be undertaken in Workstream 4, when further information and business case data from Workstream 3 will also be available.

The emerging guiding principles are as follows:

HSR routes need to be located such that they provide additional capacity for the national transport system where there is forecast to be unmet demand on the long-distance routes and create high-value capacity relief on the existing rail network.

HSR needs to serve places which are capable of stimulating economies to achieve growth, regeneration and wider productivity benefits and to stimulate and support a sustainable pattern of development.

HSR has to be planned to address the whole journey, as identified in TaSTS, to make it an attractive, lower carbon, alternative to car use.

HSR needs to be able to attract travellers away from short-haul aviation to/from major international hub airports in order:

- to free-up runway capacity for more valuable longer-distance services *or*
- to reduce carbon emissions, *or*
- to provide a suitable HSR service in cases where it has been found necessary to withdraw air services that have a significant effect on business travel and the economy.

HSR needs to be planned as a system to be properly integrated with other transport facilities to maximise the value of the investment, with complementary measures identified as necessary, to ensure a comprehensive and nationwide spread of benefits and with each phase of development reflecting this aim, to the fullest extent possible.

1 Introduction

1.1 Purpose of Workstream 2

Workstream 2	To explore the strategic choices to be made in defining the network
Deliverables	Identification of key issues and strategic choices for the development of a HSR network for Britain
Inputs	Including: Report from Workstream 1; findings from Consultation assignment; workshops, international references.

1.2 Introduction to high-Speed Rail

Since the development of the high-speed rail technology in Japan, and the opening of Europe's first high-speed rail lines in France, there has been a significant increase in the number of countries turning to high-speed rail as way of developing their national transport infrastructure.

On average, Europe has been adding 187 kms every year to its high-speed rail network since 1982, and the rate of projected growth for the next 15 years is 554 kms per year[1].

High-speed rail projects are under construction and development throughout the world. Amongst others, the US, South America, the Middle East, India and China have, or are planning HSR. The UIC estimates that by 2025, the world will have more than 30,000 kms of high-speed railway.

Furthermore, the number of train sets that can operate to high-speed standards and the number of destinations that can be reached by a combination of high-speed and conventional rail infrastructure continues to increase. France, considered the cradle of high-speed rail in Europe, has 1850 kms of high-speed railway, but 7000 kms of routes are served by high-speed trains[2]. In Germany, which has concentrated on introduction of high-speed services on upgraded routes, there is a growing network of high-speed services that enables journey times between principal cities to continue to fall.

Technological developments have produced tilting trains that provide greater levels of passenger comfort at high speeds on conventional railways as well as high-speed rolling-stock such as Alstom's AGV[3] train, for example, which can run at 360 kph using 30% less energy than a TGV train, and has a flexible-length multiple-unit design.

[1] UIC (September 2007). Conference on Modern Railways, China Railway Society, Beijing. Presentation

[2] SNCF

[3] Alstom (2009). Automotrice à Grande Vitesse. www.alstom.com

1.3 Developing a Sustainable Transport System

The UK Government has made specific commitments to tackle climate change, support national and regional economic growth and develop transportation. The Climate Change Act commits to quantified objectives (an 80% reduction in carbon emissions by 2050)[4], the UK Government national transport objectives are primarily set out in the publication 'Towards a Sustainable Transport System[5]' (TaSTS), published in October 2007, which presents the government agenda to tackle transport congestion and improve transport networks whilst satisfying the twin objectives of both economic growth and reduction of carbon emissions.

In November 2008, the Secretary of State for Transport issued a formal consultation paper entitled "Delivering a Sustainable Transport System[6]" (DaSTS). Here is an extract from the introduction by the Secretary of State for Transport:

> *'When TaSTS was published, economic prospects were good. Today, the global economy is in trouble. Governments, companies and households across the world have to think harder about their priorities. In the UK, we need to support people and businesses through the downturn, and help them emerge stronger on the other side. We have thought hard about transport's contribution to this.*
>
> *The Government remains committed to investment and to tackling the problems of congestion and crowding. The Eddington study warned that congested cities, crowded trains, delays at ports and queues at airports are not just a nuisance to individual travellers. They are also a tax on the productivity of our businesses and a deterrent to inward investment. If we don't tackle them, they will become a brake on economic growth and on employment.*
>
> *We still want to cut transport's carbon footprint. It is wrong to think that, in a time of economic difficulty, we can put the climate change agenda on the back burner for a while. We cannot. Global warming requires urgent action. And the Stern report leaves no doubt about the massive economic price we would pay if we failed to address it. But Stern also stresses the importance of tackling climate change in the most economically efficient manner. That means preserving freedom of choice, facing people with the true carbon cost of those choices, forcing the pace of technological change, and helping people reduce their need to travel or switch to lower-carbon modes. It does not mean rationing transport demand by constraining the capacity of our transport networks.*
>
> *We remain committed to serious long-term transport planning, as set out in TaSTS. This is based on specifying clearly the challenges to be addressed, looking cross-modally at a range of options, and backing the solution that has the best fit against our five transport goals and delivers the best value for money. It is based on engagement with stakeholders throughout the process. And it is based on a realistic recognition that we are planning for an uncertain future. In asking taxpayers to support a major transport investment programme, we must be able to assure them that we are backing the best solutions. Given the urgent need to stimulate economic growth and cut greenhouse gas emissions, we shall accelerate the pace of this work, and will start by investigating options for rail electrification, managed motorways and the case for new railway lines. But we shall not cut corners. '*

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[4] Department for Environment Food and Rural Affairs (November 2007), Climate Change Act 2008, http://www.defra.gov.uk/ENVIRONMENT/climatechange/uk/legislation/.

[5] Department for Transport (October 2007), Towards a Sustainable Transport System, http://www.dft.gov.uk/about/strategy/transportstrategy/tasts.

[6] Department for Transport (November 2008), Developing a Sustainable Transport System, http://www.dft.gov.uk/about/strategy/transportstrategy/dasts.

The Scottish Policy position is set out in the recently published National Planning Framework[7] document, and the National Transport Strategy, which specifically invoke the objective of improved transport links with England and of high-speed rail.

Para 23. While the expansion of direct air links has dramatically improved Scotland's international connectivity in recent years, air travel is making a growing contribution to greenhouse gas emissions. A key issue over the next 25 years will be how to maintain and enhance this connectivity, with all the economic and other benefits that this will bring, while tackling the challenge of climate change. Faster cross-border rail links would make the train more competitive with the plane for many journeys to and from London and other UK cities, potentially helping to reduce emissions from short-haul flights. The new Eurostar terminal at St. Pancras offers opportunities for easier rail journeys between Scotland and the Continent. For the majority of overseas trips and business trips between the North of Scotland and the South of England, however, flying is likely to remain the only practical option.

Para 119. The services offered by Edinburgh, Glasgow and Prestwick airports are in some respects complementary and there may be potential for strengthening connections between them. Linking our main cities and airports with higher speed trains could offer a much wider choice of destinations, allow mass passenger transfer between airports, and open up the South-West to more visitors. Increased capacity on rail services between Prestwick Airport and Glasgow city centre will be the minimum requirement over the next 25 years.

Para 120. Cross-Border road and rail links are of prime economic importance and congestion and lack of infrastructure outwith Scotland can have an adverse impact on access to Europe and other parts of the UK. The economic benefits of tourism can be spread more widely if more of Scotland can be brought within 3 hours of major English cities. There is a need to improve journey times and the frequency of rail services to key destinations such as London, Manchester, Leeds and Birmingham. Reducing journey times on routes between Aberdeen and Newcastle would improve the connectivity of knowledge economy clusters on the East Coast. Improvements to the West Coast Main Line would allow more cross-Border freight to be moved by rail. The Scottish Government will work with the UK Government and other bodies to strengthen cross-Border transport links.

Para 121. A regular and reliable 4-hour journey time on existing lines between Central Scotland and London would help to make the train more competitive with flying. London's high speed link to the Continent makes it possible for a journey such as Inverness to Marseilles to be completed in a day. However, the scope for further increases in speed on the existing rail network is limited. The Scottish Government will pursue discussions with the UK Government on the development of a high-speed rail link to reduce journey times between Central Scotland and London to under 3 hours and provide direct rail services to the Continent.

[7]Scottish Government (December 2008), National Planning Framework 2, http://www.scotland.gov.uk/Publications/2008/12/12093953/0.

1.4 Our Approach

Our brief was to use Workstream 2 to work with Greengauge 21 and their Consultation Adviser Bircham Dyson Bell (BDB) to identify and explore the key strategic choices for high-speed rail network development in Britain.

We make reference to material that is quoted in Workstream 1, the review of previous work on high-speed rail in the UK, and we refer to future tasks to be undertaken in the following Workstreams:

- Workstream 3, which will be used to construct a business case model for evaluating options and forecasting demand. The methodology used in this model is to be presented in the WS3 report.
- Workstream 4, which will be presented as a series of corridor reports, and which uses further consultation with stakeholders, geographical input and regional considerations to develop options for the five route corridors identified in the Greengage 21 publication 'Next Steps'[8]
- Workstream 5, which will be undertaken in parallel with Workstream 4 and develop network options, discuss phasing and assess national benefits of a high-speed rail network.

Returning to Workstream 2, this can be seen as a process of seeking to resolve a number of open strategic questions before the design of the UK's high-speed network can be taken further forward. Our report is presented as follows:

In Section 2, we describe the output from the Consultation process being led by BDB. We helped to shape both the questionnaire and interview structure being used by BDB in order to ensure that key information can be extracted and incorporated into Workstream 2. BDB have provided valuable feedback from their interviews. We have met and discussed with stakeholders their particular objectives and the implications of these for network design.

In Section 3, we make reference to national and international experience and relevant evidence in order to explore the objectives that would have to be met for a HSR network to be successful. We use the same sequence of objectives used by the Department for Transport in their document TaSTS.

In Section 4, we discuss the market potential for a high-speed rail network in the UK; especially by analysis of the future demand for rail, car and air travel and population growth. .

In Section 5, we identify constraints on the development of high-speed rail, which include physical, technical and development limitations, transport policy perspectives and operating considerations.

Finally, in Section 6, based on the conclusions of this structured discussion, we draw together a set of guiding principles, or conclusion, and present their implications. These conclusions are intended to be key pointers to the successful, cost-effective development of high-speed rail in Britain and the choices in principle that need to be made.

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[8] Greengauge21 (Nov 2007). The next steps for High Speed Rail in Britain. www.greengauge21.net/assets/GG21_PR1107.pdf

2 Consultation Feedback

2.1 Introduction

Our view of wider stakeholder objectives comes from the work of Greengauge 21's Consultation Advisor, BDB, informed by interviews and meetings with [47] stakeholders drawn from regional and national organisations. These organisations' views will be incorporated into a longer report by BDB[9], but the initial feedback, from regional-level development organisations have been summarised here.

2.2 Economic Development of Regions

The Comprehensive Spending Review in 2007 committed the Government to continue the Regional Economic Performance Public Service Agreement (PSA) to:

> "Make sustainable improvements in the economic performance of all English regions and reduce the persistent gap in growth rates between the regions".

Scottish Government objectives are similar:

> "To focus Government and public services on creating a more successful country, with opportunities for all of Scotland to flourish, through increasing sustainable economic growth."

The Department for Business, Enterprise and Regulatory Reform (BERR) is the lead UK department for delivery of the objective whilst HM Treasury, the Department for Communities and Local Government, the Department for Innovation, Universities and Skills, the Department for Work and Pensions, the Department for Transport and the Department for Environment, Food and Rural Affairs are all contributing departments

National economic prosperity (and an appropriate regional share) was reflected strongly as the primary objective from the stakeholder consultation process.

As considered in Section 4 of this report, most forecasts are for the economy of London and the South-East to grow more strongly than that in the rest of the UK, unless specific measures are taken to counteract this trend. Consultees suggest that achieving this objective requires positive intervention, which might take the form of transport investment or other intervention.

Stakeholders consider that fast reliable access to London is needed to encourage businesses to locate outside London and the South-East. This is consistent with the conclusions of Eddington[10].

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[9] BDB consultation report for Greengauge to be produced in 2009.

[10] Eddington, R. (December 2008). The Eddington Transport Study.
http://www.dft.gov.uk/about/strategy/transportstrategy/eddingtonstudy.

2.3 Journey Times

Stakeholders generally believe there to be an overall benefit associated with faster transport journey times, particularly from city centre to city centre. Economic and demand modelling to be conducted in later Workstreams will determine the extent to which this is likely to be the case; (we also consider relevant international experience on this point).

Scottish stakeholders expressed the objective of a 3 hour journey time to London in order that high-speed rail might become a viable consumer alternative to air, particularly for the business travel market. Reduced journey times are cited as important objectives by English stakeholders where their current rail journey time to a London rail terminus is in excess of 2 hours. These journey time objectives would facilitate day return trips to London, which are seen as important in order to capture the business market for long-distance national travel.

Journey time objectives are seen as the second most important objectives, after economic regeneration, and would suggest that journey times of 3 hours to Scotland and 2 hours to certain cities in England are important targets to be achieved, especially in regions where the benefits of recent rail investment, notably the West Coast Route Modernisation, have not been felt.

While reduced journey time to London would be the most important attribute of HSR for most consultees, in some areas improved journey times between regions outside London and the South-East was also considered important. This was particularly the case for the northern regions, where journey times in the trans-Pennine corridor are considered too long.

2.4 Comparison with other modes

Reduction in demand for air travel, which can be a consequence of a HSR network, was perceived to be an advantage by itself. The fact that good quality rail travel can offer more effective use of travel time was also seen as an important advantage that HSR has over both road and air modes.

Rail is generally accepted as a greener form of travel by consultees; acknowledging the complexity of carbon emission and electricity sources debate.

2.5 Accessibility

Whilst the regional development benefits of HSR were accepted by consultees, the potential for this to be a disbenefit to those without access to the network was identified. The importance of access to the network with existing public transportation links was also cited as important.

The most important need was to meet the requirements of business travellers, but the need for leisure as well as business travellers to be served by HSR was also important to Stakeholders.

The need for access to HS1 and international travel connections was important for consultees from Birmingham, but generally secondary to the need for effective links with the centre of London.

Accessibility to London Heathrow (as an international gateway) was considered important and the potential for improving efficacy of the airport by reducing the number of short-haul flights was acknowledged.

2.6 Funding

It was considered important that funding for HSR is not at the expense of other essential public services, but accepted that the business case must be proven.

2.7 Phasing

It was considered inevitable that construction of a high-speed rail network was undertaken in logical phases, but with assurances that more distant or later parts (of the network) were not abandoned or neglected.

3 The Objectives of High-Speed Rail

3.1 Introduction

In this Section, we make reference to national and international experience and relevant evidence in order to explore the objectives that would have to be met for a HSR network to be successful. We use the same sequence of objectives used by the Department for Transport in their document TaSTS:

- Maximising the overall competitiveness and productivity of the national economy, including here the regional economic impact and reduction in congestion;
- Reducing transport's emissions of CO2 and other greenhouse gases;
- Contributing to better health and longer life-expectancy, including safety and security;
- Improving quality of life for transport users and non-transport users;
- Promoting greater equality of transport opportunity.

Scotland's National Transport Strategy[11] is similar, but with the inclusion of a specific objective to reduce journey times. They are set out on the website as:

- **Improve journey times and connections** between our cities and towns and our global markets to tackle congestion and provide access to key markets - ***wealthier and fairer, safer and stronger***;
- **Reduce emissions** to tackle climate change - safer and stronger, ***wealthier and fairer;***
- **Improve quality, accessibility and affordability** of transport, to give people the choice of public transport and real alternatives to the car. - ***greener, healthier, smarter.***

The Wales Transport Strategy[12] sets out its long term outcomes under the headings of Social, Economic and Environmental, with strategic priorities covering:

- reducing greenhouse gas emissions and other environmental impacts;
- integrating local transport;
- improving access between key settlements and sites;
- enhancing international connectivity;
- increasing safety and security.

The priority of international connectivity is particularly relevant to high speed rail.

Both the Scottish and Welsh objectives are very similar to those of the UK DfT.

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[11] Scottish Government (December 2006). National Transport Strategy. http://www.scotland.gov.uk/Topics/Transport/NTS

[12] The Welsh Assembly Government (April 2008). The Wales Transport Strategy. http://new.wales.gov.uk/deet/publications/transport/wts/wtstrategy/wtspdfloen.pdf?lang=en.

High-speed lines throughout the world have been constructed in order to satisfy a range of political, social and environmental needs. The UK network will have its own priorities and transport challenges to overcome and be a response to the UK's political, economic and geographical priorities.

3.2 Competitiveness and Productivity of the National Economy

The first of the transport goals in DaSTS is 'to support national economic competitiveness and growth, by delivering reliable and efficient transport networks'[13]. The Eddington study demonstrated that there 'has been a compelling link between the transport system and prosperity throughout history' and that this continued to hold true for the UK[14]. In this context, the particular role of transport is to facilitate business travel, journeys to work and the movement of freight.

Historically increased economic growth has been linked to increased demand for transport, although in recent years the link has not been as strong as in the past. Figure 3.1 illustrates this relationship, in a graph published by National Statistics, showing clearly the changing relationship between economic growth (GDP) and increasing mobility since 1958. There is an indication that the earlier link between economic growth and travel demand has weakened. It is debatable the extent to which this weakening of the link is due to congestion on highways suppressing demand rather than inherent economic factors. The DfT's National Road Transport Forecasts[15] show significantly higher growth on motorways and in rural areas than in urban areas, particularly London; this supports the view that congestion is, at least in part, responsible for the lower recent growth in car traffic. Whatever the reason for recent changes, it remains clear that growth in GDP leads to growth in the demand for transport.

Eddington identified that unreliable travel times for business travellers and freight resulting from capacity limitations risked acting as a constraint on economic growth.

Furthermore, such economic growth as does occur, is likely to result in increased demand for leisure travel, contributing still further to congestion and so constraining future growth.

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[13] Department for Transport (November 2008). Developing a Sustainable Transport System. Paragraph 1.5. http://www.dft.gov.uk/about/strategy/transportstrategy/dasts.

[14] Department for Transport (November 2008). Developing a Sustainable Transport System. Paragraph 1.7. http://www.dft.gov.uk/about/strategy/transportstrategy/dasts.

[15] Department for Transport (December 2008). Road Transport Forecasts 2008. http://www.dft.gov.uk/pgr/economics/ntm/roadtransportforcasts08.

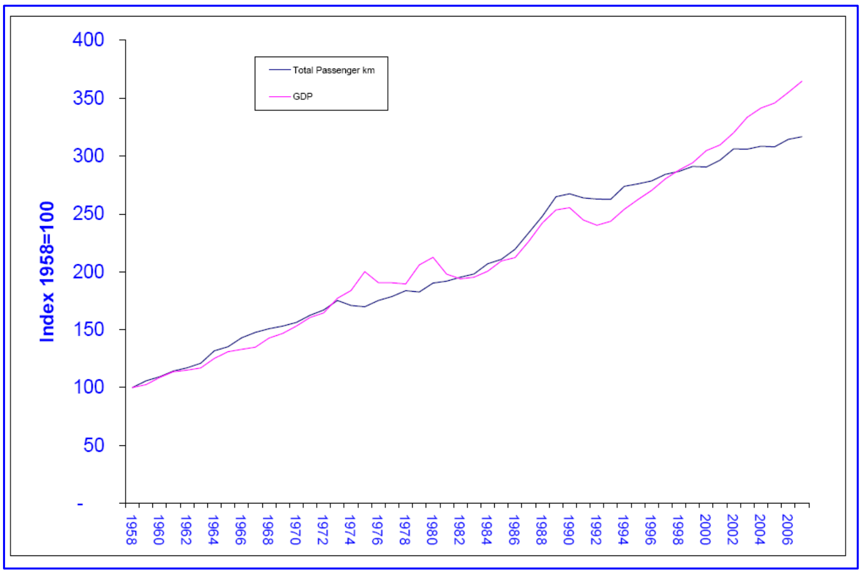


Figure 3.1 Increased travel and economic growth[16][17]

It can be considered that high-speed rail can contribute to meeting transport goals through:

- Providing faster travel in key business corridors between city centres;
- Improving connectivity between regional centres;
- Providing services on which travellers (particularly business travellers) can make valuable use of their travel time;
- Providing reliable public transport services and journey times;
- Releasing capacity for additional rail services; (and so also improving their reliability)
- Releasing capacity for additional freight services.

The UK Government does not currently have an explicitly stated objective of transport mode transfer to rail or to other carbon friendly modes, although this can be implied from the other stated objectives. The European Commission and some other European countries have announced objectives to encourage rail use and reduce travel by car and air. For example, France has announced an intention that all significant centres of population (>100,000 inhabitants) should have a high-speed rail service, and that nowhere in France should be more than 100 km from a station served by high-speed services. Spain has set similar objectives: all provincial capitals should be connected to the high-speed network, and 90% of the mainland population should be within 50 km of a high-speed rail station.

Eddington recommended transport investment be targeted at linking key centres where there is a lack of existing transport capacity, in order to encourage economic growth. We discuss the capacity and congestion implications of HSR in Section 3.3. Eddington did not cite the potential benefits of faster journey times, nor the ability to work efficiently onboard trains, however, these are significant additional potential benefits of HSR.

The value placed on travel time by business travellers is well documented[18]. An on-going study for the Department for Transport (DfT) into 'Productive Use of Travel Time' (presented at European Transport

[16] Department of Transport (Downloaded November 2008). Transport Statistics Great Britain: 2008 edition.

http://www.dft.gov.uk/pgr/statistics/datatablespublications/tsgb/2008edition/sectiononemodalcomparisons.pdf.

[17]National Statistics (Downloaded December 2008). National accounts: GDP: expenditure at current market prices.

http://www.statistics.gov.uk/STATBASE/tsdataset.asp?vlnk=208&More=N&All=Y.

Conference, 2008) suggested that most business travellers consider that they can work on board a long-distance train as efficiently as they can in the office. The evidence from journey time elasticities is that business travellers value the journey time savings possible on rail and make mode choice decisions based on the journey time, and that the ability to work on board is then an added benefit.

The greatest volume of business travel (for a single origin/destination) is to/from central London and this must therefore be a prime market for HSR. However, with increasing road congestion in and around other cities, rail is becoming more important as a business travel mode; current rail services between other cities are often much slower and the possibility of improving these through the development of HSR should also be considered.

Eddington also identified transportation to international gateways as important; by implication airports and HS1 stations. However, the principal arguments in favour of a HSR service to Heathrow relate to regional economics and carbon emissions; we therefore consider it further under these headings. A further way that HSR can aid economic growth is through providing additional international connectivity. This could be through interchange at St Pancras with Eurostar services, or potentially by direct services from some regional cities to Paris and/or Brussels.

Implications for design of high-speed rail
High-speed rail needs to provide fast links to London and there is also potential for other city links where HSR can make a significant improvement in journey times
High speed rail should also improve the reliability of journey times between cities, in comparison with both current rail and other modes
High-speed rail services need to be of a quality that allows effective working by business travellers

3.3 Regional and Local Economic Impact of High Speed Rail

It is very difficult to establish the economic impact of a new high-speed rail link, even after the event, as generally a number of different elements will have resulted in the total economic growth of a region or city. We are developing a methodology, in Workstream 3, to quantify the employment impacts and the overall economic impact, based on land use transport interaction modelling.

Evidence from the UK on the development impacts of high speed rail is limited. However, the route for HS1 was specifically chosen to serve Stratford because of its need for development, and both St Pancras and Ebbsfleet are located in sites planned for major development.

International evidence illustrates that HSR has been broadly beneficial to regional economies, although there may be several success indicators, only some of which are easily determined. Local development and the willingness of local regions to pay for a high speed rail service are two important measures. We start by considering this latter point, and then the observed local regeneration benefits, before considering its relevance to the UK situation.

Financial support

To demonstrate the views of regional authorities in other countries, a useful indicator of the benefit they expect is the amount that the local authorities are prepared to pay to support the construction of a high-

[18] Department of Transport (2009). WebTAG. http://www.webtag.org.uk/

speed line. In France there is now a mechanism to allow this to happen, as French regions have a significant level of their own funding. Recent lines have received significant financial support from the French regions, as can be seen in Table 3.1**Error! Reference source not found.** below.

Table 3.1 Financial support by French local authorities for construction of high-speed lines

Route	Percentage paid by local authorities	Amount paid by local authorities
LN3 - Northern line, 1993, Paris-Lille (333 km)	2%	€69M
LN4 – Rhône-Alpes, 1994, Lyon-Valence (104 km)	70% of rolling stock	€97M
LN5 – Med, 2001, Valence-Marseille (250 km)	10%	€20M
East line first phase, 2007, Paris-Baudrecourt (Lorraine) (300 km)	23%	€896M
RR East branch first phase (project), Dijon-Mulhouse (190 km)	29%	€623M
Brittany PDLL (project), Le Mans-Rennes (182 km)	39%	€931M

In 1993-4 French local authorities contributed little or nothing to high-speed line construction. Since then, the proportion of total construction costs which they have been willing to pay has steadily increased, as additional funding has been devolved to the regions. The extent of the current levels of contribution to HSR suggests that the regions are well aware of the potential development benefits. These figures can be considered as a minimum valuation they place on HSR connections; it is likely that some of the contribution from the state (not included) also represents regional benefits.

Local Regeneration Benefits

It would appear that HSR can generate local business benefits, particularly where this is accompanied by a proactive planning policy that has encouraged the development of high-quality business centres in the vicinity of the high-speed rail stations.[19] The transformation of the segment of Lille between Lille Europe (the new high-speed station) and Lille Flandres (the old principal station) is a good example, as is the development of the area around Lyon Part Dieu, the new station for TGV services.

However, local economic impact of a high-speed station can be variable and success depends on a number of parameters, including size and economic dynamism of the city, level of rail service immediate location of the HSR station. In particular, Parkway type station have generally not delivered local regeneration benefits, and have a disadvantage of increasing highway traffic.

Harman[20] identified that the primary focus of HSR business travel was the service sector of the economy, hence a positive effect could be expected here. Cities that have seen positive growth from HSR have been those which either already had, or were taking strong steps to encourage, this sector. The necessary planning infrastructure for success consists of appropriate office developments, hotels, and possibly retail facilities, in a suitable commercial centre.

Lyon, for example, saw office rentals in the Part Dieu sector (near its new TGV station) increase in price and many firms relocating the area. While Lyon was already an affluent city, Lille had traditionally depended on a number of manufacturing industries. It has positively sought to diversify into the service

[19] Although the regional economic benefit must be seen as stretching beyond the immediate vicinity of the station.

[20] Harman, R. (June 2006). High Speed Trains and the Development and Regeneration of Cities. Greengauge 21

sector and has seen extensive redevelopment in the area between the new Lille Europe (TGV) station and the old Lille Flandres station.

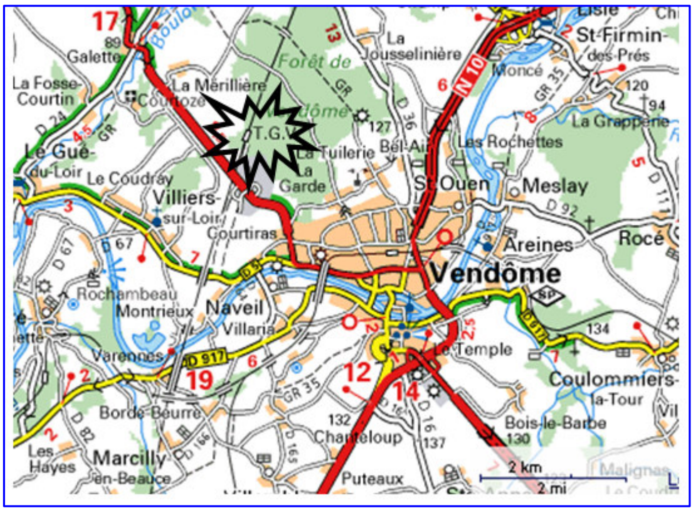
Le Mans, 211 km from Paris, with 195,000 inhabitants (in 1999), a station in the city-centre and a journey time to Paris of 54 min, is another good example. Before building the station, the town put in place a development plan to control and reorganize the surrounding area. Consequently the "NOVAXIS technopole" around Le Mans station is considered a great success, with 74 insurance, IT and communication companies employing 2,800 people in 60,000 m² of commercial floorspace.

Köln, Germany, has similarly redeveloped around a new station opposite the old station on the other side of the Rhine. In Belgium, rather than construct anew, stations at Brussels South, Antwerp and Liège were rebuilt and significant development implemented. Cordoba, Spain, constructed a new station next to the existing station. In Turin, Italy, a major redevelopment of the city centre took place around the new station.

In all the cases where new stations have been built, care was taken to ensure that they were well integrated into the public transport network. This was found to ensure that the benefits of HSR were not exclusive to the immediate location of the station, but were spread throughout the city and indeed region.

Contrary examples, where local development has not been successfully encouraged include the French town of Tours, a similar distance from Paris to Le Mans, and with a population of 300,000, but through a failure to introduce a comprehensive local development plan, along with the TGV station being located outside the city centre, has resulted in a failure to attract development into the area, although passenger numbers on the Tour-Paris route have grown from 1.2 million a year in 1989 to 2.0 million a year in 2002.

Valence station has successfully attracted passengers, but not yet succeeded in its regeneration objectives. Located 495 km from Paris on the Paris-Marseille TGV line, Valence TGV station (16 km from Valence), carries 1.8 million passengers per year. It has a shuttle-bus service to the city centre (less than 20 minutes - but 60% of passengers use their own car to travel to the station). 70,000 inhabitants live in the city and most passengers are commuters going to Lyon. This station is now considered as the *de facto* Lyon-South station. The 160 ha commercial park of Rovaltain, close to Valence TGV station, provides 500 jobs, these figures are growing, but this development is slow.



In some cases in France, stations have been constructed in rural areas, as Parkway stations (sometimes fairly close to cities, as in the case of Avignon and Aix-en-Provence), in other case in rural environments such as Haute Picardie. These stations have been much less successful in attracting economic development to their regions than those in city centres. Nonetheless, stations in rural environments encourage workers to remain in these areas - workers who contribute to the local economy.

Figure 3.2: Location of Vendôme station

Vendôme TGV station is located 161 km from Paris on the Bordeaux route of the Atlantic LGV. This is one of two (with le Creusot) very small French cities served by the high-speed rail network. 11 daily TGV trains run to and from Paris (42' journey time). Regular bus shuttles offer connections between the high-speed rail station and the city centre. Despite creation of a 159 ha technology park close to the station, the take-up has been slow and only 8 ha are currently in use. Being served by HSR has not been enough to improve the economy of this region, but it has reduced the employment migration to larger neighbouring cities. The station's arrival has altered travel patterns and that weekly trips are replaced by daily commuting in many cases.

The French government requires post-implementation evaluations of major infrastructure projects. These are called LOTI (La Loi d'Orientation sur le Transport Intérieur). They include the economic impacts of the projects, but generally do not manage to quantify these (see for example that for the LGV Méditerranée[21]). Its conclusions (page 37) based on surveys of policy makers, are that the local regional development and the HSR were complementary in generating the economic development. The greatest benefits accrued when there were both strong local/regional planning policy and the HSR gave significant improvements to the rail service, especially to Paris.

We conclude this consideration of the impact of high speed rail on various locations with a summary indicating the strength of impact on the region and the associated characteristics of the city served and the location of its station.

Table 3.2 Summary of effects of HSR on local European economies

City	TGV Serves City Centre	Impact on Local Economy	Comment
Lyon	Yes, new station	Reinforced an already strong service sector	Strong growth around new station which resulted from a focused development programme
Lille	Yes, new station	Helped to develop a new service sector in the economy	Major redevelopment of the area between the new and old stations
Le Mans	Yes, renovated station	Encouraged growth in economy particularly in area around station	Also led to increase in commuting to Paris, but not at the expense of local economy
Köln	Yes, new station	Led to economic growth in service orientated sector	Extended the city centre
Brussels	Yes	Encouraged growth in economy particularly in area around station	Already the capital city and also EU main city
Antwerp Liège	Yes	Encouraged growth in economy particularly in area around station	
Cordoba	Yes, new station next to old	Helped to develop a new service sector in the	Assisted in refocusing economy on service sector

[21] http://www2.equipement.gouv.fr/rapports/themes_rapports/transport/2001-0183/sommaire.htm

		economy	
Turin	Yes, new station	Encouraged growth in economy	Major reorganisation of city centre
Tours	Yes at edge of city	Little economic impact	No active plan for development
Avignon Aix-en-Province Vendome Valence	Outside city	Little economic impact	Development planned but was not successful
Haute Picardie	Rural	Residential economic impact	Inward development planned but not successful

Access to airports

The stakeholder consultation undertaken by BDB highlighted access to Heathrow as of importance to many regions, both as a driver of economic prosperity and to reduce the carbon emissions associated with domestic air travel.

International evidence illustrates that airports can successfully be served by high-speed rail services and other long-distance trains in order to increase airlines' passenger catchment areas. Examples include Paris (Charles de Gaulle), Frankfurt, Amsterdam (Schiphol) and Copenhagen. Figure 3.3 illustrates the wide range of services and their journey times for high-speed rail services that directly connect French regional capitals with Paris (Charles de Gaulle) airport. These direct services are part of the inter-regional services developed by SNCF and are in addition to those services running to the central Paris rail stations.

Figure 3.3 – TGV services available from Paris CDG Airport

Without a direct service to LHR, it is unlikely that HSR would significantly reduce the number of UK domestic flights, since a high percentage of travellers on these flights are actually interlining[22] at Heathrow (DaSTS states that 67% of passengers on Manchester – LHR flights are interlining); evidence from BAA is that this has now increased to 74%.

The case for services to Heathrow is built around its very wide catchment area and its predominant use for business travel. 16% of Heathrow traffic comes from the catchment area of HSR (ie places at least about 100 km from Heathrow); this is a total of 6.9m trips in 2007/8. This compares to 11% at Stansted (2.3m trips) and 12% at Manchester (1.7m trips), although if Yorkshire and Humberside is included within the Manchester Airport catchment area, this increases to 31% (4.1m trips); 36% of Heathrow

[22] Interlining: Catching onward interconnecting flights.

traffic is for business, compared to 19% at Stansted and 20% at Manchester[23]. Hence, no other airport is similar in terms of the potential demand for HSR and its economic impact. The case for serving airports other than Heathrow will be weaker due to both their smaller throughputs and their smaller catchment areas, with Manchester and Stansted being the most likely candidates. It is worth noting that when secondary airports have been served in Europe (such as Lyon), the use of HSR as an access mode to air has been minimal.

To capture the interline market, it will be important that HSR is fully integrated into the airline product through easy interchange, integrated ticketing and effective joint marketing. This is the case today on a few routes, for example Air France sells Paris CDG to Brussels by TGV as if it were an air service.

Overall there appears to be a case for serving Heathrow, and this will strengthen if the airport expands.

UK Discussion and Comparison

The opportunity exists for the UK to learn from the international experience. The key points above are:

- that the cities served should be of reasonable size;
- regional economic benefits are only achieved when the station is located in or close to the city centre and well connected;
- if the station is on the edge of the city centre, then particular attention should be given to regeneration plans for its immediate neighbourhood;
- in all cases, development plans should be made which focus on the needs of the service sector in the vicinity of the station.

There is some concern that high speed rail might draw economic activity away from the region and its city towards London, with increased commuting. Evidence from the UK suggests this phenomenon does not necessarily lead to weaker cities; it is quite possible for certain UK cities to have a considerable number of commuters to London yet maintain a thriving local economy, especially one based on specific areas of expertise. Good examples of this are Reading, with its strong IT-based economy and Cambridge with its research/ innovation based economy. Both are within 45 minutes of London by train and also have good motorway connections.

On the contrary, Boddy *et al*[24] found that a significant reason for lower regional productivity was travel time (not distance) from London. Reducing journey times could potentially spread the positive effects of agglomeration focussed on London.

We are including an assessment of the economic impact, and specifically that on employment, within our business case model. In addition, Greengauge 21 is commissioning research from an expert in transport land use and development into what measures need to be put in place to ensure that regional economic benefits are achieved.

Achieving regional economic benefits

The greatest volume of business travel (for a single origin/destination) is to/from central London and this must therefore be a prime market for HSR. The regional economic benefits are achieved through the much improved accessibility to this prime market, which encourages businesses (particularly those in the service sector) to locate in these accessible regions. Journey time is the principle measure of this accessibility.

There are a number of thresholds in journey times, with 3 or 3.5 hours seen as being competitive with air, 2 hours allowing easy day trips, and 1 hour allowing easy half day trips.

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[23] Civil Aviation Authority (CAA)(2007). CAA Passenger Survey Report. http://www.caa.co.uk/docs/81/2007CAAPaxSurveyReport.pdf

[24] Boddy. M, Hudson. J, Plumridge. A, Webber. J (2005). Regional Productivity Differentials: Explaining the Gap. University of the West of England, Department of Economics.

However, with increasing road congestion in other cities, rail is becoming more important as a business travel mode to /from cities other than London; current rail services between other cities are often much slower and the possibility of improving these in the context of HSR should be addressed.

Alongside the desire for fast access to London (and other cities), there is also a need for increasing transport capacity in the regions, particularly for commuting to key or central business areas. This has been expressed as an important objective in the stakeholder consultations and will be an important consideration when specific corridors are studied in Workstream 4.

Current population forecasts (from TEMPRO) are for London and the South-East to grow by 22% to 2035, faster than the rest of the country (more detail on growth by region is provided in section 4.4). This will cause increasing strain on housing stock and other essential facilities including transport capacity. A policy that effectively enlarges the catchment area of London's economy would allow some of this growth to be achieved outside London and the South-East.

A further government objective for transport is to support a sustainable future. Encouraging development in city centres, best served by public transport can support this objective. High-speed rail can be a strong catalyst in strengthening city centres as previously observed, contrasting with highway construction which tends to disperse development.

Implications for design of high-speed rail
Proactive planning policies and consideration of the local economic dynamic are important to attain the regional regeneration benefits of HSR
Journey time targets are around 3 hours (preferably less) from Edinburgh and Glasgow to London to give effective competition with air; less than 2 hours from the North West, Yorkshire and if possible Newcastle to allow easy day trips to London; less than 1 hour from Birmingham to make half day trips realistic
Journey time and service frequency are factors, but not the only considerations in terms of regional development
City centre stations are needed to support a policy of sustainable development and to minimise journey times for most travellers
Out-of-town stations may be worthwhile for accessibility reasons (for those with a car), but they are unlikely to assist regional development; any such proposals will need careful evaluation in terms of the impact on overall car trips, and where possible they should also provide public transport accessibility as well as car

3.4 Congestion Relief and Capacity Enhancement Objectives

Introduction

The UK already has congested networks on all modes of transport, both urban and inter-urban. In many cases these are more congested than those of other European countries. Figure 3.4 illustrates that the UK has a relatively modest motorway network in relation to the amount of national car traffic when compared to most other European countries. We recognise this may not be a very good indicator of congestion, but alternatives are not available for international comparison; it supports the argument that congestion may be considered generally higher in the UK.

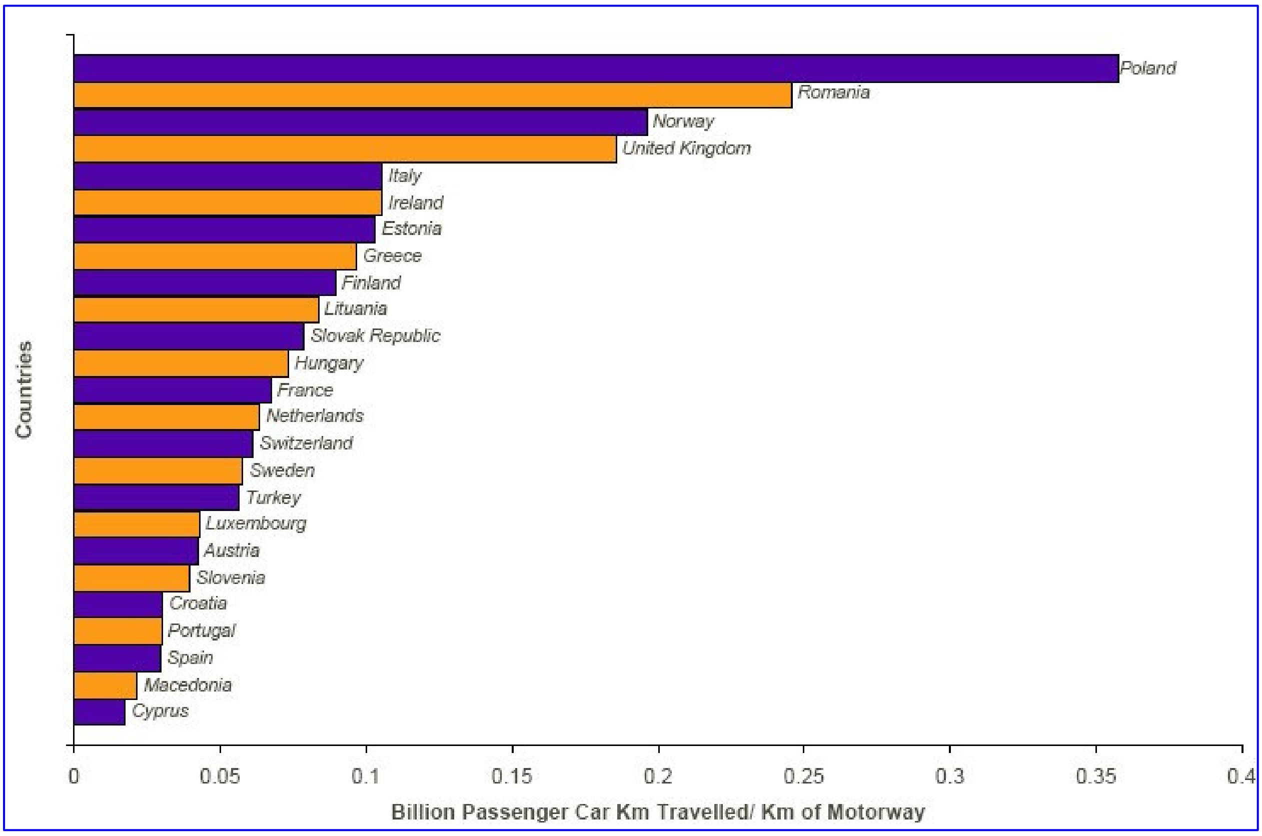

Figure 3.4 Distance Travelled v Total Motorway Length in European Countries[25]

The UK is also forecasting substantial population growth (more than 10 million by 2035[26]), which will inevitably increase transport congestion, unless there is a substantial change in either travel behaviour or provision of infrastructure. Figure 3.5 shows current level of congestion on the strategic rail network, and Figure 3.6 that forecast in 2025 on the road network. While the current recession may mean immediate growth is reduced, it is likely to delay future congestion rather than prevent it.

[25] European Commission Directorate General for Energy (2008). EU Energy and Transport in Figures 2007/08. http://ec.europa.eu/dgs/energy_transport/figures/pocketbook/doc/2007/2007_pocketbook_all_en.pdf

[26] using data from TEMPRO 5.1, version 54 (15/02/08)P/A, date as specified on Tempro website: 01 July 2008

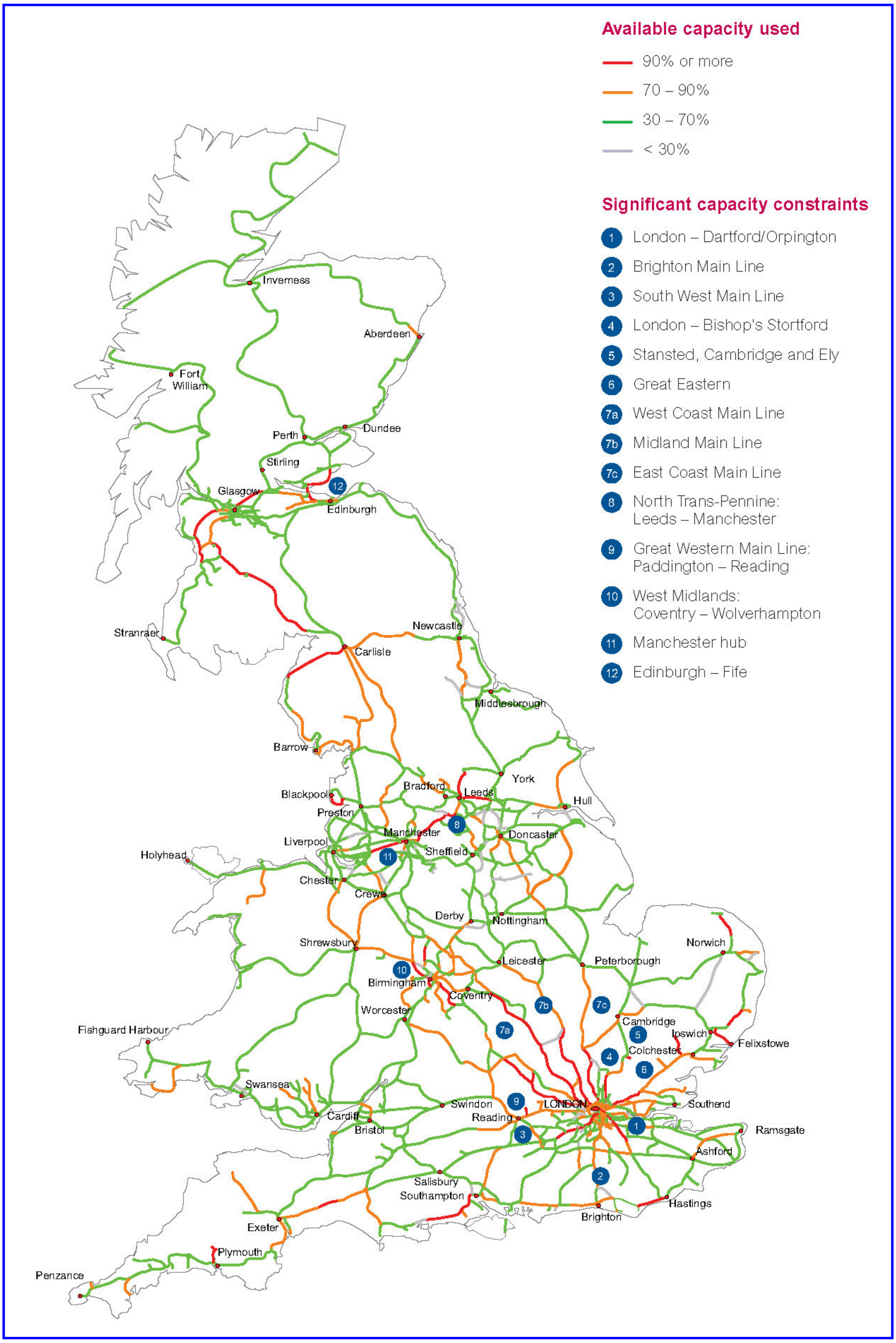

Figure 3.5 Track Congestion on the Strategic Rail Network[27]

[27] Network Rail (2007). Business Plan 2007. http://www.networkrail.co.uk/aspx/3085.aspx

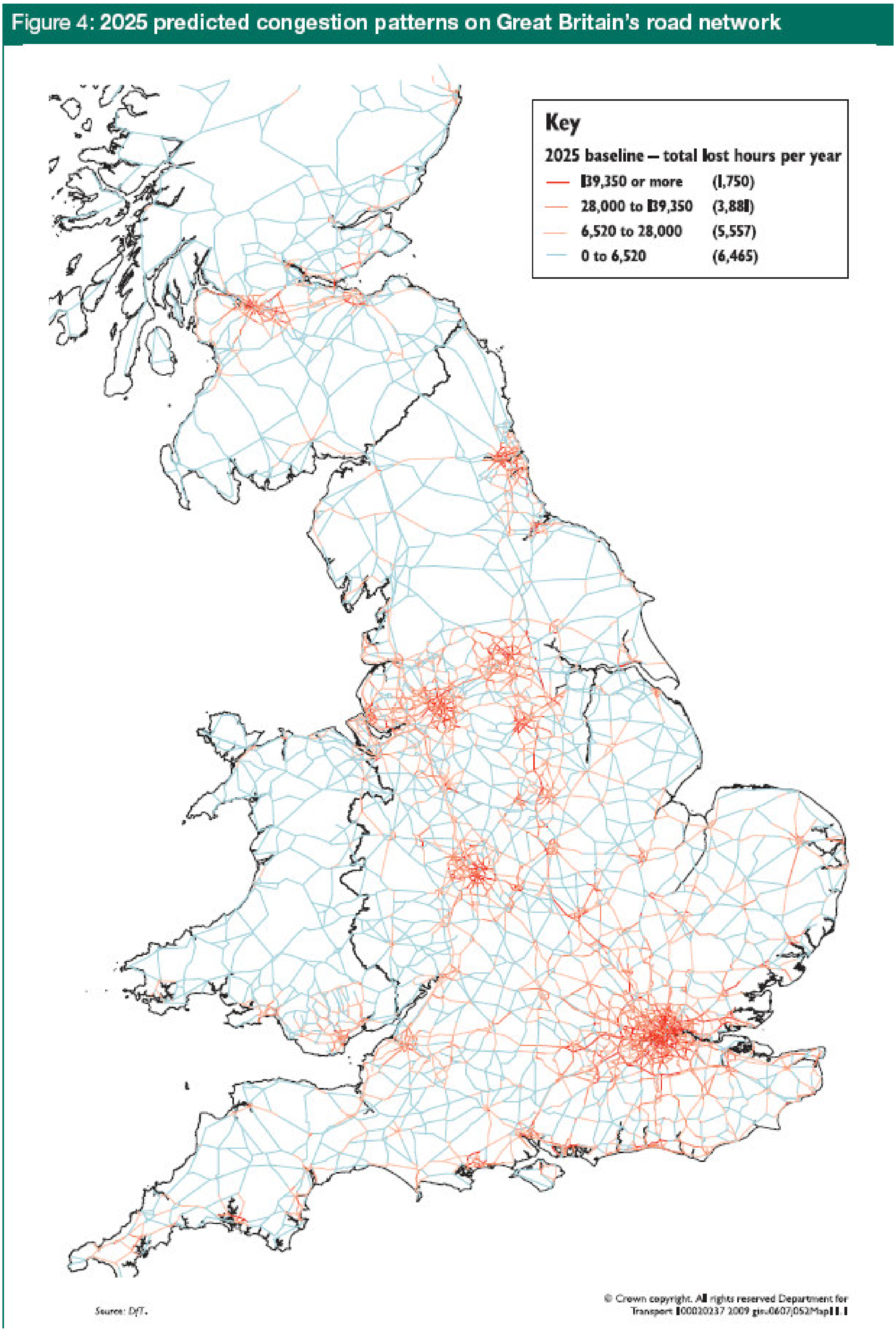

Figure 3.6 Congestion on the Strategic Highways[28]

[28] Department for Transport (July 2008), Roads: Delivering Choice and Reliability.

http://www.dft.gov.uk/press/speechesstatements/statements/wmsroadsdeliveringchoice

The rail congestion statistics presented above relate to trains on sections of track; these need to be supplemented by the extent of excess loading on trains (high load factors). Eddington provides forecasts of crowding on trains arriving London[29]. Forecasts for 2026 show significant overcrowding with 15% of long distance demand being suppressed in the peak in the reference case (suppression on LSE outer suburban services is 11% and on inner suburban services 7%). Only a modest amount of this suppression is likely to transfer to other periods of the day.

It can be seen that rail track congestion is greater on the lines north out of London, the Transpennine corridor between Manchester and Leeds, and in the commuting areas around London, Birmingham, Manchester, Leeds and Edinburgh. Other capacity constrained corridors are where there is only single track, or (more relevant to this study) where freight and passenger flows interact (eg sections of both the East and West Coast Main Lines).

Freight Congestion

While much of the congestion related to passenger services is in specific locations in conurbations, for freight the issue is more difficult, because routes are generally longer and more diverse. Figure 3.5, taken from Network Rail's Freight Route Utilisation Strategy (RUS), shows the capacity gaps predicted to occur by 2015. While HSR may address capacity issues on the West and East Coast Main Lines, which may have a positive impact on freight, other strategies will need to be implemented to improve freight access to ports such as Felixstowe and Southampton. As Keith Heller (CEO of English Welsh and Scottish Railway) pointed out in the Robert Reid lecture (6 February 2008) the routes into and around London are particularly constrained with demand for commuter services conflicting with freight and creating a major bottleneck between the Thames ports and the rest of the UK.

[29] Eddington, R. (December 2008). The Eddington Transport Study. Table 4.5. http://www.dft.gov.uk/about/strategy/transportstrategy/eddingtonstudy.

Figure 3.7 Key Capacity Gaps in the UK Rail Network for Freight

Highway Congestion

For the strategic road network, congestion is again at its greatest around London (including the M25), and again on the Transpennine corridor (M62), the M6 from the West Midlands to the North West, and around the conurbations of Birmingham, Manchester, Sheffield and Leeds.

Highway congestion is expected to increase substantially; compared to 2003, congestion (measured as lost time/km) is expected to increase by only 1% by 2010, but 17% by 2015 and 37% by 2025. Average vehicle speeds are expected to fall by 3% by 2015 and 5% by 2025[30]. The congestion increases and vehicle speed reductions are greatest in London and other large urban areas, demonstrating the need to provide additional transport capacity in these areas.

Options for reducing highway congestion are limited. Eddington strongly supported the principle of road-user charging, but this is politically less likely to occur in the near term than was thought when his report was published.[31]

Highway construction to deliver significant reductions in congestion would have to be on a massive scale, bearing in mind that much of the additional capacity would be taken up by the release of previously suppressed traffic.

Proposals for hard-shoulder running and managed flow are likely to increase capacity and reduce congestions in certain areas, though there is evidence that where additional road capacity is provided, it transfers congestion to other locations or is readily filled with newly generated traffic.

Air capacity enhancement

Looking to other modes: air capacity could be increased, but there is currently no consensus support for additional runway capacity in the South-East; the classic rail network could be expanded; a new high-speed rail network could be constructed; new freight railway lines could be built; lifestyle changes to reduce the need for travel could be encouraged.

High-Speed Rail and Capacity Enhancement

Rail has the capacity to transport more passengers than it does today, through the enhancement of signalling systems and increasing capacity or length of rolling-stock, but it is also the case that railways can operate more trains per hour if they run are at similar speeds, rather than differing speeds. Increased rail capacity can reduce crowding and have an economic value which needs to be taken into account in the appraisal of HSR.

A high-speed rail line can remove faster trains from the operating timetable, assuming additional capacity is provided at terminals and their access routes, and assuming the high-speed network results in less demand for classic long-distance trains, so capacity released on the classic network can be used for a combination of local passenger and freight services, according to need. By aligning services of broadly similar average speeds, an increase in the number of train paths can be achieved, providing relief to capacity problems on the classic networks.

As access to the network is modified, managed changes in capacity can be achieved in response to passenger demand, through increasing the number and frequency of local services. The study will seek to place an economic value on the reduction in crowding in London and other cities that will result from the opportunity to operate additional local services; it will also place a value on the opportunity to run additional freight services.

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[30] Department for Transport (December 2008). Road Transport Forecasts 2008.

http://www.dft.gov.uk/pgr/economics/ntm/roadtransportforcasts08/

[31] November 2008 vote in Manchester against and London mayoral objections to extension of London scheme

The introduction of compulsory reservation systems (which is normal on high speed rail in France, though not in Germany) has an interesting consequence. It acts to predict and manage passenger journeys, and safeguard quality (where customers require flexibility, free changes of departure time are permitted). By comparison with open systems, this allows management of higher load factors and safeguards passenger quality.

In addition, high-speed rail can be designed to abstract from both air and car, releasing valuable runway slots at airports, and also releasing capacity on the strategic road network. These two points are discussed further in future chapters.

Notably, in order to perform its task and fulfil its position in the transport chain, including abstracting from other modes, HSR needs to perform a role as a product, focused on specific customer needs, and in particular providing an on-board environment that allows people to make good use of the time. Modern trains typically provide electric sockets, wifi access, tables, luggage space, spacious serviced terminals, easy access by public transport, and car parking at out-of town stations as appropriate.

Hence, capacity can be generated in the rail mode, where there is technologically potential to do so, without reduction in passenger safety and without compromising environmental targets.

Implications for design of high-speed rail

The high-speed network should be designed to increase overall capacity of the rail network by releasing capacity where it is needed on the classic network for slower services, especially providing additional local passenger services in the key conurbations; to be effective at substituting for current Intercity services, HSR will need to serve the same main city pairs

Operating methods, such as seat reservations can be effective to maximise capacity benefit; low prices at off-peak times can encourage people who have flexibility to travel when space is available, thus making best use of the available capacity

Where the high-speed network also needs to create capacity for freight services, this will need to be integrated with other plans to ensure that freight can access its key destinations.

The high speed rail network should seek to increase overall transport capacity where it is needed, and not just that of the rail network

3.5 Climate Change and Energy Security Objectives

Introduction

The objective of carbon emission reduction has been clearly identified by the UK Government and carried forward into primary legislation in the Climate Change Act.

Recently updated Delivering a Sustainable Railway[32] data is shown in Figure 3.6. This illustrates the relative consumption of carbon dioxide per passenger kilometre, after taking into consideration the prevalent load factors for the different modes of transport:

- Urban bus load factor – 20%
- Inter-city coach load factor – 60%
- Inter-city train load factor – 40%
- Domestic airline load factor – 70%
- Car load factor – 30%

Furthermore road, air and diesel-powered rail vehicle factors have been adjusted to account for refinery losses and electric-powered vehicles take account of grid losses. The aviation figures also include a factor for radiative forcing (due to the nature of the emissions).

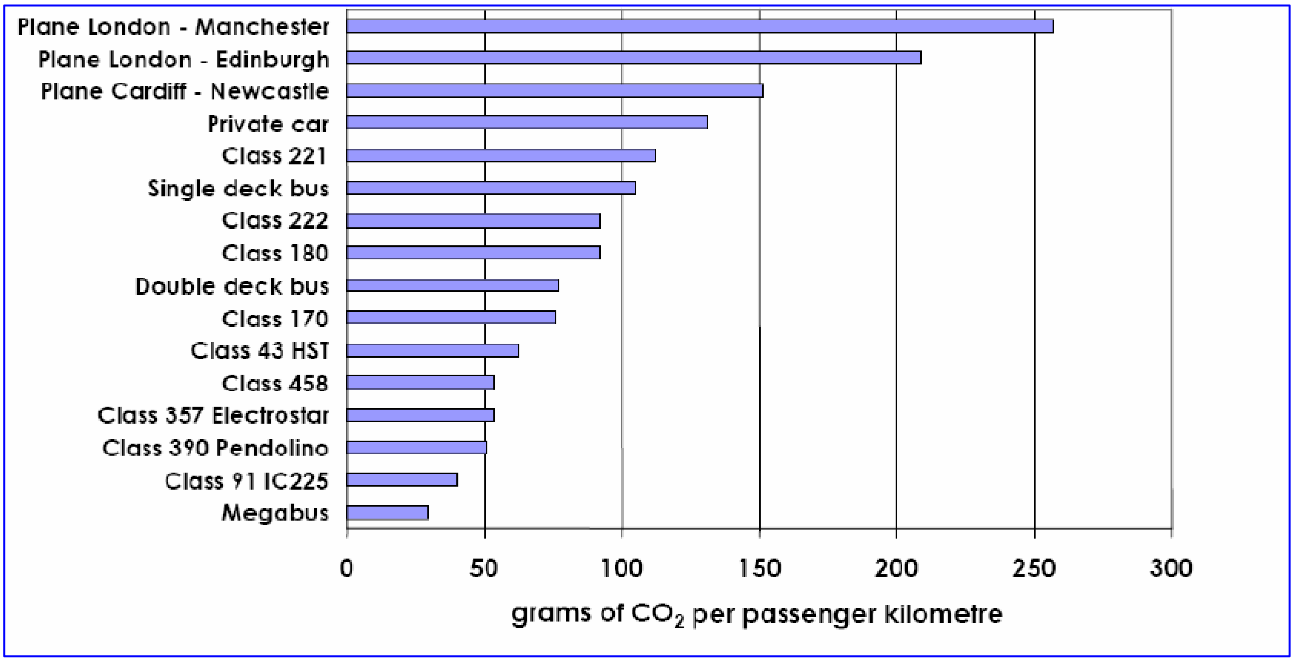

Figure 3.8 Carbon Costs of Different UK Transport Modes[33]

The Association of Train Operating Companies (ATOC) is undertaking a research exercise into current and future energy use and carbon emissions from the different modes of transport. Our conclusions below are based on a preliminary draft of ATOC's document.

[32] Department for Transport (July 2007). Delivering a Sustainable Railway – White Paper CM7176, http://www.dft.gov.uk/about/strategy/whitepapers/whitepapercm7176/

[33] Department for Transport (Downloaded on 16/12/08). http://www.dft.gov.uk/162259/187604/263473/relativecarbonperform.pdf

Future Air Impact

Air is currently the most expensive mode in terms of carbon emissions. Whilst some efficiency can be expected regarding the carbon emissions of future aircraft designs, including increase in their capacity and load factors, this is likely to represent only a relatively modest reduction, less than the 80% reduction proposed by government. Growth in air demand will make this target harder to achieve. Increased mobility predicated on an increase in the modal share of air, is very unlikely to be consistent with the government's carbon emission reduction objectives.

As will be illustrated in future chapters, high-speed rail can be designed to abstract from short-distance air between cities; it is mainly traffic on domestic flights that is a target market for HSR, but there may also be some potential on flows such as Birmingham/Manchester to Paris/Brussels. The more challenging design task is to attract travellers from short-haul flights that connect into long-haul flights (interlining passengers). To achieve this, the rail service needs to be as easy and attractive to use as air. In the UK this implies, at a minimum, direct rail services to be provided to Heathrow (the principal UK airport where such interlining occur).

HSR in the UK could also be designed to be an attractive transport solution to and from continental European cities, with services such as Birmingham to Paris. A direct service via HS1 would increase attractiveness and hence abstraction.

Future Car Impact

In the future, cars are likely to become lower emitters of carbon than they are today. Hybrid vehicles are commonplace and the electric car may become the principal private mode of the future; the King Review[34] of low carbon cars indicated that by 2050 petrol/ diesel cars could be almost non-existent. However, the cost of electricity for private cars is likely to be significantly greater per kilometre than the current cost of petrol, even when taxation is taken into account[35]. This is because electricity is currently more expensive than petrol for equivalent performance (were it not, most cars would now be electric), and all fuel prices can be expected to increase significantly in the future. Thus although carbon reduction could be achieved, it is at the expense of a substantially increased cost of motoring. Furthermore, the range of such cars is currently much less than petrol/diesel and they take much longer to refuel (re-charge). This implies they may be less suitable as a substitute for long-distance travel, but we could envisage a future where electric cars replace petrol vehicles for local and mid-distance journeys, whilst rail takes a larger proportion of long-distance travel; high-speed rail would clearly help to facilitate this.

Future Rail Impact

Carbon emissions from rail depend critically on three elements: speed; load factor and carbon content of electricity used for traction, where rail services are electric (as is the case for all HSR services throughout the world).

[34] King,J. (2007). The King Review of Low Carbon Cars. http://www.hm-treasury.gov.uk/king_review_index.htm

[35] King,J. (2007). The King Review of Low Carbon Cars. http://www.hm-treasury.gov.uk/king_review_index.htm

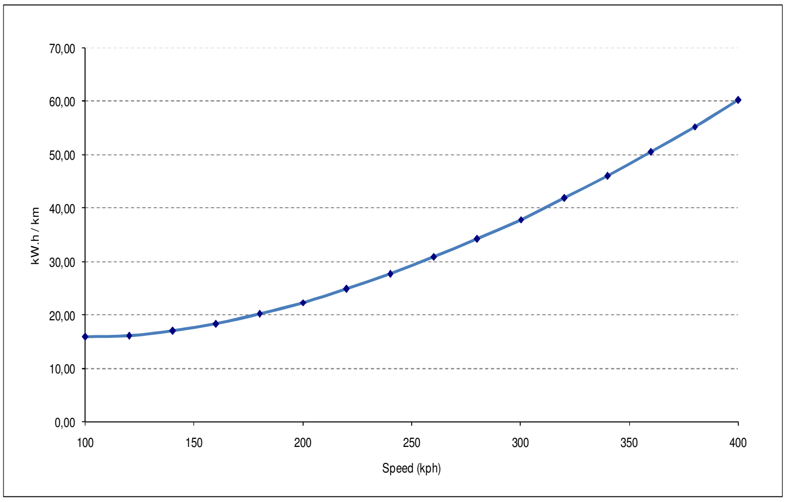

Figure 3.9 Power Consumption of TGV Duplex (Multiple Units)[36]

Whilst electrified rail transport can be thought of as a low-carbon mode, it needs to be recognised that the degree of energy consumption per train, and hence emissions is affected by operating speed. Figure 3.9. shows the power consumption of the most commonly used French high-speed train, Alstom's TGV Duplex. The forthcoming Alstom AGV, is lighter and has distributed power units; it is anticipated to be approximately 15% more energy efficient[37] than the TGV which has power cars at both ends of the train.

Whilst the quoted load factor of 40% for intercity rail may be correct today, this is expected to increase substantially in the future (without HSR), as demand growth rates are about 3% pa and there is only limited ability to increase the number of trains operated. Many high-speed rail services operate at much higher load factors; for example, 70% average load factors are typical on French TGV services; TGV Est from Paris to Strasbourg was achieving 75% average load factors within three months of starting service. The high load factor is much easier to achieve with limited stop services such as HSR, and can also be managed through the use of controlled seat reservation systems which are appropriate to such services.

As shown in Figure 3.8 for the Class 390 Pendolino (used by Virgin Trains on the West Coast Main Line) and the Class 91 IC225 (used on the East Coast Main Line), carbon dioxide emissions are low relative to other modes, but rail with electric traction can benefit from any future de-carbonisation of UK electricity generation.

As has already been mentioned in Section 2.1, it is a government objective to reduce carbon emissions by 80% by 2050. Other objectives (as defined by the DfT's WebTAG website) include a desire to reduce all greenhouse gases, reduce noise pollution and to protect and enhance the land as well as improving local air quality.

Whilst the DfT acknowledges (Delivering a Sustainable Railway, July 2007, para 11.7) that the rail sector, along with all modes of transport, needs to reduce its carbon footprint, it also states that rail's most significant contribution to cutting carbon emissions will be to provide increased carrying capacity, thereby providing a facility for modal shift from other, more polluting forms of transport such as air and road.

In summary, whilst faster high-speed rail consumes more electricity per seat km than classic rail on a like-for-like basis, it can be expected to achieve higher load factors off-setting this, and the significant reduction in journey times that it offers is expected to abstract traffic from air and car (this will be

[36] Systra technical department

[37] Alstom (downloaded 15/12/08), AGV: Performance and Modularity.
http://www.transport.alstom.com/home/elibrary/technical/products/32033.EN.php?languageId=EN&dir=/home/elibrary/technical/products.

discussed further in Section 4). Depending on the extent to which this occurs it can both reduce carbon emissions and alleviate congestion on other modes. If designed to increase overall capacity, it will also lead to reduced congestion on classic rail, leaving space for more freight and local passenger traffic, and a further reduction in road passenger and freight traffic. The overall impact of HSR on carbon emissions will be quantified in Workstream 4.

An objective of high speed rail is therefore to be a cost effective way of increasing transport capacity and simultaneously reducing carbon emissions.

Implications for design of high-speed rail
To reduce carbon emissions, high-speed rail needs to be designed with high energy efficiency, high load factors, and to maximise abstraction from both air and car
A direct service to Heathrow will be important for air abstraction
Direct services between some UK cities and near-continental destinations should be considered, implying the need for a connection to HS1

3.6 Safety, Health and Security Objectives

HSR offers a very safe mode of travel. Accidents are very rare on HSR (Japan has been operating for forty years without a single fatality) and the mode of travel is likely to create less stress than air or car. Where accessed by public transport, walk or cycle, rail can make a contribution to a healthier lifestyle.

Although the potential for security-related incidents exists on all forms of public transport, typical staffing levels on high-speed trains and at stations, driven by service quality objectives, mitigate (at least to some extent) against security risks, certainly from personal crime and potentially from terrorism.

3.7 Quality of Life and Natural Environmental Objectives

Quality of life and natural environment benefits of transport infrastructure investment schemes need to be considered from the perspective of those using the transport mode and those affected by it.

The quality of life benefit for HSR travellers should be assessed relative to other forms of travel and wider impact, such as consequential congestion reduction can also be assessed. Quality of rail travellers' time is potentially high while on board HSR, serving business and leisure travellers well. Quality of provision at stations is also an important consideration, with accessibility by walk, cycle and public transport being important elements.

For HSR to be a success, and to meet these objectives, it has to offer wider benefits, to those with access to its services and to those who do not benefit from it directly. Consideration of others must include assessment of the environmental impact of HSR on other modes. The congestion reduction impact of HSR is an important consideration in this case.

Other negative environmental impacts, include noise, land-take, disruption to other transport systems, construction disruption.

Noise effects tend to be relatively localised – whether proximity is to a motorway, rail line or airport. Linear land-based transport noise has a high impact for a short time, compared with air travel which typically affects larger areas for longer periods. Rail line development in the UK has been successfully achieved by using existing transport corridors where possible.

Land-take from new infrastructure development is inevitable, but, as with noise, intrusion can be minimised by building alongside existing transport corridors (Section 5 explores this in further detail). Relatively to rail, high-speed rail can be more readily by accommodated alongside motorways, as illustrated in the photograph of adjacent developments in Germany, below.

Figure 3.10 Aerial View of Motorway and High-Speed Line (Cologne – Frankfurt)

Land-take for HSR is less than that of a new road with similar carrying capacity, using design standards and published passenger-carrying statistics. For the sake of comparability, we consider a road designed solely for cars rather than assuming HGVs also use the road. Assuming a 2-lane dual carriage motorway carries 2,300 cars per lane[38] with an average vehicle loading of 1.58 passengers[39], the carrying capacity per hour is less than that of a high-speed rail line carrying 15 trains per hour in each direction, assuming 800-seat capacity trains with a load factor of 70%[40].

Once the relative passenger-carrying capacity and land-take of road and rail are compared, it can be seen that high-speed rail is a much more efficient use of land for passenger movement, typically about twice as efficient. A part of motorway capacity is, in reality, used by lorries, but this has been omitted from the table for simplicity.

[38] Highways Agency (Feb 2009) Design Manual for Roads and Bridges (DMRB). Volume 5, section 1, Pp D1 & D2.

http://www.standardsforhighways.co.uk/dmrb/index.htm

[39] Department of Transport (2008). Transport Trends: Current Edition. Section 1, Page 10, 2007.

http://www.dft.gov.uk/pgr/statistics/datatablespublications/trends/current/

[40]Which is currently observed on most HSR trains serving Paris.

Table 3.3 Comparative Land-Take and Capacity - Road and Rail

Mode	Design Capacity per hour (Both directions)	Load Factor	Realised Passenger Capacity per hour	Minimum Construction Width	Passengers per metre land take	Relative land take per person
2-lane Motorway	9,200 PCUs*	1.58 people per car	(9,200 x 1.58) = 14,536 pass	28.7m[41]	(14,563 ÷ 28.7) = 507	207%
3-lane Motorway	13,800 PCUs	1.58 people per car	(13,800 x 1.58) = 21,804 pass	36.1m[9]	(21,804 ÷ 36.1) = 604	174%
HSR	30 x 800-seat train set[42]	70% occupancy	(30 x 800 x 70%) = 16,800 pass	16m	(16,800 ÷ 16) = 1050	100%

*PCU = Passenger Car Unit. 1 PCU equals an average car or taxi; for the sake of comparability we exclude use by HGVs or other vehicles, which would reduce space for private cars

Due consideration must be made of all development considerations. This is a subject addressed more fully in Section 5.

The carbon cost of construction should also be taken into account when weighing the overall environmental benefits of a transport scheme. This has been estimated as likely to be approximately 10% of the total gCO_2 per passenger kilometre for a 2-track HSR from London Heathrow to Edinburgh, assuming a 40-year CO_2 payback time[43]. Whilst construction techniques are evolving to minimise this impact, it is an area that will need to be quantified and compared to alternatives in the overall business case.

Implications for design of high speed rail

City centre stations must have good public transport or walk/cycle access to a wide range of destinations within the city

High speed rail is a more efficient user of capacity than car, but use of existing transport corridors should be maximised to keep environmental impacts to a minimum

[41] Highways Agency (Feb 2009) Design Manual for Roads and Bridges (DMRB). vol6, Section 1, page 4/10. http://www.standardsforhighways.co.uk/dmrb/index.htm

[42] 800 passengers is typical eurostar capacity. 15 trains per hour - see chapter 5.

[43] Hill, N (AEA)(October 2008). The Relative Environmental Performance of High Speed Rail and Short Haul Air Transport. Presentation.

3.8 Equality of Opportunity Objectives

To meet the Government objectives[44] equality of opportunity should be considered in relation to high-speed rail provision and accessibility, which can be considered in many ways, but is defined in this context to include geographical, physical and financial accessibility. One element of equality of opportunity is to provide accessibility to HSR across the regions. Other countries have quantified this objective, for example, France has stipulated that all significant centres of population (>100,000 inhabitants) should be served by a high-speed line, and that nowhere in France should be more than 100 km from a station connected with a high-speed line; Spain has set similar objectives: all provincial capitals of the country should be connected to the high-speed network, and 90% of the peninsular population should be within 50 km of a high-speed station. In the UK context, if substantial public funds contribute to the construction of a HSR network, then there may be an expectation that all regions will benefit from the investment; this might be as a result of an improved local rail service as HSR releases capacity on the classic network.

For those living within easy access of city centres, public transport and walk will probably be the most frequent mode used to access a rail station, although taxis are also common. For those who live outside cities, car access to railheads is often used for long-distance journeys, and parkway stations close to the strategic road network and with sufficient secure parking might be considered. Ebbsfleet on HS1 appears to be successful in attracting substantial demand.

However, serving parkway stations en route between city centre stations increases journey time for through passengers by about 9 or 10 minutes (average timetable delay time, including braking and acceleration), depending on the design of the station. The consequent risk of passengers switching to other transportation modes and the inefficiency of infrastructure and fleet utilisation mean that stopping patterns are a key design factor in HSR service provision.

The diffuse nature and size of London particularly requires close attention to station locations. Central London termini have largest catchment areas, but overall journey time is a key factor in mode choice and journey times to Central London can be significant (an hour or more). It will be considered important in Workstreams 3 and 4 to include in the demand model and subsequently identify station locations to achieve the best compromise between these requirements.

In Paris (which is geographically much smaller than London), there are stations at Massy on the line TGV Atlantique and at both Paris (Charles de Gaulle) Airport and Marne La Vallée on the Paris 'bypass' line. The latter two have the advantage of not slowing the principal train flow from Paris to the north or south. (Figure 3.3); they are also destinations in their own right as well as serving a car based access market.

Geographical accessibility also means locations have to be identified that do not have a consequential impact on other transport users, by building congestion in local areas, or by encouraging adverse road travel impact to reach stations.

Physical accessibility clearly includes accessibility for disabled people; it also includes access for a growing population of elderly passengers who prefer the personal safety, comfort and independence that can be achieved through rail travel that cannot be achieved on long–distance car journeys. All such elements of social change including physical size and mobility need to be taken into account in the design standards of trains, stations and their access routes, both to comply with emerging regulations and to maximise demand potential.

[44] TaSTS objectives

Rail, and HSR in particular, can meet financial accessibility objectives if fares and services are at reasonable prices, using off-peak capacity, for example. The British rail fares system is mature and complex, offering a wide range of fares to suit all market segments. While fully-flexible fares are expensive by international comparison, the cheapest Advance fares are very cheap for those prepared to book well in advance on off-peak trains. Railcards have an established place in the British fare structure and appeal to available to young and old sectors of the market.

High-speed rail facilitates longer-distance daily commuting, increasing employment mobility. This is not always considered a transport benefit, but if achieved using carbon-efficient modes assists in achieving accessibility targets and regional development pressures on housing and services.

Implications for design of high-speed rail
Physical access to high-speed rail stations is important and needs to be addressed in the operational design as well as the identification of intermediate and terminal stations
Access from the station platform to the train needs to be made easy; the objective should be to achieve level access wherever there is new build
The high speed rail network should seek to provide accessibility for all mainland regions of the UK to meet political aspirations
Where HSR does not provide direct benefits to a region, indirect benefits should be sought through using released capacity on the classic network
High-speed rail needs to appeal to diverse market segments and offer appropriate fares structures

4 UK Market Demand for High-Speed Rail

The previous chapter considered the objectives of a high-speed rail network with reference to government policy, and TASTS in particular. We now discuss the underlying UK demographics and economic conditions and then draw some conclusion about the potential market for HSR services and likely demand.

4.1 Demography and Economy

Demography

A review of the UK's geography immediately identifies that the population density, land use, and environmental conditions require careful attention before an appropriate high-speed rail network can be devised. Figure 4.1 is a map of Britain showing key centres of population.

A number of points can be seen immediately from this map:

- The weight of London compared with the rest of the population centres
- The large area of almost joined conurbations of Liverpool, Manchester, Bradford, Leeds and Sheffield (it will be seen later that these are at a good distance to be served by high-speed rail)
- The West Midlands also represents a large centre of population which is somewhat nearer to London; it is generally considered the second largest urban area in UK
- The three cities of Nottingham, Derby and Leicester comprising the East Midlands are also an interesting market for HSR
- The other population centres are significant, but more separated from each other, notably Glasgow, Edinburgh, Newcastle, Cardiff and Bristol; some of the distances concerned are ideal for HSR.

The dispersal of population makes serving it through key nodes more difficult than in countries with more concentrated cities, such as France or Spain. This is particularly relevant in the south-east of England, which accounts for 36% of the population of Britain (see Table 4.1).

A future HSR network in the UK needs to reflect the UK context in the same way as other countries have produced a network that reflects their topography, population density and economic geography.

In comparison with other countries that have embarked upon construction of high-speed rail networks, we find that Britain, with France and Spain has a single dominant conurbation. Italy and Germany, by contrast, and to a lesser extent Japan, do not have a single dominant city. However, in terms of population density within capital and provincial cities, Britain's population density is low - more similar to that in Germany than Paris. Distances between cities are also generally relatively short in the UK, although they comparable to those found between Japanese cities.

In terms of demographic trending, Britain has a growing proportion of elderly people, many of whom are active and make considerable use of transport.

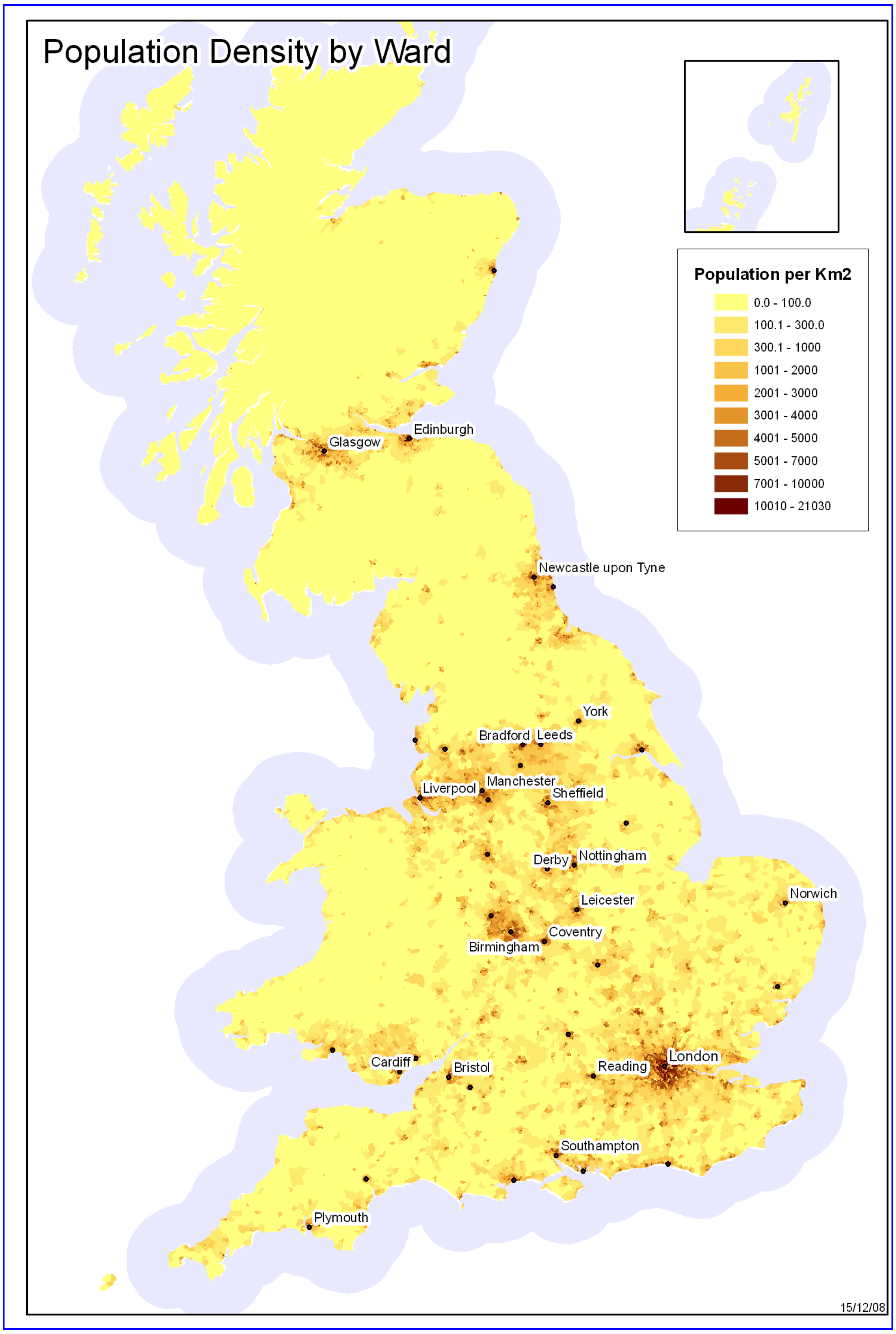

Figure 4.1 Population Density of Britain

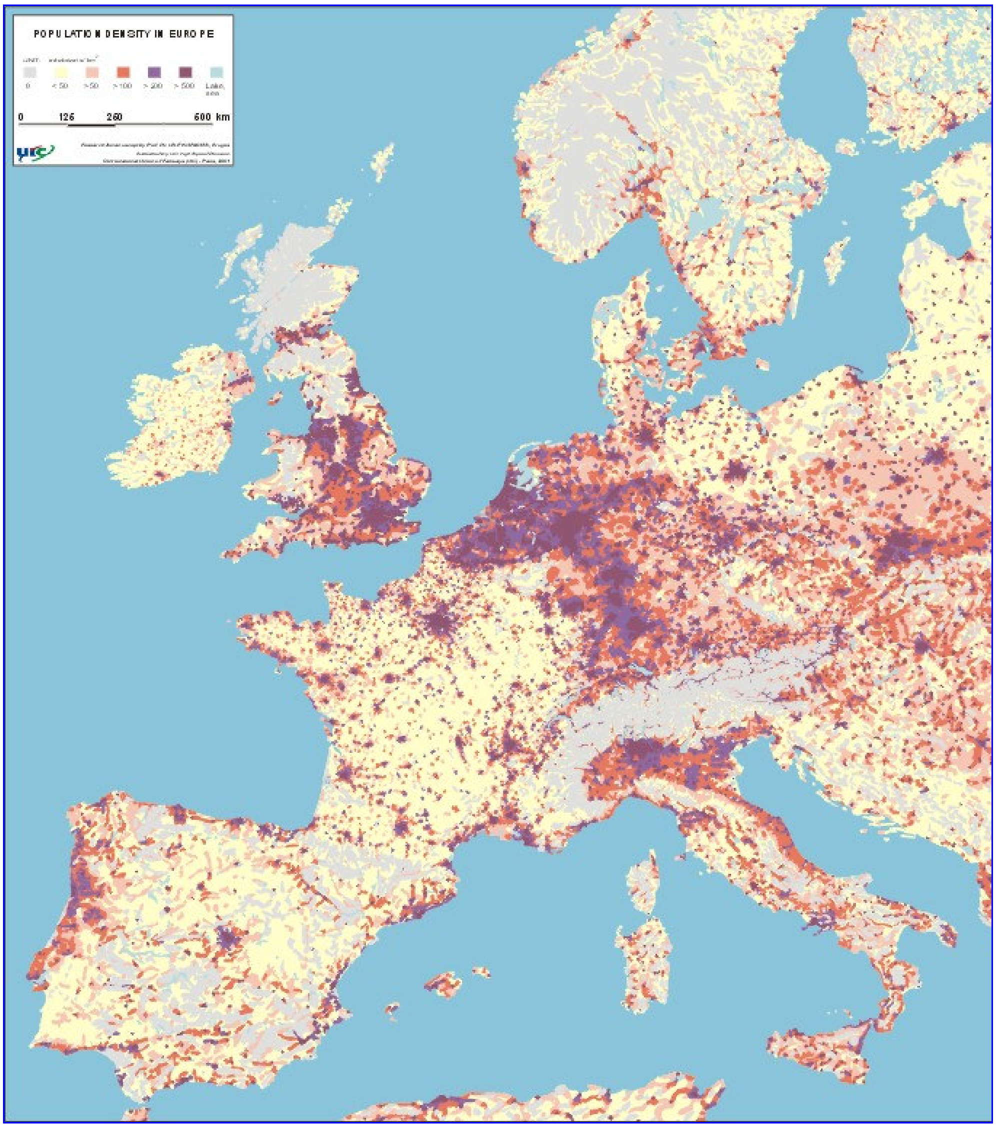

Figure 4.2 Population Density of Western Europe

Economy

Economic activity generates much of the demand for travel. Gross Domestic Product (GDP) is an indicator of a country's level of economic activity. Countries with high GDP per capita are likely to experience greater demand for longer-distance travel, both for business and leisure purposes.

In 2006 the UK had a higher per capita GDP (£22,100) than France (£19,500), Germany (£19,500), Italy (£17,700) or Spain (£18,730).

Britain's wealth is not uniformly distributed. London and the South East are significantly wealthier than the rest of the country. A key indicator of wealth is Gross Valued Added (GVA).

Table 4.1 summarises the population and GVA by region (including summaries for groups of regions.)

Table 4.1 Population and GVA (economic prosperity) by Region[45]

Region	Total Population (million) 2007	Total GVA (£m) 2007	GVA per head (£) 2007
East	5.57	116,186	20,524
East Midlands	4.31	77,864	17,698
London	7.39	229,619	30,385
North East	2.51	40,321	15,688
North West	6.78	112,955	17,433
Scotland	5.10	98,520	19,152
South East	8.17	187,971	22,624
South West	5.04	94,215	18,195
Wales	2.95	44,333	14,877
West Midlands	5.31	92,356	17,161
Yorkshire and Humber	5.08	87,393	16,880
Wider South East	**21.13**	**533,776**	**24,796**
Midlands	**9.62**	**170,220**	**17,403**
North England	**14.37**	**240,669**	**16,917**
Total England Scotland Wales	**58.21**	**1,247,721**	**20,463**

London and the South East has a GVA per capita 21% above the national average, while North England is 17% below. Indeed, all regions except London, the South East and East (which includes Essex, Hertfordshire and other areas within the London commuting region) have lower than average GVA.

The Regional Development Agencies have commissioned a research study into the economic value of the centres for each of the English regions. When this is available, it will be reviewed to identify any implications for HSR networks and stations that should be served.

Growth

In 2007, Great Britain's population stood at just over 58 million. The UK population is forecast to increase to nearly 71 million by 2040 according to TEMPRO.

Different regions in Great Britain are forecast to grow at different rates. Figure 4.3 shows that the southern regions of the British Isles are set to have more rapid growth than the northern regions. The implication on travel demand is that such demand is likely to come from large population and high growth regions in the south.

[45] Office for National Statistics (2007), Regional Gross Value Added (GVA) (2007 provisional figures) http://www.statistics.gov.uk/statbase/Product.asp?vlnk=14650

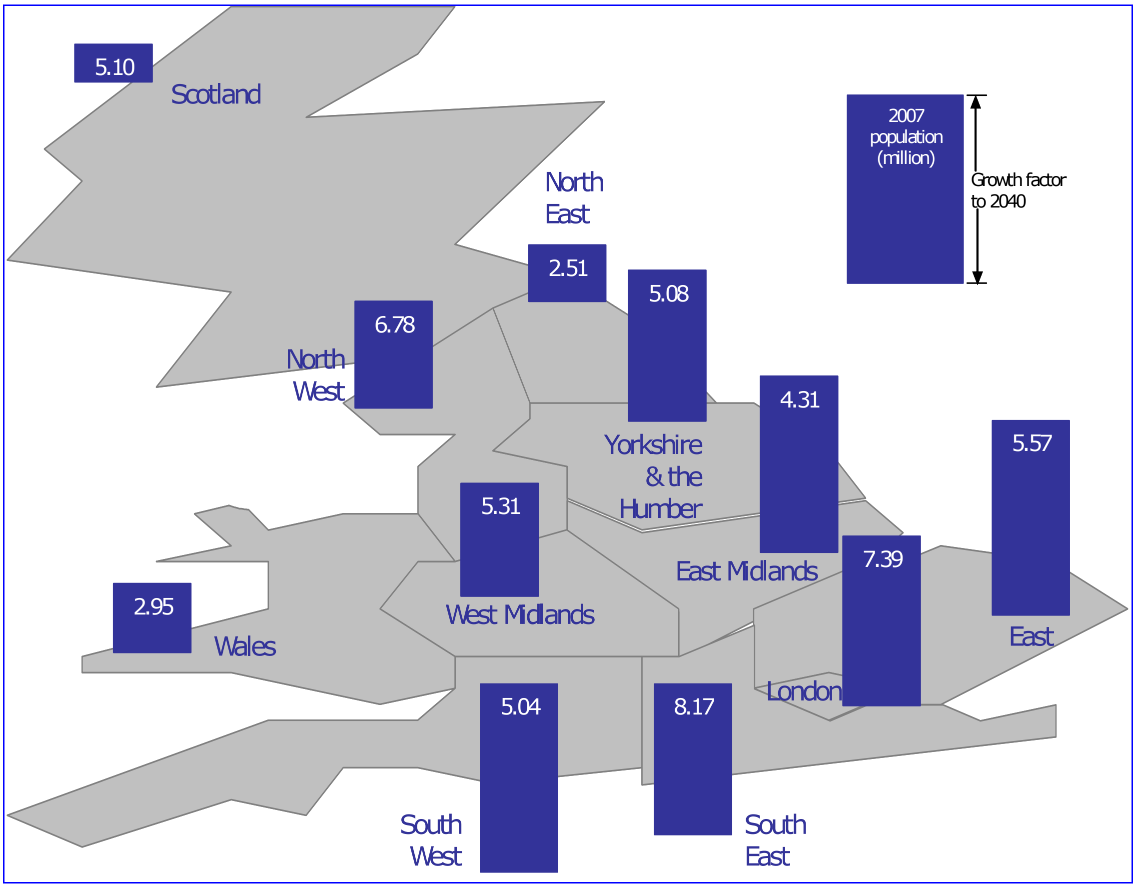

Figure 4.3 Population and Growth - Regional Differences[46]

Even within these regions, growth is focused on specific locations, with the Thames Gateway (both North and South of the Thames) and the corridor from Cambridge through to Milton Keynes/ Northampton expected to show particularly strong growth.

Growth in the economy is forecast to be similar to that of population, with, if anything, London and the South East becoming wealthier, even in relative terms. Forecasts of regional economies are generally only produced for the short term (a few years), such as the Oxford Economic Forecasts presented to the Passenger Demand Forecasting Council. The current recession has not changed the view that the economy of London and the South-East will grow more rapidly than the rest of the country.

In Section 3.2 above, we discussed the potential role of HSR in stimulating regional economic growth and the other policies that need to be adopted. If HSR is to assist in meeting government objectives of making sustainable improvements in the economic performance of all regions and over the long term reduce the persistent gap in growth rates between the regions, then it is necessary for economic benefits to be proportionally higher in the midlands/northern regions of Britain than in London and the South-East.

[46] using data from TEMPRO 5.1, version 54 (15/02/08)P/A, date as specified on Tempro website: 01 July 2008

. **Implications for design of high-speed rail**
The population and economic dominance of London and the South-East means it is the primary origin/destination for high-speed rail patronage
The strength of the London economy means that it is still more dominant in the business market, which HSR seeks to attract
The North West and Yorkshire are key destinations due to both population and distance from London; West Midlands will also be a large market; North East and Scotland are smaller markets but at a good distance form London; Bristol/ South Wales and East Midlands are next areas to be considered
Journey times to central London will be a critical component of the HSR offer to stimulate economic growth outside the wider south-east
While HSR can be a catalyst for regional economic growth, other regional policies also need to be adopted to achieve the growth
While HSR can be expected to deliver economic benefits to the Midlands and Northern regions of Britain, it will be important that it benefits all regions, including London and the wider south east

4.2 Transport Markets

In the previous Section we described the fact that much of Britain's rail and road system is already congested (and likely to become more so in coming years). Eddington states that one of the key objectives of new transport infrastructure should be to provide capacity where it is needed to facilitate economic growth.

The choice of mode is often dependent on travel distance. Figure 4.4 shows that in Britain, air travel captures approximately 40% of the demand for journeys over 350 miles[47]. Rail has a broadly constant mode share by distance band. However, it must be remembered that rail captures a much greater mode shares on journeys to/from London, because of a combination of high rail service provision and higher road congestion. In addition, rail's competitiveness is critically dependent on whether journeys are to/from city centres or suburbs. Table 4.2 shows journey times[48] between locations in city centres and suburbs in London, West Midlands and Manchester by car and rail.

[47] DfT National Travel Survey, 2004-06 average. Department of Transport (2004-06). National Travel Survey. http://www.dft.gov.uk/pgr/statistics/datatablespublications/personal/methodology/ntstechreports/

[48] Department for Transport (November 2008). Developing a Sustainable Transport System. Table A1.1 http://www.dft.gov.uk/about/strategy/transportstrategy/dasts.

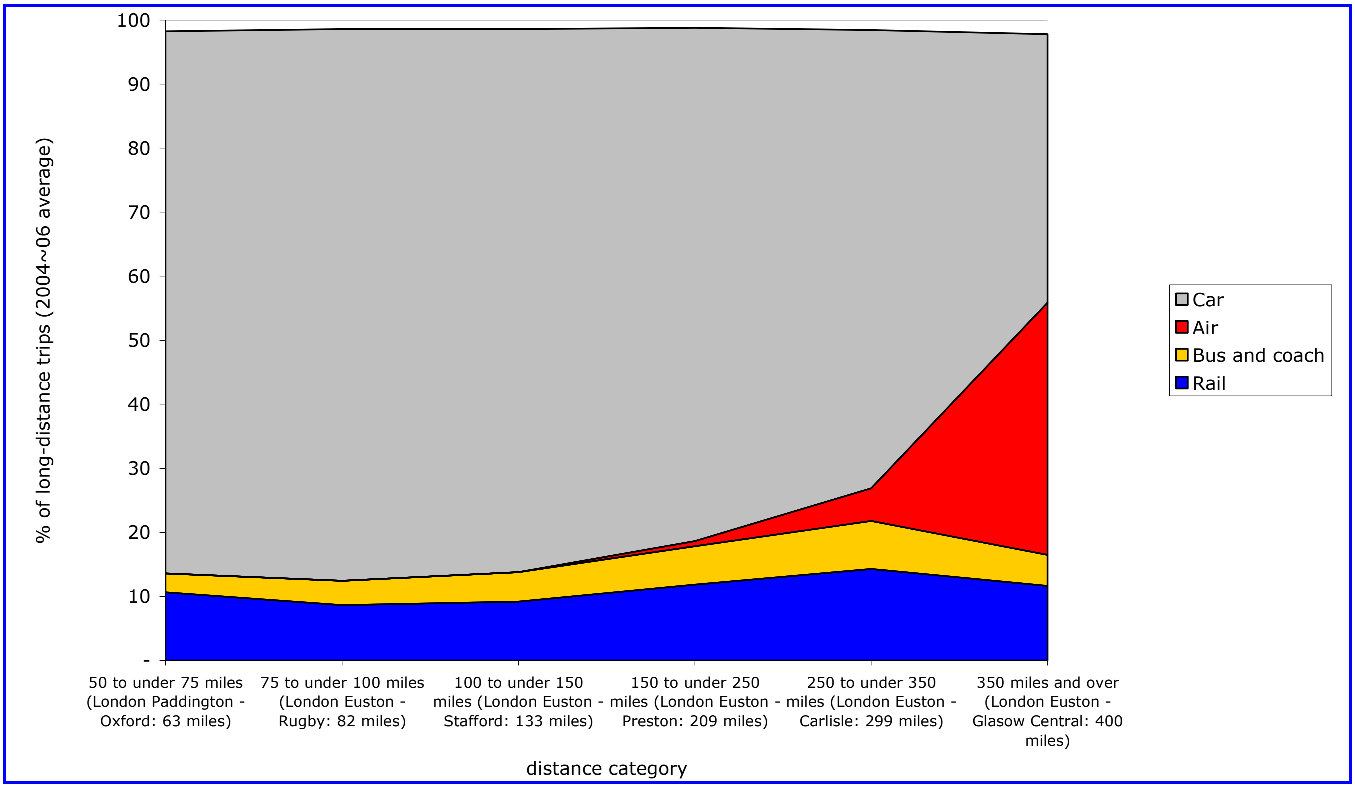

Figure 4.4 Market Shares (by Mode) of Long-Distance Travel

Table 4.2 Journey times between London and suburbs, and other cities and suburbs[49]

Region	London centre Rail	London centre Car	Surbiton Rail	Surbiton Car
Birmingham centre	2h14	3h00	3h00	2h45
Walsall	2h30	2h56	3h15	2h44
Manchester centre	2h51	4h22	3h35	4h07
Trafford Centre	3h20	4h11	4h05	4h04

It is immediately apparent that car journey times to the suburbs are generally slightly lower than to the city centre, while rail journey times are much longer; on London Manchester, while rail has a 90 minute advantage on city centre to city centre journeys, between suburbs journey times are comparable.

Figure 4.5 shows rail and air demand to/ from London. The figure is illustrative only. When comparing the numbers, it must be remembered that the catchment areas of the airports is considerably greater than that of the rail stations. Nevertheless, it can be seen that there is effectively a cut-off point for journey length beyond which it becomes advantageous for air travel (ie trips between London and Scotland).

[49] DaSTS Annex 1 Table A1.1 for car journey times; National Rail website for rail with 30 min access time at London centre, 20 min at other city centres; note, in selecting Surbiton, the DfT chose one of the best rail connected locations in south London

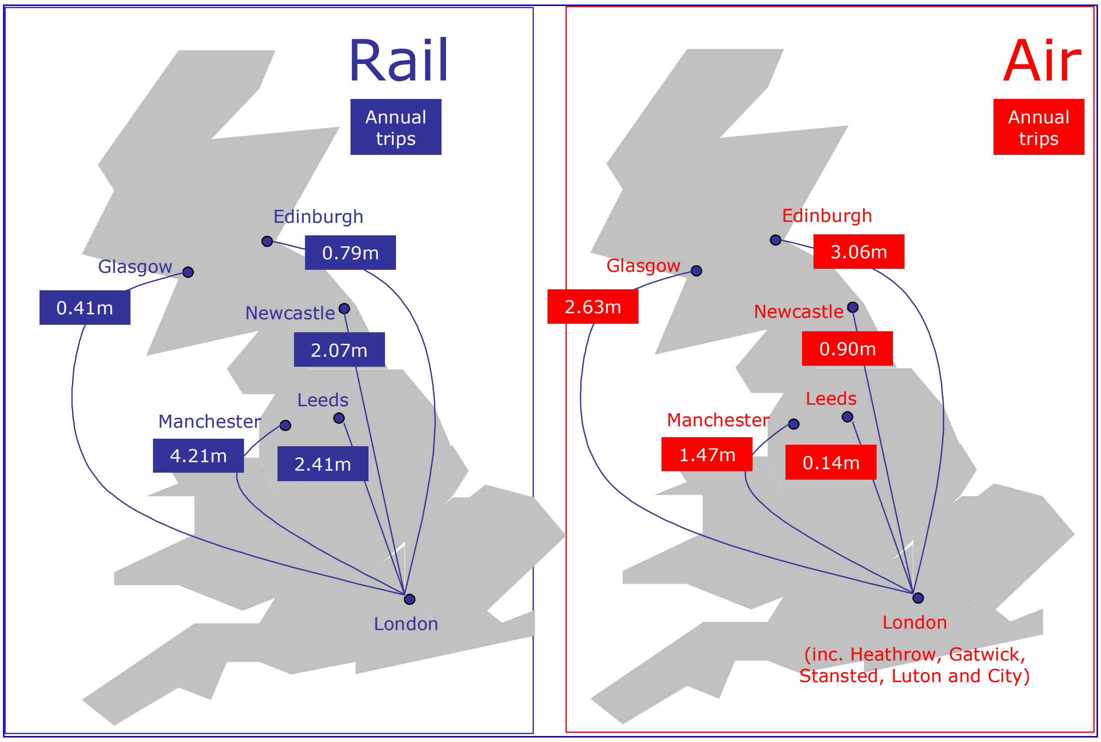

Figure 4.5 Comparison of Rail and Air demand, single trips, including interlining [50]

In choosing between rail and air, journey time is the key, although higher rail journey times are accepted because of the much more use that can be made of time on train compared with air (where most time is spent in access journeys or within airports). People tend to prefer planes if the alternative is to spend many hours on the train. Figure 4.6 shows (in blue) the rail - air share for a wide range of flows between British cities. In red are shown other flows (many of the latter are French). The red line shows the expected rail market share - a relationship used by SNCF. It can be seen that at longer journey times the British experience is of lower mode shares than in France. This may be due to a mix of factors: our more spread-out cities (implying that city centre stations are not as popular as in France) and higher fares in Britain than in France for long-distance rail travel. France does not have an effective domestic low-cost airline market. The lack of a high speed rail network in Britain may mean that the comparable air journey time for a similar rail journey time may be slightly shorter in Britain than France, although the impact is likely to be small as so much of short haul air time consists of take off and landing.

[50] MOIRA 0431, All Operators (OR02), May 2088 timetables

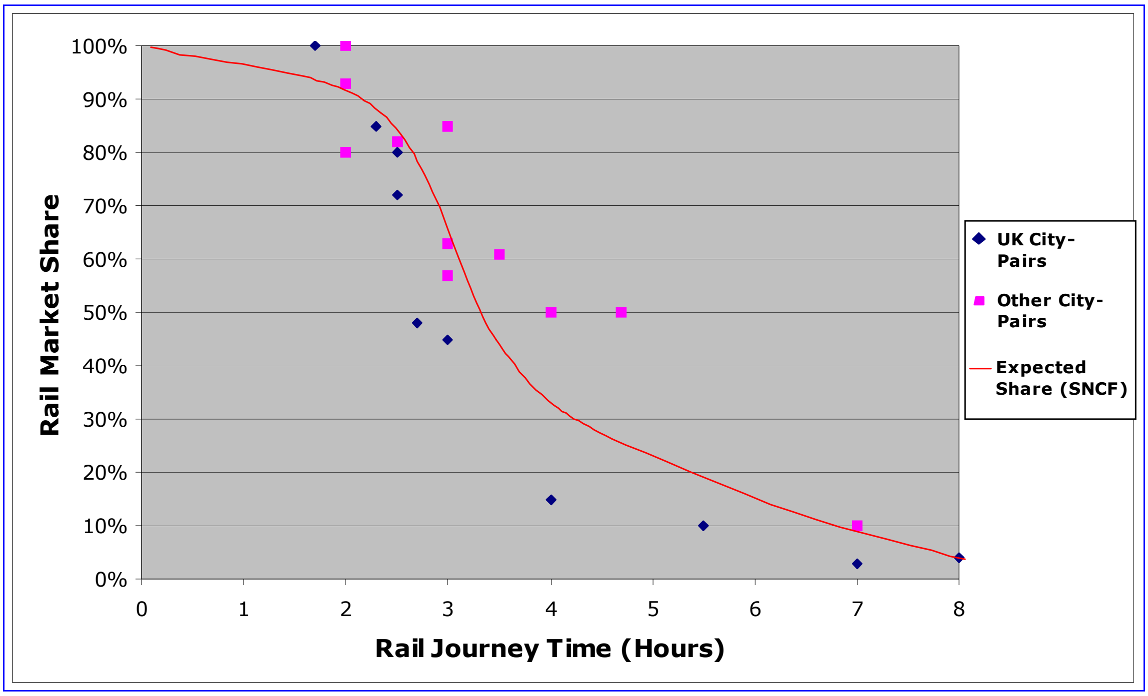

Figure 4.6 Rail / Air Mode Shares

The experience of Eurostar, Figure 4.7, is informative, because the rail/air mode share can be seen to increase against a background of increasing demand for flights (green line). The introduction of Eurostar services (blue line), in 1994, caused a reduction of London-Paris air passengers (red). The initial sharp decline was followed by 12 years of further gradual reductions as air travel on this route reduced by 2 million passengers. Eurostar passenger numbers grew to over 8 million passengers by 2007, despite the (first) fire in the Channel Tunnel, demonstrating that an additional 6 million passenger journeys have been generated.

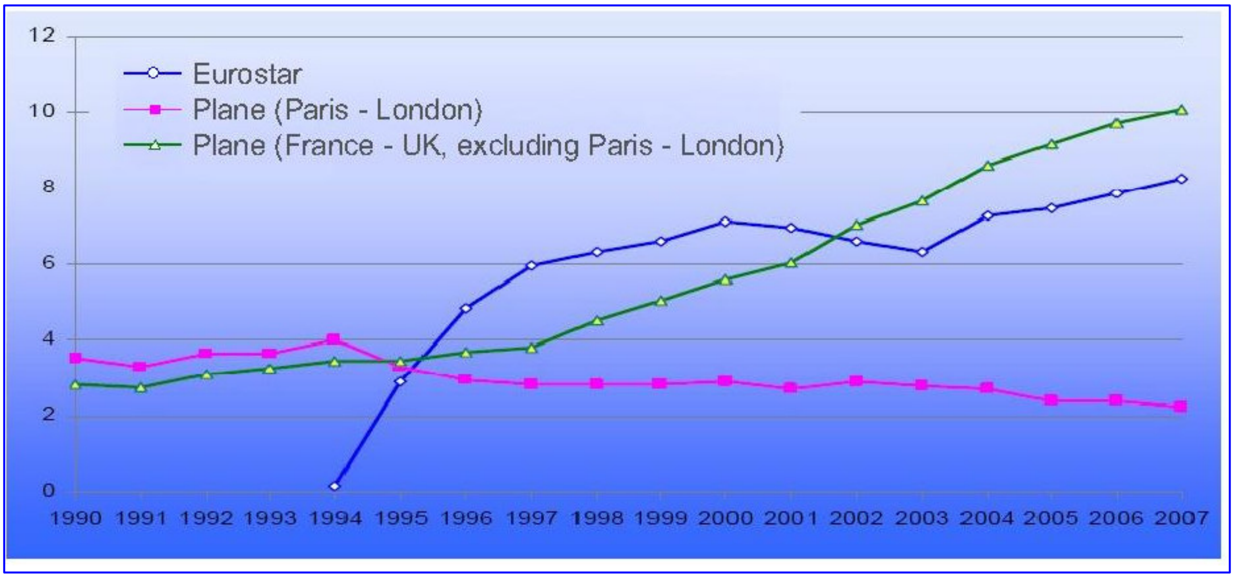

Figure 4.7 Evolution of Eurostar and Airline Traffic Following Opening of the Channel Tunnel[51]

Figure 4.8 shows a similar picture for the impact of French TGV lines on air traffic**.**

[51] French Ministry (DGAC) "Les Notes Thematiques", July 2008

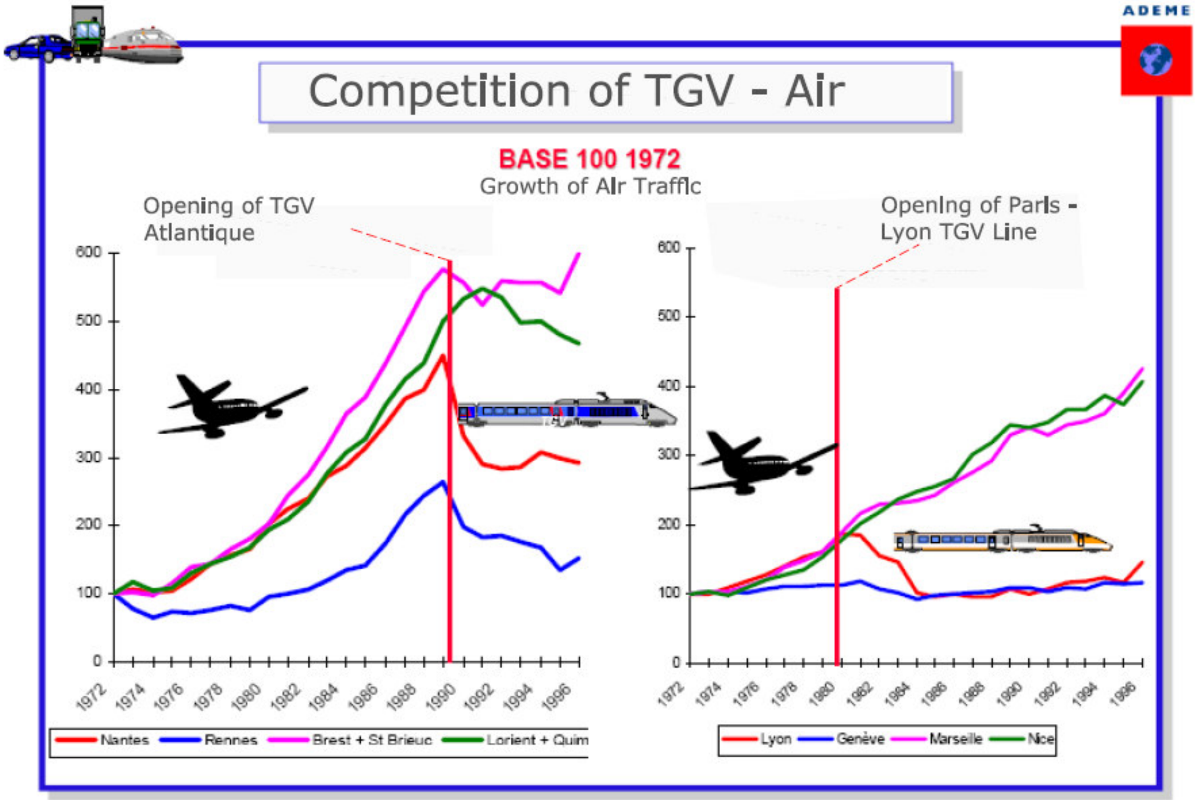

Figure 4.8 Impact of TGV Services on Air Traffic in France

High-speed rail competes with air and conventional rail and is likely to be successful in the travel market of journey distances between 175 and 800 km as can be seen from Figure 4.9.

Air is not competitive for short-distance journeys due to access and egress times to and from airports and time spent at airport security. Whether one flies a short distance or across continents, the times spent on the ground changes little, so, the longer the target distance, the more advantageous it is to take the plane.

In contrast, access and egress times for conventional rail are mostly shorter than for air. Hence, conventional rail tends to be competitive for shorter-distance travel. However, it is slower than air in terms of vehicle speed, making it less attractive for longer-distance trips.

High-speed rail has most of the advantages of conventional rail. Access and egress times for high-speed rail may be slightly longer than conventional rail in some cases, but still much shorter than air. The faster speeds of high-speed rail mean that it can compete with air at much longer distances. Therefore, while air is competitive over very long distance journeys and conventional rail is competitive over short distance journeys, there is a substantial middle-ground in which high-speed rail is more competitive than both air and conventional rail.

In the British context, 800 km (the point at which air is more competitive than HSR in figure 4.9) is longer than any distance between major cities, London to Edinburgh and Glasgow both being about 650 km; hence with high-speed rail, air should achieve only a minority share on all major flows; there is one caveat to this, however: for passengers interlining at Heathrow (or another) airport, where the normally significant access time of air will not apply.

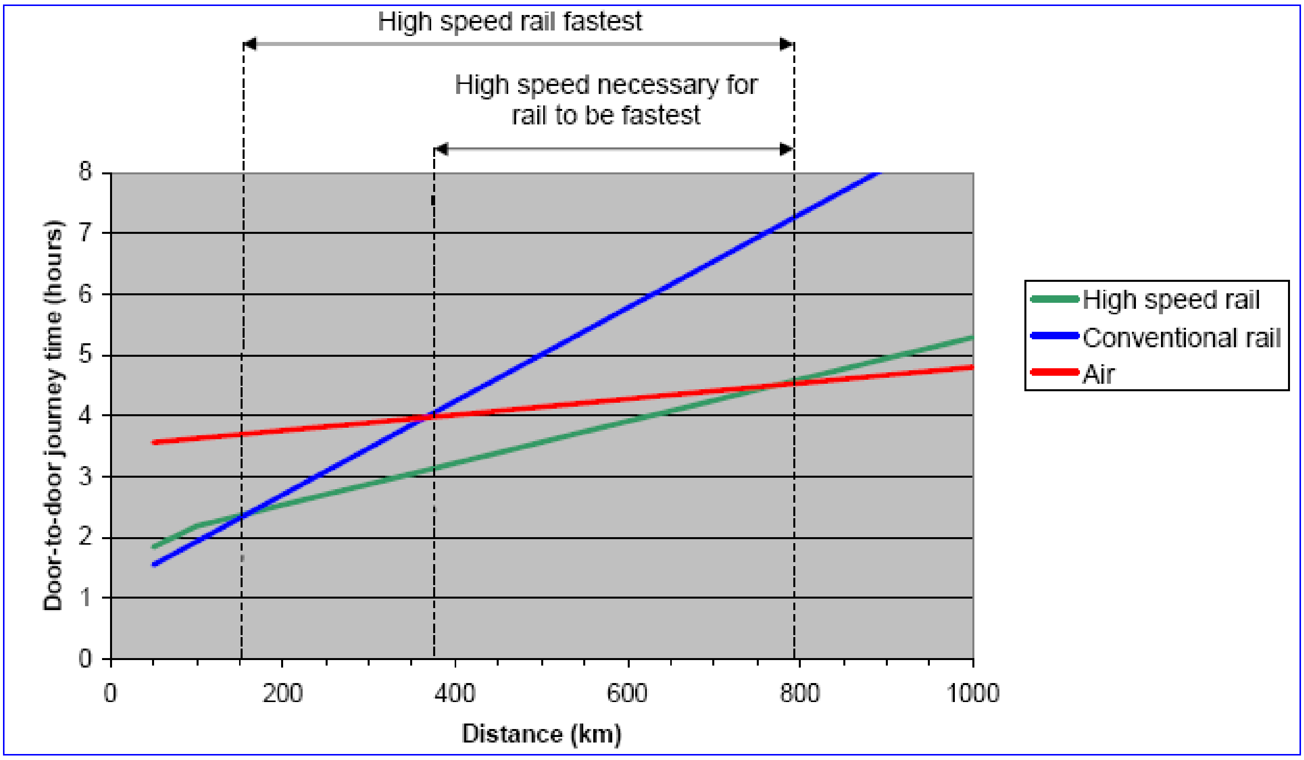

Figure 4.9 Competitiveness of HSR at Various Distances (SYSTRA analysis)

At the lower distance, 175 km (the point at which HSR is more competitive than conventional rail in figure 4.9) is slightly less than the distance between London and Birmingham (185 km) and Bristol (190 km), indicating that there may only be likely to be a modest advantage for high speed rail compared to classic for these flows; although, this depends critically on which stations are served by HSR and classic rail. Whereas for London to Manchester (300 km) and Edinburgh/Glasgow (650 km) high speed rail is seen to have a strong advantage over both air and classic rail.

However, because of the high volume of interlining on the current flights to these cities (74% between Manchester and Heathrow, about 50% on Heathrow to Scottish airports), it is unlikely that anything other than a direct connection via high-speed rail network would result in a significant reduction in flights. In the UK context, high-speed rail to serve Heathrow would therefore be desirable in terms of the potential for high-speed rail to replace short-haul flights to Leeds/Bradford, Newcastle, Manchester, Durham/Teesside and Glasgow and Edinburgh. An HSR network serving Heathrow would also encourage those who currently interline at Paris (CDG), Amsterdam or Frankfurt to use Heathrow, thus strengthening Heathrow's competitiveness compared to other European airports for long haul flights.

It should be noted that Heathrow is already effectively the primary airport for international flights from the South West of England, but access by rail is poor (either via Paddington and Heathrow Express or the coach link from Reading). The objective of HSR here would be to reduce car and taxi journeys.

Overall, consultees considered that easy access to Heathrow would encourage businesses to relocate to their area and hence lead to some economic regeneration.

Heathrow also provides a potential access station to an HSR network for passengers from the west of London; however, car parking is likely to be very expensive, and the highway network is very crowded; so the impacts of such a station would need to be considered from that perspective.

Details of access to Heathrow will be considered further in Workstream 4.

Impact of HSR on Car Traffic

Introduction of HSR can be shown to have a clear impact on road traffic, though not so clearly as its affect on air traffic. Figure 4.10 shows the traffic on major French motorways over 15 years. Some of these motorways are not in competition with the new TGV route (Paris to East France – the A4 and Paris to Normandy- the A13) and one being in direct competition (Paris to Lyon – the A6).

While all three were on the same growth trend before the launching of TGV service between Paris and Lyon, the effect was immediate on the A6, and traffic growth suddenly tailed off in 1982. The traffic on the other motorways was not affected.

In 1990, the High Speed Line was extended by 150 km, saving an additional 40 minutes on the southern destination, and the A6 traffic was once more affected.

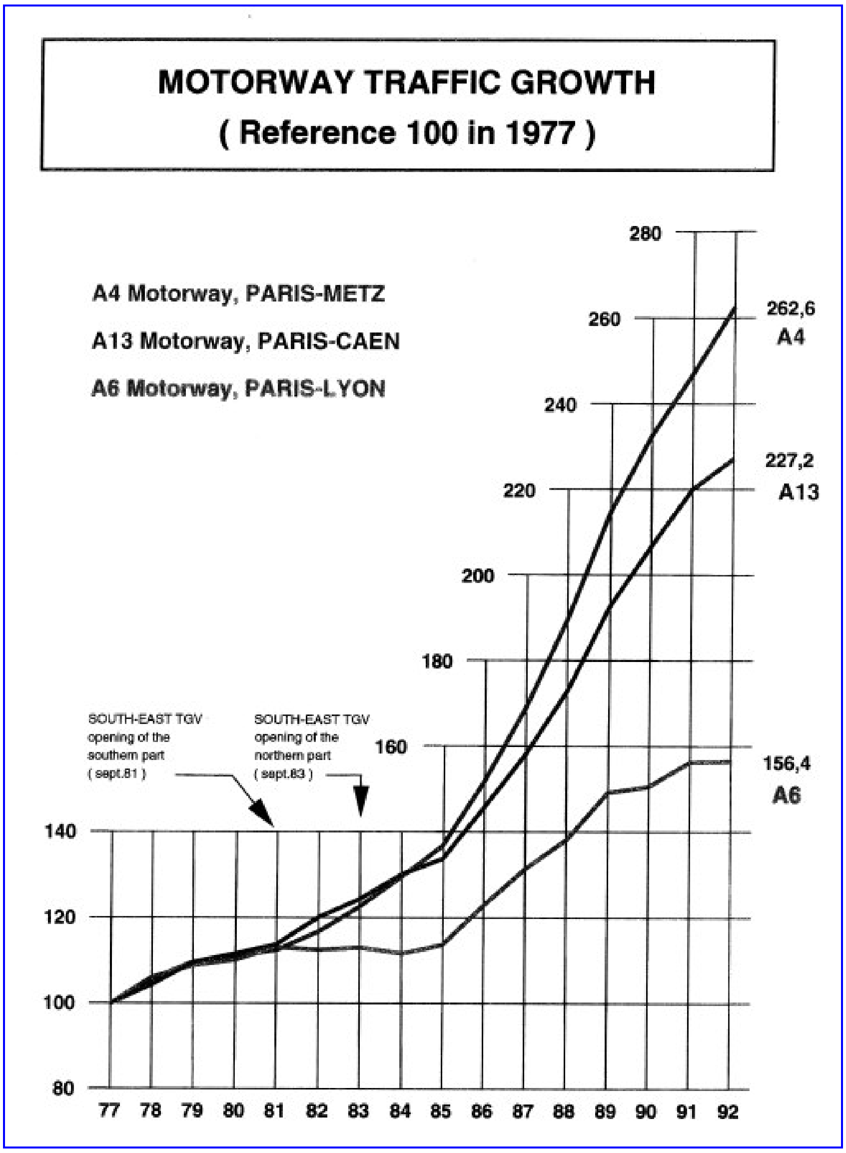

Figure 4.10 Traffic growth in France and the effect of the introduction of TGV services

While high-speed rail clearly has abstracted from car traffic, critical to the extent of abstraction is distance (and more importantly journey time) from individuals' origin and destination. Rail will capture much greater shares of city centre traffic than of those to/from surrounding areas. Data is not readily available to quantify this, but we will adopt a zoning system specifically designed to address this issue in our forecasting model (to be developed in Workstream 3).

Implications for design of high-speed rail
The flows from London to north England and Scotland are at an ideal distance for high-speed rail
High-speed rail should be designed to capture the majority of the domestic air market excluding those interlining
In addition, the interlining passenger market could be within the scope of HSR if a direct Heathrow service were provided
Increasing highway congestion will both increase demand for high-speed rail and make it more important to the economy

4.3 Total Demand for HSR Services

In Workstream 3 we will develop a model to provide robust forecasts of the demand for high-speed rail. However, to inform the network development, it is useful to have an understanding of the potential scale of passenger demand and to enable initial assessment of the likely frequency of service and hence sizing of the HSR infrastructure. Particular issues of interest are whether a single route north of London is likely to suffice in terms of capacity, and the broad number of platforms required for high-speed rail (and released from the classic network) in London and other major cities. The frequency of service to Heathrow is also of interest, as the market requirements for a frequent service may not be matched by forecast service demand.

The principal determinants of capacity are essentially the demands to/from London. We have therefore initially concentrated on these. The process we have adopted is to start from the current rail demand to the various cities, applied exogenous growth and the growth due to the faster trains. This gives us a forecast demand for a notional design year of about 2040. Applying an average load factor gives us the number of trains per day, which we convert into trains per typical busy (but not necessarily busiest) hour.

Table 4.3 is an indicative calculation showing existing demand and inferences drawn from this to HSR trains per hour.

Exogenous growth is currently running at 5% to 6% pa, but standard forecasts (eg those used for HLOS, RUSs) are much lower at about 2% pa. A conservative forecast of exogenous growth would be about +50% in 30 years; figures up to +100% are certainly plausible. We will test the two scenarios.

The impact of a High Speed Network itself will be substantial based on experience elsewhere; even taking into account the rather higher classic rail speeds in Britain, we could expect about 50% growth due to the speed improvements on most flows, but rather less on shorter distances (say 25%) and rather more where there is currently air competition – we have assumed the current air non-interlining market is abstracted in addition to the 50% growth in rail; the growth figure in the Table combines this with the exogenous growth.

We have assumed that single deck trains will be operated with the option of either 200m or 400m (two units coupled together). This gives a capacity of about 750 passengers if long (400m) trains are used. Because of the UK loading gauge, we have not assumed double-deck trains. An average load factor of about 70% is assumed which regularly is achieved in France, but does require the train service pattern to follow demand to some extent, rather than following a totally regular hourly pattern.

We have assumed 365 days per year, but then added 20% to cater for an above-average day. With an operating day of about 14 hours, we can estimate that the proportion of trains in a busy hour might be about 10% of the number of daily trains.

Table 4.3 Indicative Calculation - Number of Trains Required Per Hour (Low Estimate)

Flow	Current demand (m) pa	Growth (exog + speed)	2040 demand (m) pa	Load per train	Trains per day per direction	Trains per busy hour
London – Glasgow	0.41	5.49	2.25	525	7	1
London – Edinburgh	0.76	4.26	3.24	525	10	1
London – Newcastle	2.07	2.47	5.11	525	16	2
London – Leeds	2.41	2.28	5.49	525	17	2
London – Manchester	4.21	2.34	9.84	525	31	3
London – Liverpool	1.19	2.25	2.68	525	8	1
London – Sheffield	0.79	2.25	1.78	525	6	1
London – Birmingham	7.98	1.88	14.97	525	47	5
London – Nottingham	1.15	1.88	2.16	525	7	1
London – Cardiff	1.54	2.25	3.47	525	11	1
London – Bristol	4.67	1.88	8.76	525	27	3
TOTAL	**27.18**		**61.17**		**192**	**21**

Note that the numbers of train above are only indicative prior to completion of the demand forecasting model; furthermore, they assume that the classic service does not seek to compete on the shorter distance flows. The economic value of the different services will also be different, with the longer distance journeys typically having larger economic value per passenger.

The high estimate is 33% greater (100% increase rather than 50%), implying about 28 trains per hour per direction.

Some of the above figures appear lower than the current service pattern (eg those to Edinburgh); the reason is that some intermediate cities have been excluded from the figures, as these may or may not be included in a high-speed network. (Examples are York and Darlington on the East Coast route to Edinburgh). In reality, some of the above flows would be combined, but this will depend on the network configuration. For example, if an East Coast alignment to Scotland is selected, then the Edinburgh and Newcastle flows will be combined, giving a total of 3 trains per hour.

Furthermore, if trains are operated on and off the current rail network, they may need to be half the proposed length (very few current stations can take 400m trains). This would double the demand for numbers of trains. It may be that this can be addressed by splitting/joining some trains - as occurs today on some French TGV services and Thalys.

The implications of the above broad level of train service are discussed more fully in the following sections, however, as the current capacity of a two track high-speed rail route is normally 12 trains per hour, (but might be expected to increase to 15 with new technology, as discussed further in Section 5 of this report) there appears to be sufficient demand for two such routes to the north of London (even if Bristol and Cardiff are excluded).

Stations

HSR stations can be very large and the requirements are discussed further in Section 5 of this report. For through-stations two platforms may be adequate except in the largest cities, but with terminus stations many more platforms are required to accommodate train operational requirements.

Access to stations is an important issue, with large numbers of passengers arriving or departing together. For city centres, public transport access will be important, along with taxis. This may imply the station should be located close to current principal stations, as these typically have good public transport networks (rail, metro and bus).

If parkway stations are considered, these will need to demonstrate that they are positive in terms of their overall, taking local transport and environmental considerations into account. Access should be encouraged for electric and other environmentally friendly vehicles, with suitable facilities provided.

Heathrow

We now consider the likely demand for travel to Heathrow if a direct HSR service is provided. We cannot base this on current rail demand.

We have only considered a limited number of destinations, and assumed that 100% (50% from Scotland because air will still be reasonably attractive with a HSR journey time between 2.5 and 3 hours) of current interlining passengers (ie those accessing by air) and 50% of current surface access might transfer to high-speed rail. We have excluded domestic passengers (apart from interliners) as these are more likely to travel to central London, and have assumed an increase in the throughput of Heathrow of 25% (this compares to DfT forecast[52] of 27% increase to 2030 when airport is very close to full without third runway). If the third runway is built, then these figures will be significantly higher.

Table 4.4 High Level Estimation of Number of Trains Required To/From Heathrow Per Hour

Flow	Current Interline demand (m) pa	Current surface access demand (m) pa	2040 demand (m) pa	Load per train	Trains per day per direction	Trains per busy hour
Scotland	1.19	0.08	0.79	262	5	0.5
Manchester/Liverpool	0.65	0.24	0.96	262	6	0.5
Sheffield/Leeds/Newcastle	0.36	0.57	0.81	262	5	0.5
Birmingham	-	1.20	0.75	262	5	0.5
Bristol/Cardiff	-	2.31	1.44	262	9	1
TOTAL	**2.20**	**4.40**	**4.75**		**30**	**3**

[52] Department of Transport (Feb 2007), Adding Capacity at Heathrow airport – Consultation Document.
http://www.dft.gov.uk/consultations/closed/heathrowconsultation/consultationdocument/annexc.pdf

We can immediately see an area for further study: to be attractive for airline passengers who might reasonably need to catch a specific departing flight, the service frequency needs to be at least one per hour; this is the frequency offered on domestic flights from principal cities such as Manchester, Edinburgh and Glasgow. Even on our assumption that we can serve more than one city with a single train (which depends on the structure of the HSR network), many of the above flows do not have a viable flow. Furthermore, previous studies[53] have demonstrated that an interchange in a rail access journey to the airport suppressed demand by approximately 50%.

The solution to this will require further consolidation of demand by serving Heathrow by trains that also serve other markets, such as London to Birmingham/Manchester, or placing Heathrow as an intermediate station on a cross-London service.

Other Airports

Both the size and catchment areas of other UK airports are much smaller than Heathrow. For example, there are only 0.33M interlining passengers at Stansted (15% of the number of Heathrow) and surface access demand from Sheffield/Leeds/Newcastle corridor (most easily served) is only 0.28M. This would justify only 1.5 trains per day – clearly inadequate for an airport access service. Manchester Airport has significant surface access from the West Midlands (1.19M) and from Yorkshire/NE (4.6M) which might justify an HSR service and certainly justifies further study in Workstream 4. In all these cases, airport demand can be expected to grow strongly. Manchester could double in size by 2040, and in some scenarios Stansted could grow by even more. It is likely that the demand will continue to grow at all airports; the question is the policy on whether to expand the airport to cater for it.

The key to serving other airports will be whether they can conveniently be located on a high speed line; this includes Stansted, Manchester, Birmingham and East Midlands.

Implications for design of high-speed rail
The demand for high speed rail will exceed the capacity of a double track railway to the north if the majority of destinations are served from London
We are likely to need 12 to 15 platforms in central London to cater for a HSR network
All city centre stations require good public transport and walk/cycle access; any out of town stations need to be justified on reducing overall emissions and should provide facilities for environmentally friendly private vehicles such as electric cars
Heathrow Airport needs an hourly service to meet the requirements of air passengers; this means that either flows to several cities need to be combined, or Heathrow flows need to be combined with those to central London
Other airports are unlikely to have sufficient demand to warrant an HSR service, unless they can be served en route to somewhere else

[53] unpublished work by MVA - for the Strategic Rail Authority in 2000

5 Constraints on HSR Development

5.1 Introduction

Having identified the objectives to be served by a future network of high-speed rail lines and considered the market demand and UK context, it is necessary to take into consideration certain UK-specific constraints on the development of the network design, before it is possible to move forward to develop the shape of a future network.

We have identified several categories of constraints:

1. **Development** (existing transport infrastructure, spatial requirements for HSR, etc)
2. **Natural and topographic**
3. **Technical** (interoperability with existing network, rolling-stock, gauge, capacity, commercial speed and maximum speeds, etc)
4. **Transport economic and regulatory** (open access, franchising systems, access charging)
5. **Recent transport developments, phasing and cost**

In this section we discuss these in turn.

5.2 Development Constraints

It is clear that the development of a high-speed rail network in the UK is significantly constrained by the density and degree of development of the country.

Land-use designations, development constraints, the complexity of property ownership and the inevitable variation of political perspective make the UK a unique and complex environment in which to construct new infrastructure. New linear transport infrastructure brings its own particular challenges, particularly for services which bring limited or indirect benefits to the neighbours and landowners affected by the need to take land for construction and operation of the railway.

That said, the experience of route development of HS1 has been formative and this project has resulted in substantial development in both process and standards relevant to additional new infrastructure.

- A parliamentary process was resurrected and developed in the form of the Hybrid Bill process, resulting in the CTRL Act (and subsequently Crossrail Act). Despite the demands of this process, it demonstrably succeeded in securing the necessary powers for the construction and operation of the railway infrastructure.
- In the process, HS1 set a number of other precedents of value in respect of the future process for development of route options in the UK.
- The quality of local and regional consultation and communication established a new UK benchmark.
- Environmental mitigation standards relevant to the context of high-speed rail infrastructure have been established by HS1, including the management of the varied impacts on ecology, archaeology, noise, vibration and other matters related to the permanent impact of the line.
- Further standards were established in relation to the temporary construction impact of the project.

The UK does have an extensive network of existing transport corridors, including motorways, and both heavily and lightly used rail routes, which should be fully assessed as part of the corridor studies of Workstream 4.

Population centres, land use designations and regional and unitary authority level spatial plans will form an important input to WS4.

Again, lessons learnt from HS1 include the need for caution over land use blight and route publication.

They also indicate the clear advantages of identification of alignment and operating solutions that:

- Reduce the vertical alignment profile to reduce the impact of train noise and use cuttings and tunnels to reduce impact on environmentally sensitive locations and property.
- Make use of redundant or under-used infrastructure assets (such as St Pancras)
- Make use of existing transportation corridors for the alignment (M20, Ashford-Folkestone railway) even if running parallel to highways leads to issues of curvature
- Position stations to encourage or support regional development objectives (Stratford International)
- Facilitate park-and-ride use (Ebbsfleet station which is meeting its forecast patronage) where this significantly reduces access time to HSR
- Use the high-speed infrastructure to facilitate better local journey times (introduction of 'domestic' services in 2009)

The potential to reduce congestion on the existing lines is an important and critical benefit from a HSR network, enabling train operators to run long and medium distance services on new infrastructure, freeing capacity for local services.

Stations

Whilst identification of station locations, as intermediate stops or termini, are a key component of Workstream 4, but it is worthwhile to make some technical observations related to their operation and layout.

Nowadays, design of high-speed rail stations requires track platforms to be away from the high-speed lines themselves, using loop lines with 170 kph line speed, dictated by the entry and exit turnouts. To optimise line capacity, it is usually considered appropriate to increase the loop length and to overtake a stopping train with a non-stop train, in which case, in additional to the time allowed in the timetable for the stopping train itself, the other trains are also affected.

Figure 5.1 illustrates the fact that the overtaking train is timed later (4'20" to be exact) after its normal pathway to ensure the stopping train is clear, allow sufficient margin to avoid delay. The departure of the stopping train has a further effect of eliminating a pathway that might have been used for a non-stop train, before returning to a high-speed pathway itself. To achieve 2'42" dwell time at the station has added 8'38" to the overall journey time of the stopping train in this case, and eliminated two high-speed train paths that might have been available for other non-stop services.

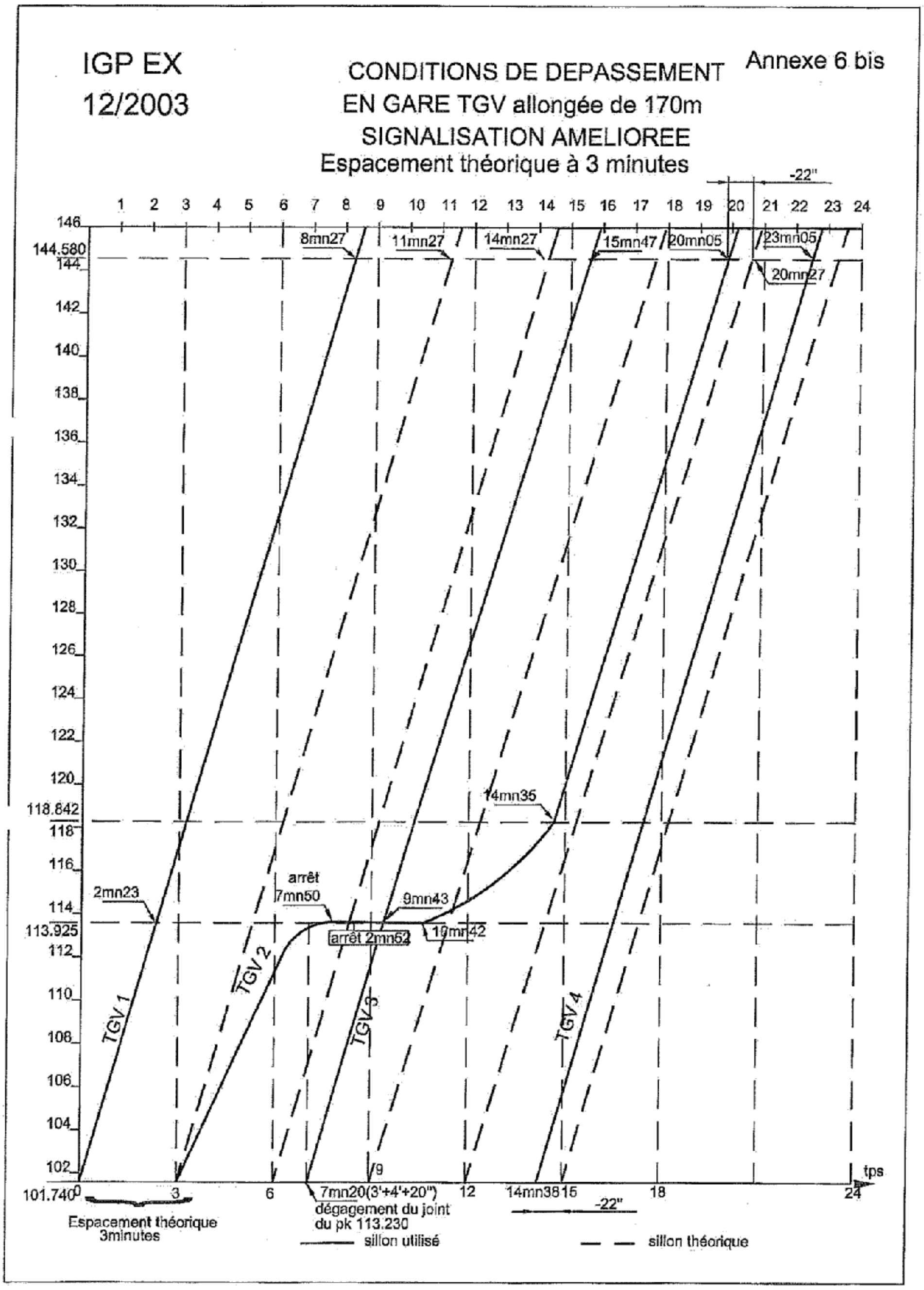

Figure 5.1 Typical Stopping Train Diagram

Sufficient platforms are required to allow for the expected traffic and the number of stopping trains, taking into consideration terminating trains, any other operational requirements and passenger considerations. Sidings for operational and maintenance use may also be required at stations.

Platforms are normally 400 m long for high-speed running (this is the TSI standard) to maximise capacity on the expensive high speed network, although 200m platforms for shorter trains may be considered on sections of the existing network, for example, depending on operational design.

Curves at platform should be avoided for safety reasons and to reduce the gaps to the platform edge. Usual platform widths are 10 m. Heights of platforms are normally dictated by gauge and rolling-stock considerations.

Additional considerations would normally include waiting areas, passenger facilities, security, control and ticket sales facilities. The additional considerations include car parking, collection/drop-off facilities, access from the existing network and interchanges with other forms of public transport.

Assessing termini stations requires assessment of the expected traffic, as well as consideration of the commercial requirements and operational needs. The number of platform tracks required depends on the expected level of service, and takes into consideration train access time into the station, time for dispersal of incoming passengers, cleaning, etc…). 30 minutes is a typical minimum period between the arrival of a loaded high-speed train and its departure, although for short journeys this might be reduced (26 minutes reversing times are daily set at Paris-Nord, and 15 minutes reversing times are daily set in Japan).

Depots

Inevitably train services require depots for regular inspection, cleaning and maintenance.

The Eurostar depot at North Pole has been abandoned in favour of the Temple Mills Depot, which is accessible to HS1 southbound trains via connection line at Stratford in East London.

Depot - how much land is needed for a depot?

Temple Mills is the maintenance depot for all 11 Eurostar train sets in the UK, with overall dimensions of the 8-track train shed being 450m long by 64m wide, with a floor to ceiling height of approximately 12m. High-level walkways in the roof trusses provide access to the shed services and key features of the depot. Overhead gantry cranes form part of the facilities, which include a fully-fitted automated overhead electrification system, a bogie drop which allows two trains to be worked on simultaneously, toilet discharge equipment which allows two trains to be cleaned simultaneously, a bi-directional carriage wash facility, and fully automated wheel-condition monitoring equipment.

The facility is served by a fan of tracks that allow trains to be marshalled and shunted as necessary between the high-speed line and the depot. Facilities also include staff accommodation and parking.

5.3 Natural and Topographical Constraints

The topography of Britain presents certain constraints to the development of a high-speed rail network. Although these are not described extensively in this report, and will be examined in further detail in Workstream 4, it is interesting to note that they have largely been reflected in the historical development of the 'classic' rail infrastructure, constructed in the 19th century, at a time when there was a lower population density than there is today. The designers of the day had considerable regard for reduction in construction and operational costs through optimisation of rail gradients, since for steam trains this was an even greater imperative than for today's electric and diesel trains. 19th century solutions for overcoming the greater of Britain's topographical challenges and so connecting centres of population across areas of open country remain good indicators for today's rail engineers. However, these assumptions need to be re-assessed in the light of modern high-speed rail design parameters.

5.4 Technical Constraints

Regulations and Legislation

European and UK railway standards aim to ensure that future high-speed railway lines are safe in operation, and satisfy the broader market development objective of inter-operability of rail products and services throughout the European network.

- A new Interoperability Directive, 2008/57/EC, was published in the Official Journal of the European Union on 18 July 2008. It set out a number of essential requirements to be met for interoperability, which include safety, reliability and availability, health, environmental protection and technical compatibility along with others specific to certain sub-systems.
- Technical Specifications for Interoperability (TSIs) developed by the European Railway Agency, define the technical standards required to satisfy the essential requirements of the Interoperability Directives. The UK has two years (from July 2008) to transpose the requirements into domestic legislation, which will be done by a revision of the Railways (Interoperability) Regulations, which establish how these changes are applied in the UK.
- TSIs apply to sub-systems including track, stations, energy, rolling-stock, signaling, operations, maintenance and IT systems.

Interoperability can also be used to describe the practical consideration of the movement of trains between existing railway lines and high-speed rail lines. The inter-changeability of services between networks is considered to be generally desirable and this point is explored more fully below, having due regard to cost and future developments in technology.

Development of the appropriate standards for HS1 resulted in several derogations from TSIs, which are mandatory for high-speed rail lines in the UK. The development of future standards is a matter that is under review with the RSSB.

Over the timescales of the development of an HSR network, the Technical Standards will inevitably change. The principles behind the standards must be adhered to, but the specific details can be challenged if an appropriate case can be made.

Segregation or Integration?

Segregating high-speed trains on a dedicated network increases operating capacity (when compared with operating mixed traffic speeds) and can lead to dramatic increases in punctuality of trains and reliability of the timetabled services. It also allows higher capacity trains to be operated, notably double-deck trains, since the train envelope (and structure gauge) can be specified without reference to the existing infrastructure.

A segregated railway can operate an homogeneous train fleet on a network fitted with wholly appropriate operational facilities (such as bi-directional signalling, regular cross-over points and high-technology systems such as Centralized Traffic Control, cab-based signals (such as TVM 430 and ERTMS) and Electronic Interlocking. Train delays are generally not spread from the classical network to the new network.

However, building entirely new infrastructure is costly. It requires new tracks and new stations in urban areas and since stations are normally required close to existing transport interchanges this poses certain challenges.

Only three national rail network operators have adopted a segregated strategy – and these are mostly for historical reasons:

- The original Japanese rail network was built with a small track gauge unable to cope with high-speed traffic. A standard (1435mm) gauge has been adopted for the high-speed rail line, but with wider rolling-stock than is used in Europe (3.4 m).

- This has also been adopted for the Taiwan high speed rail network for the same reason.

- The Spanish HSR network chose to adopt the standard gauge, rather than its broader traditional (1668mm) gauge in order to integrate its high-speed rail system with the European network. In both cases, operators still decided that the benefits of interchange between networks justified construction of some rolling-stock able to run on both rail networks (using variable gauge in the Spanish case).

The main advantages of designing for operation of high-speed services on conventional as well as high-speed lines are:

- The ability to use historical stations located close to city centres (where capacity exists), with good connections to urban transport systems and the associated reduction in end-to-end journey time.
- The ability to extend high-speed services to beyond the high-speed rail lines by running on conventional lines. (In 2007, the French national high speed network included 1,850 km of 300 km/h TGV high-speed lines and 7000 km of conventional lines served by TGV train sets.)
- The ability to improve other services by partial use of the high-speed network, reducing trip time, as will be the case on the HS1 network when Southeastern introduces its Javelin service from East Kent in 2009.

- Ease of access to rolling-stock depots and use of infrastructure maintenance vehicles. The capacity for rolling-stock interchange if lines are connected.
- The value of phased development - there is a practical need to expand the network progressively – during the construction of HS1, services from Channel Tunnel to London followed three routes: firstly, Folkestone to London Waterloo on existing lines; then using the first completed section of high-speed line to Gravesend (Fawkham Junction) and on to Waterloo; and finally, using the new line, all the way to London St Pancras from November 2007.

There is a particular challenge at terminal stations, well served by public transport and ideally suited for HSR, but with a need for approaching tracks to be segregated to avoid faults and train delays affecting HSR services. Principal French HSR terminus stations (Paris Gare du Nord, Paris Gare du Lyon, Marseilles, Lyon), have developed an 'elementary station' approach that divides station approach tracks into separated operating zones for local, longer-distance and HSR services. While this is not essential, it clearly assists in providing a reliable HSR service. The extent this should be adopted in the UK will depend on a combination of cost and level of HSR and classic train services.

If high speed trains are to be operated on the classic UK network for any significant length, and in particular the West Coast Main Line, they will probably need to be tilting trains. Without this, significant time will be lost on the classic network compared to today's Intercity trains and the high speed trains will become unattractive.

Mixed Traffic or Dedicated Passenger High-Speed Traffic?

Building railway lines that are able to operate passenger high-speed trains capable of competing with other transportation modes (planes, coaches and cars) and also capable of carrying slower trains such as freight trains, appears to offer the best of both worlds, giving two sources of revenue and selling available train paths.

This was the original intention for HS1. Freight loops were constructed, but freight services have not yet operated. Generally there are constraints in the use of mixed traffic such as:

- Access agreements between operators
- Safety constraints associated with aerodynamics of passing high-speed services and freight wagons
- Operating challenges of timetabling slower and faster mixed traffic on the same tracks resulting in loss of capacity
- The cost of cab-based signalling systems having to be installed in freight locomotives or other train cabs that have a wider origin/destination network beyond HSR.
- Reduction in maximum permissible cant to reduce rail head sidewear by freight trains leads to requirements for shallower track curves; consequently higher track costs and fewer alignment options.
- And, as already seen, much lower gradients are needed to permit use by heavy freight trains.

Accepted good operating practice is to dedicate new lines to high-speed passenger traffic (and in the case of SNCF high speed postal service in a TGV) and to create increased capacity for freight and commuter trains on the existing infrastructure. Germany constructed some high speed lines for both passenger and freight, and freight trains are operated on a daily basis on the Hanover-Würzburg high speed section of line, but no more mixed high speed traffic line are planned. No other countries in Europe have mixed-traffic HSR lines (except where they provide the only crossing of major physical barriers - the Channel Tunnel and Lyon – Turin).

To conclude, there may be a market for the operation of freight services on UK high-speed railway lines and consequential economic and environmental benefits. However, freight access to high-speed infrastructure needs to be carefully managed so that it does not disproportionately reduce the capacity or the value of the HSR infrastructure. There may be opportunities for using a HSR corridor alignment to construct additional track capacity for freight where demand flows are significant.

Capacity Constraints

A high-speed line has capacity constraints determined by both the safe operational spacing of trains on the line and the rolling-stock capacity.

The line capacity of HSR is directly linked to the stopping patterns chosen for trains on the route; the most critical factor being the difference between running times of trains with different stopping patterns. Overall, the highest capacity is obtained using only one stopping pattern - no intermediate stops on the journey (or all trains stopping at the same intermediate station), but for customer service and operational reasons this in not always preferable. Journey time calculations on high-speed lines are normally based on the minimum journey time, plus between 5% and 7% as an additional margin to ensure punctuality.

Various systems for calculation of line capacity are used in France on different lines, depending on the signalling systems and operating rules:

- 3’45” (3 minutes 45 seconds) is the technical headway on the South-East LGV, which uses the TVM 300 signalling system to achieve 12 paths per hour, partly due to the increased interval of between 4’ and 6’ applied when leaving Paris on the classic network.
- 3’45” is also the technical headway on the Atlantique LGV, using the same signalling in circumstances that permit more regular train interval of 5’ and achieve 12 paths per hour.
- By using TVM430 on the Northern & Eastern LGV lines, and reducing the technical headway to 2’45”, an increase to 16 train paths per hour have been achieved – with a regular interval of 3’ when leaving Paris. (4 ‘free’ paths per hour are applied on this route to accommodate any operational difficulties and improve reliability.)

ERTMS is a development that is to be applied on the LGV Eastern in the future, and when working as single signalling system (rather than one also monitored by the TVM 430 system) a reduction in technical headway to 2’30” will enable 18 paths per hour to operate, although this has not yet been demonstrated in service.

The presence of junctions (points and crossovers) also has a direct impact on line capacity, depending on the maximum speed allowed when running on the divergent route and the design of the points and crossovers used. Good design practice would reduce the number of conflicting moves on interfaces with the existing rail network, by installation of ‘flying’ or grade-separated junctions and reducing the potential for conflicting train movements, carefully evaluating the train headways and stopping patterns, in order to reduce the risk of train delays and ensure reliability is not affected by the use of the existing network – even short distances at the approach to terminal stations.

Train capacity varies with train design, and is naturally constrained by the length and width of the rolling-stock and the track gauge (structure gauge or train envelope). Single deck trainsets normally offer between 350 and 400 seats depending on the first/second class ratio, the size of the buffet bar and the seat spacing. Double-deck trainset versions have higher capacity (500 to 550 seats) but gauge considerations will restrict their application in the UK to new lines that can accommodate these trains.

There are several possible configurations, depending on passenger market and train length. For example, with 2 power cars push-pulling 8 double-deck coaches, a 500 seat capacity train can be formed from 3 first class coaches (offering 60 seats each), a buffet bar in the 4th coach, and 4 further second class coaches (90 seats each). This ratio can be modified to accommodate marketing decisions or local habits, thus providing more or less total seating accommodation. Coupling this to another trainset doubles the capacity to 1000 seats in a 400m long double-deck train, but this length may not be compatible with most existing stations.

Gradients

The notable advantage of a high-speed line, designed for that purpose alone, as opposed to a mixed traffic line, designed as a compromise between speeds and rolling-stock, is the gradient profile that can be achieved. Freight trains require gradients of no more than 10 – 15 per thousand (1.0% - to 1.5%) whereas 25‰ – 40‰ (2.5% - to 4.0%) is permitted for high-speed passenger trains.

Figure 5.2 represents this comparison graphically. It shows the design of the German NBS Hannover – Würzburg lines, designed for both high-speed passenger and freight traffic at 12.5 per thousand, and compares the vertical alignment with the design applied for the NBS Köln – Rhein/Main line designed for 300kph passenger services. The extent to which the alignment has been able to follow the surrounding topography, with a consequential reduction in civil engineering cost, is immediately apparent.

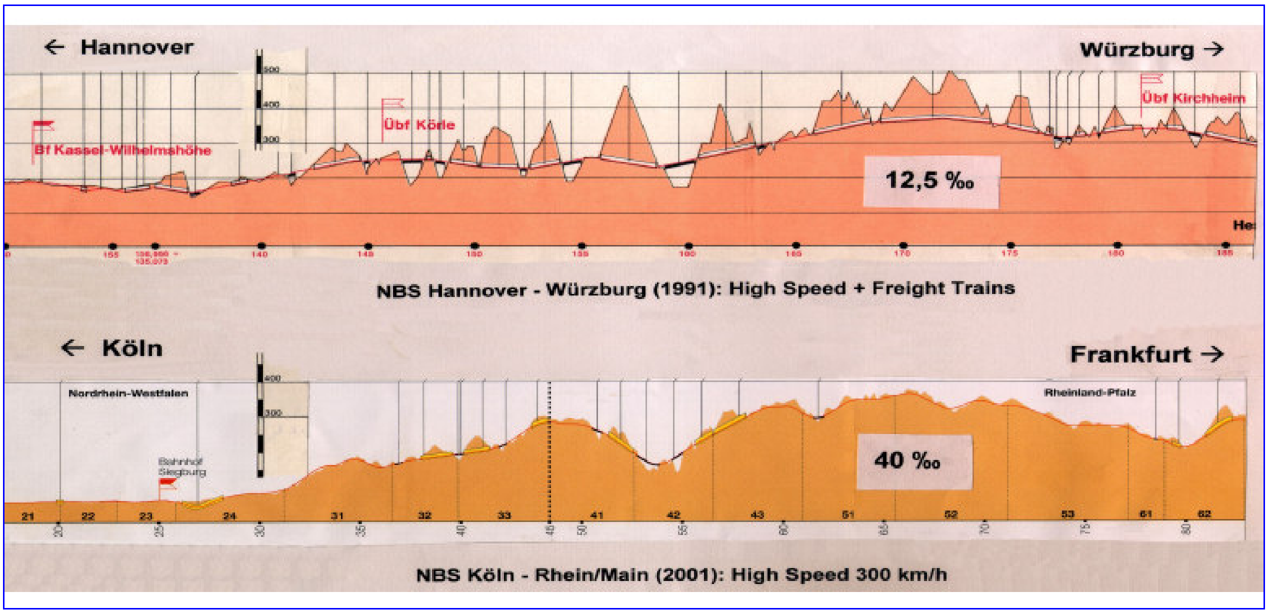

Figure 5.2 Permissible Gradients (Shown In Per Thousand) Of HSR For Mixed And Passenger-Only Rail Lines[54]

Although largely to be addressed in Workstream 4, we need to pay particular attention to topography in certain areas of the UK:

- Lancaster to the Solway Firth
- The Solway Firth to the Scottish Central Belt
- Tyneside to Edinburgh via the East Coast Main Line Route
- Yorkshire - Lancashire Trans-Pennine routes

However, by high-speed line standards, some of the most severe and notorious existing gradients in the UK are not excessive. The West Coast Main Line gradients from Beattock Station to Beattock Summit, ten miles, averages between 1 in 69 (1.45%) and 1 in 88 (1.14%). Shap - a gradient four miles long - is 1 in 75 (1.33%).[55]

Curvature

High-speed lines necessarily need shallower curves than lower-speed lines. Although minimum motorway radii are lower than those of high-speed rail, the minimum curve for a high-speed line carrying 300kph trains is typically 3500 metres, which draws a close curvature comparison with the majority of the motorway network, implying that alignment can follow existing motorway corridors. High-speed rail lines have less flexibility in their curvature than motorways because comfort considerations dictate the need for designed alignments which comprise regular circular curves and straight sections connected by designed geometrical transitions. Higher speeds can generally be achieved with tighter curvature on lines that are not designed to carry freight, since alignment and the amount of cant on curves can be optimised around a single operating (equilibrium) speed and clearly defined rolling-stock characteristics.

Experience of design development of HS1[56] was that:

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[54] Deutsche Bahn

[55] Transport Britain (December 2008). London Euston to Glasgow Central; The route of the Royal Scot. http://www.transportbritain.co.uk/route%20of%20the%20royal%20scot.html

[56] Meeting with Jeremy Candfield 26 /11/2008

- Use of existing transport corridors was advantageous in terms of planning, environmental impact and public perception.
- Addition of high-speed rail alongside existing rail lines was difficult and costly, both in terms of the alignment and construction of the new line and the essential modifications to the existing lines' structures and stations.
- Following the motorway and trunk network was generally advantageous in terms of public perception, alignment design and environmental mitigation.

Other Technical Constraints

In addition to the constraints referred to above, there are further considerations:

Structure Gauge – the need for bridges and tunnels to be large enough to accept trains passing at high speed for aerodynamic and safety reasons; also for platform edges to be consistent with the gauge of the trains. Routes from the Channel Tunnel to London Waterloo were upgraded before Eurostar trains were first introduced. Single deck high speed trains can be configured to be consistent with UK gauge (as in the case of Eurostar), but it is unlikely that double deck trains can be. Modifications can be made to existing infrastructure, and in some cases this may be appropriate; but if extensive running on the classic network is foreseen, this might be expensive. The most complex issue is platform edges, where to allow easy access platforms should be at a similar height to train floors and relatively close to them; this means that it is difficult or impossible to design platforms that can operate with trains of very different floor heights or widths at platform level.

Electrification – which is typically 1 x 25kV AC, (or 2 x 25kV AC in the case of HS1 reducing the number of substations). Strengthening of the catenary network to take greater upward pressure of HS services may be required. Boundaries between HSR and other forms of electrification require careful design, but can be achieved (HS1 has boundaries with 750 V DC electrification).

Rolling stock has to be capable of using available sources of electricity. The 'three capitals' Eurostar trains, until 2007, drew current from three rail networks - 25kV 50Hz AC, 3kV DC, 750V DC third rail. However, there are no plans for the HSR network in the UK to extend to the southern regions that use the 750V DC third rail, and none of HS1 currently uses this system. Therefore, all future trains need only be compatible with the 25kV 50Hz AC.

Signalling – to operate above the speed at which drivers can be expected to use lineside signals safely, high-speed trains must use cab-based signalling. (HS1 uses TVM 430).

Security – the potential need for screening of passengers and border control checks changes over time; the ability to operate direct services to Europe is affected by this consideration.

5.5 Future Transport Developments, Phasing and Cost

An important aspect of the development of high-speed rail in the UK is need to take full account of time. New infrastructure takes time to plan, design, build and commission. Full account needs to be taken of the consultation process, legal processes for land acquisition, preliminary design, tendering, major civil works and the need for systems installation and testing. The Channel Tunnel Rail Link Act was passed in 1996, after extensive design development, consultation and acquisition, which started in 1990. The line to St Pancras opened in 2007. During such a period of time economic cycles, technical developments and political changes are inevitable.

Future Developments

Here we briefly take note of the most significant influences that the inevitable progress of time will have on the project:

Technological developments in rolling-stock since the advent of high-speed rail have emphasised three aspects: speed; flexibility in service; and economy.

The speed of high-speed trains is normally considered to be above 250kph. HS1 has a maximum speed of 300kph. However, there has been significant speed evolution since the first high-speed lines were built – the world speed record has advanced from 330kph in 1979 to 575kph today and passenger trains have followed this evolution, such that design speeds above 300kph are expected and the commercial speed, defined as origin-destination distance / journey time, has also increased as alignments take advantage of achieving higher speeds during the journey. This evolution in maximum speed should be taken into account when undertaking preliminary design to meet target journey objectives (such as Scotland to London in less than 3 hours).

New rolling-stock has introduced multiple unit stock types, with high speed capability. This has implications for both overall journey time and environmental efficiency. More flexible train lengths and configurations that enable trains to be split into separate operating units[57], facilitate flexible operating patterns, more destinations served and higher load factors.

Energy consumption assumptions made in 2009 will need to be re-visited as new data is published, but the improvements which reduce carbon footprint can be considered likely.

The signalling systems for controlling high-speed train movements are inevitably based on technology that uses cab-signalling, since drivers cannot use lineside signals at very high speeds. European standardisation, in the form of ERTMS, is making slow progress, but projects are overcoming the challenges or developing both operating principles and the technology to improve capacity of existing and high-speed lines through this technology. Train services using ERTMS between the existing network and new lines are foreseeable.

Meanwhile, in the a similar development in the south-east of England, Hitachi Javelin trains will be in service in 2009 with dual-signalling capability – able to run in both lineside signalling areas and use cab-based signalling on the HS1 - a development with significant implications for future interchange of services between high-speed lines and conventional tracks.

Electrification is also gathering pace in the UK, with recent strengthening of the AC systems on the West Coast Main Line to an autotransformer system similar to that used on HS1. Infill of non-electrified lines, and announced projects to electrify both Glasgow - Edinburgh and the Great Western Main Line will improve the quality of services on these routes and have implications for the future flexible development of high-speed rail services that may be able to use the electrified lines. These investments and the line-speed improvements carried out in the past decade will need to be taken into consideration in WS4.

Other major rail projects of note include Crossrail, which will have a significant effect on the West-East travel patterns in London (particularly flows to from London to Heathrow) and will change the use of certain London termini. Whilst the use of Crossrail tunnels for HSR is neither foreseeable, desirable or technically likely, the implications of the project should be taken into account. Similarly, the arrival of new Thameslink and East London Line services, following these major investments, will be important considerations in analysing the congestion and development pressures in the London area.

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[57] Notably the Alstom AGV divisible into 3 x 133m units each with high-speed motor bogies

On the road network, projects including active road traffic management, hard shoulder running and congestion charging are all likely to be implemented, or to return to the topical agenda in the next decade, so the future developments of road transport corridors have to take these changes into consideration.

Airport growth, including, for example the usage patterns at London Heathrow's two runways, the status of a third runway there and the expansion of other airports, will also have implications for the future traffic demand and justification for HSR interchanges at airports.

Phased Construction and Cost

Phasing of the construction of a high-speed network will be considered in detail in Workstream 5. In all countries that currently have a high-speed rail network, a phased introduction has occurred. This enables the considerable construction effort (some of which uses skills specific to the railways such as signalling) to be used efficiently. It also phases the need for the provision of funding which will be significant irrespective of the balance of private or public sources. Finally, it allows evolution of the network, and the generation of improved knowledge and skills, related to planning, construction, operations, revenue forecasts and engineering. One of the objectives of WS5 of this study will be to provide an indicative overall strategic phasing plan.

International experience of developing a network would indicate that a national objective for the network is a pre-requisite to an effective plan. Lines can then be built as part of a coherent master-plan. Inevitably, those with the strongest business case are constructed first, with intermediate infrastructure solutions associated with the operation of services on both part of the new and part of the old networks being used as a way of reconciling the inevitable funding and construction programme with the need to generate train ridership.

6 Conclusions

6.1 Introduction

The previous sections of this document have discussed various objectives for a high-speed rail network in the UK as emerged from the stakeholder consultation, and have reviewed these in the context of both the UK transport market and constraints on the solutions that might be adopted.

From this analysis, we now draw together some *guiding principles* that will be valuable in order to make strategic choices about network options to be explored in Workstreams 4 and 5.

The *guiding principles* are designed to address a number of important points:

- This development programme aims to develop a national *strategy* for high speed rail, not a single project;
- There is a clear need, emerging from discussions with Public Interest Group members, to consider the needs of *customers* first, followed by the configuration of rail services and then the infrastructure needed to deliver these;
- In considering what is potentially a very important development of the nation's infrastructure, the role of transport is recognised as being to *support the nation's broader, long-term social, environmental and economic objectives*;
- The overall impact of HSR should be to *reduce carbon emissions* from the transport sector.

Guiding Principles

(i) Capacity

HSR routes need to be located such that they provide additional capacity for the national transport system where there is forecast to be unmet demand on the long-distance routes and create high-value capacity relief on the existing rail network.

(ii) Sustainable Economic Regeneration

HSR needs to serve places which are capable of stimulating economies to achieve growth, regeneration and wider productivity benefits and to stimulate and support a sustainable pattern of development.

(iii) The Whole Journey

HSR has to be planned to address the whole journey, as identified in TaSTS, to make it an attractive, lower carbon, alternative to car use.

(iv) Modal Switch from Aviation

HSR needs to be able to attract travellers away from short-haul aviation to/from major international hub airports in order:

- **to free-up runway capacity for more valuable longer-distance services, *or***
- **to reduce carbon emissions, *or***
- **to provide a suitable HSR service in cases where it has been found necessary to withdraw air services that have a significant effect on business travel and the economy.**

(v) Phased Development to deliver Comprehensive Benefits

HSR needs to be planned as a system to be properly integrated with other transport facilities to maximise the value of the investment, with complementary measures identified as necessary, to ensure a comprehensive and nationwide spread of benefits and with each phase of development reflecting this aim, to the fullest extent possible.

6.2 Guiding Principles

(i) Capacity

HSR routes need to be located such that they provide additional capacity for the national transport system where there is forecast to be unmet demand on the long-distance routes and create high-value capacity relief on the existing rail network.

1. This means that HSR routes need to provide additional capacity into the centre of the major cities they serve, including London, Birmingham, Glasgow, Edinburgh, Manchester and Leeds, where the inter-urban rail network is operating at, or close to, capacity.

2. Similarly, HSR networks need to be planned so that they create additional commuting capacity where there is forecast to be a capacity short-fall on current plans.

3. Freight network capacity released on the main lines needs to be matched by suitable availability of paths to reach terminals, ports and to cross London. Insofar as this challenge arises, it needs to be addressed as part of the thinking on HSR otherwise its benefits will be reduced.

4. HSR capacity needs to be provided where it can help overcome constraints in the networks of complementary or competing transport modes

5. There is a need to demonstrate that corridor growth forecasts are resilient in the face of economic and demographic uncertainty.

(ii) Sustainable Economic Regeneration

HSR needs to serve places which are capable of stimulating economies to achieve growth, regeneration and wider productivity benefits and to stimulate and support a sustainable pattern of development.

1. HSR needs to provide direct access to city centres or, possibly, other locations where large-scale regeneration and high development densities are considered desirable and where the economic benefits of agglomeration can be realised, or where existing or projected demand is intense.

2. Cities so served need to have complementary local, city-region and regional development plans across the relevant sectors so that HSR has a material economic impact.

3. The effect of HSR needs to be such that the locational disadvantages of northern and western cities are seen to have been materially reduced and unwanted long-term development pressure in the southeast relieved.

4. The overall HSR service offer needs to be perceived to offer a step-change in quality, with faster journeys offering an advance in accessibility and a level of reliability that fosters investor confidence.

5. The energy characteristics of HSR and its ability to lead to a sustainable choice of travel mode will need to be treated as critical design considerations.

(iii) The Whole Journey

HSR has to be planned to address the whole journey, as identified in TaSTS, to make it an attractive, lower carbon, alternative to car use.

1. HSR services will have to offer safe and secure, attractive, reliable and substantially reduced journey times, able to attract travel not only to and from city centres but across wider catchments and across social and income groups.

2. To create a connected sustainable alternative to car travel across a wide set of destinations, there is a need to have HSR stations serve as hubs, connected conveniently into feeder rail and other public transport services and accessible by walking.

3. There will have to be substantial provision for road-based access modes, including cycle and private car, at HSR stations, planned from the outset to minimise overall carbon emissions and local highway congestion.

4. Parkway stations will only be considered if they do not detract from the ability to achieve the objectives set in relation (a) to city centres and (b) to achieving an overall reduction in carbon.

(iv) Modal Switch from Aviation

HSR needs to be able to attract travellers away from short-haul aviation to/from major international hub airports in order:

- **to free-up runway capacity for more valuable longer-distance services *or***
- **to reduce carbon emissions, *or***
- **to provide a suitable HSR service in cases where economically-significant air services have been or are at risk of being withdrawn.**

1. HSR has to be able to offer journey times that can win significant route/hub market share.

2. Direct HSR access to airports should only be considered where there is sufficient demand for viable HSR services.

3. To be an acceptable substitute for international inter-lining traffic, access from HSR to air terminals should be as attractive, and convenient, including on security and ticketing issues, as from another flight.

4. HSR has to be able to match effective airline frequency. Since the capacity of an HSR train is much higher than a typical domestic aircraft, this can only be viable if *either* there are large-scale airline passenger flows (typically with vibrant inter-airline operator competition) *or* the HSR service not only serves the airport market but also other valued destinations and/or a string of city destinations that can be attractively served by a single airport service.

5. To address the near-continent short-haul market, HSR services will need to be capable of direct operation over the HS1 route and onwards over the expanding European high-speed rail network.

(v) Phased Development to deliver Comprehensive Benefits

HSR needs to be planned as a system to be properly integrated with other transport facilities to maximise the value of the investment, with complementary measures identified as necessary, to ensure a comprehensive and nationwide spread of benefits and with each phase of development reflecting this aim, to the fullest extent possible.

1. There will have to be a long-term national strategy with a phased flexible implementation approach.

2. To ensure the long term benefits of HSR are secured for the cities, regions and devolved nations, the delivery of HSR should be supported by complementary planning and economic development measures.

3. Ways should be found to ensure that areas through which new HSR infrastructure passes are able to benefit from improved local services where this is feasible, and do so without the provision of non-viable capacity-consuming stations on the HSR alignment itself.

4. The benefits of freeing capacity on existing main lines needs to be demonstrated for communities that may not be directly served by HSR.

5. The HSR long term network strategy needs to address all of the English regions and the devolved nations.

6.3 Preliminary Technical Conclusions

To provide benefits across Britain, and to allow phased development, the high-speed rail network needs to be technically compatible with the existing rail system.

The design itself should maximise train capacity on the part of the route dedicated to high-speed trains, to optimise train flows, with high-capacity rolling-stock where possible.

The potential for use of tilting trains should be considered, to allow onward operation of rolling-stock and passenger services on the existing network.

Although reduced journey time is an objective, rather than speed, international experience indicates that design should maximise speed where possible.

To facilitate national network coverage, and to accommodate forecast future demand, sufficient capacity for two rail routes (or one 4-track line) north from London are likely to be required.