A Strategy for a High Speed Rail Network in Britain – John Segal, MVA Consultancy

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Introduction

This paper considers what high speed rail in Britain could and should look like in forty years time. There has been substantial recent interest in high speed rail, most of which has focused on the next steps: where should the first high speed rail line be constructed[1,2]? By contrast, this paper focuses on the longer term: what does a strategy look like?

While it does consider the shape of the network and the nature of services that might operate on it, the paper is also as much about the objectives of high speed rail; what are we seeking to achieve with it; indeed, why would we want high speed rail?

It is based on work undertaken by SYSTRA[3] and MVA Consultancy[4] for Greengauge 21 from September 2008 to September 2009. Greengauge 21 is a Limited Company with the objective of furthering the debate in Britain around high speed rail. In 2008, it formed a Public Interest Group of interested stakeholders who went on to fund the study described in this paper. The Public Interest Group[5] consists of a number of UK Regional Development Agencies, cities, Rail and other transport operators; various government bodies[6] acted as observers on the Steering Group of the study.

The objective of this study was to develop a strategy for a high speed rail network in Britain, identifying and taking account of the different objectives of relevant stakeholders. SYSTRA and MVA were the Principal Consultants, with other consultants undertaking parallel studies into stakeholder and public consultation, market research, planning issues and funding.

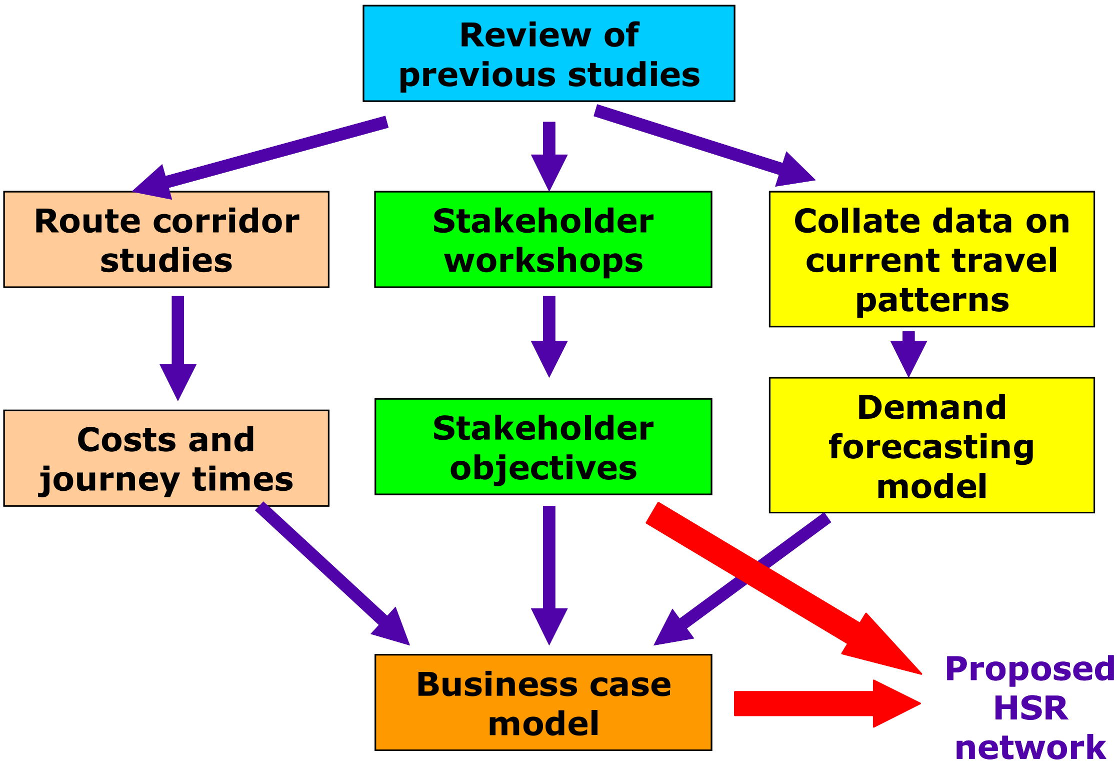
Following this brief introduction, we:

- describe the study methodology
- review the findings of previous studies and technical issues
- present the Guiding Principles we identified for high speed rail in Britain
- discuss route selection and costing
- present our methodology for demand forecasting
- explain the process for economic appraisal, including how Wider Impacts (Wider Economic Benefits) were estimated
- present our main conclusions and recommendations on the shape of a high speed rail network.

This paper represents the views of the author and not necessarily those of Greengauge 21 or any members of the Public Interest Group.

Study Methodology

The following diagram summarises the methodology adopted in the study.



We started with a review of previous studies to identify:

- reasons for high speed rail
- technical constraints and standards
- key elements of a high speed rail network, including associated works
- what did other plans look like and why
- previous appraisal elements.

We then discussed with stakeholders the objectives for high speed rail and developed jointly with them some Guiding Principles.

We collated data on existing travel patterns and developed models for demand forecasting and business case appraisal.

Finally, we tested a wide range of high speed rail network to identify which best met the objectives identified.

Review of previous studies

We considered a wide range of previous studies, some of them in the public domain, others private. They were very varied in their approach, some being engineering led, others came from a railway operational angle. In some, objectives were clearly stated, others assumed a case for high speed rail. Our overall conclusions drawn from this review were:

- the principal objective in most cases (where it was stated) was to increase rail capacity
- economic regeneration was also a fundamental objective; however, while there were many cases where high speed rail had had a positive impact on local economies, this was not universally so; the key criteria to create positive economic impacts seemed to be:
  - stations must be in city centres or other locations where economic activity can be generated
  - such economic regeneration must be planned (Lille is an excellent example) – while the market will respond, governmental action is usually required at least to kick start the regeneration
- public transport access to stations is vitally important
- integration with the existing rail network is important; through running to destinations off the core network (where a new high speed line cannot be justified) substantially increases benefits
- technical standards on gauge, train length, gradients, curvature, etc were established
- maximum speed was between 300 kph and 350 kph to maintain high capacity; lower speeds (200 kph) could be considered in tunnels, passing stations, or other specific geographical features, but these will affect journey times for non-stop trains
- line capacity was established as 15 trains per hour; but this is reduced if there are intermediate stations; if trains are not of a standard speed (and acceleration) capability, then this will be substantially reduced
- intermediate stops cost about ten minutes of journey time and also affect line capacity.

Guiding Principles for High Speed Rail

We held a number of workshops with stakeholders so as to understand their objectives for high speed rail. From these we developed five Guiding Principles. These are detailed below.

Guiding Principles for High Speed Rail development

1. 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.

- HSR routes need to provide additional capacity into the centre of the major cities they serve, particularly where the inter-urban rail network is operating at, or close to, capacity.
- 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.
- 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.

2. Sustainable Economic Competitiveness	**HSR needs to serve places which are capable of stimulating economies to achieve growth, recovery and wider productivity benefits, and to stimulate and support a sustainable pattern of development.**

- HSR needs to access city centres and to have high-quality stations where large-scale regeneration and high development densities are considered desirable, or where existing demand is intense.
- Cities so served need to have complementary city-region and regional development plans across the relevant sectors so that HSR has a material economic impact.
- The effect of HSR needs to be such that the locational disadvantages of northern and western cities are reduced and pressure from long-term development in the southeast relieved.
- 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.

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

- 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.
- To create a connected rail-based alternative 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.
- 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.
- 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.

4. Modal Switch - Aviation	**HSR needs 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; and/or reduce carbon emissions; and/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.**

- To be an acceptable substitute for international inter-lining traffic, access from HSR to air terminals has to be as attractive and convenient, including security and ticketing issues, as from another flight.
- HSR has to be able to offer journey times that will compete effectively with air and win significant route market share.
- HSR has to be able to match effective airline frequency. The capacity of an HSR train is much higher than a typical domestic aircraft; this means either the air passenger flows are large or the HSR service not only serves the airport market but also other destinations, and/or a series of cities that can be attractively served by a single airport service.
- 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.

5 An Integrated Network for All	**HSR needs to be planned as a system, developed in a staged programme, properly integrated with other transport facilities to maximise its value, with complementary measures identified as necessary, to ensure a comprehensive (nationwide) spread of benefits that has relevance and appeal across all social groups and types of traveller.**

- There will have to be a long-term national strategy with a phased flexible implementation approach.
- 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
- The benefits of freeing capacity on existing main lines and local networks need to be demonstrated for communities that may not be directly served by HSR.
- The HSR long term network strategy needs to address all of the English regions and the devolved nations.

There was agreement of all stakeholders on these objectives, although the priorities might differ. For example, from Scotland journey time to London was generally considered most important (especially achieving less than three hours from both Edinburgh and Glasgow), whereas for locations in England, capacity of the transport network and access to Heathrow were more important. All parties were strongly in favour of reducing carbon emissions, although the balance between the importance of this and economic regeneration varied. Interconnection within certain regions was seen as very important in some cases (most particularly the north of England).

Route selection and costing

The study was not intended to design specific routes. However, it was important to be able to establish that routes were in principle feasible, including access to city centre stations where appropriate, and to be able to estimate costs at a high level. We therefore did consider the various route corridors to ensure feasibility, any major environmental issues, likely length in tunnel or viaduct (because of the impact on cost), and access to potential stations (although we were not definitive as to the best locations for these).

Infrastructure costs were based on the experience of high speed rail in Britain (the Channel Tunnel Rail Link – High Speed 1) and abroad, particularly France. Capital costs of rolling stock and operating costs were also estimated. Outline changes to the classic rail service were assessed and the associated cost changes taken into account.

We did not consider the appropriate institutional arrangements (franchising, regulation, etc) although a separate study did look at funding issues; we provided an assessment of annual cash flows for a number of scenarios to this study.

Demand forecasting

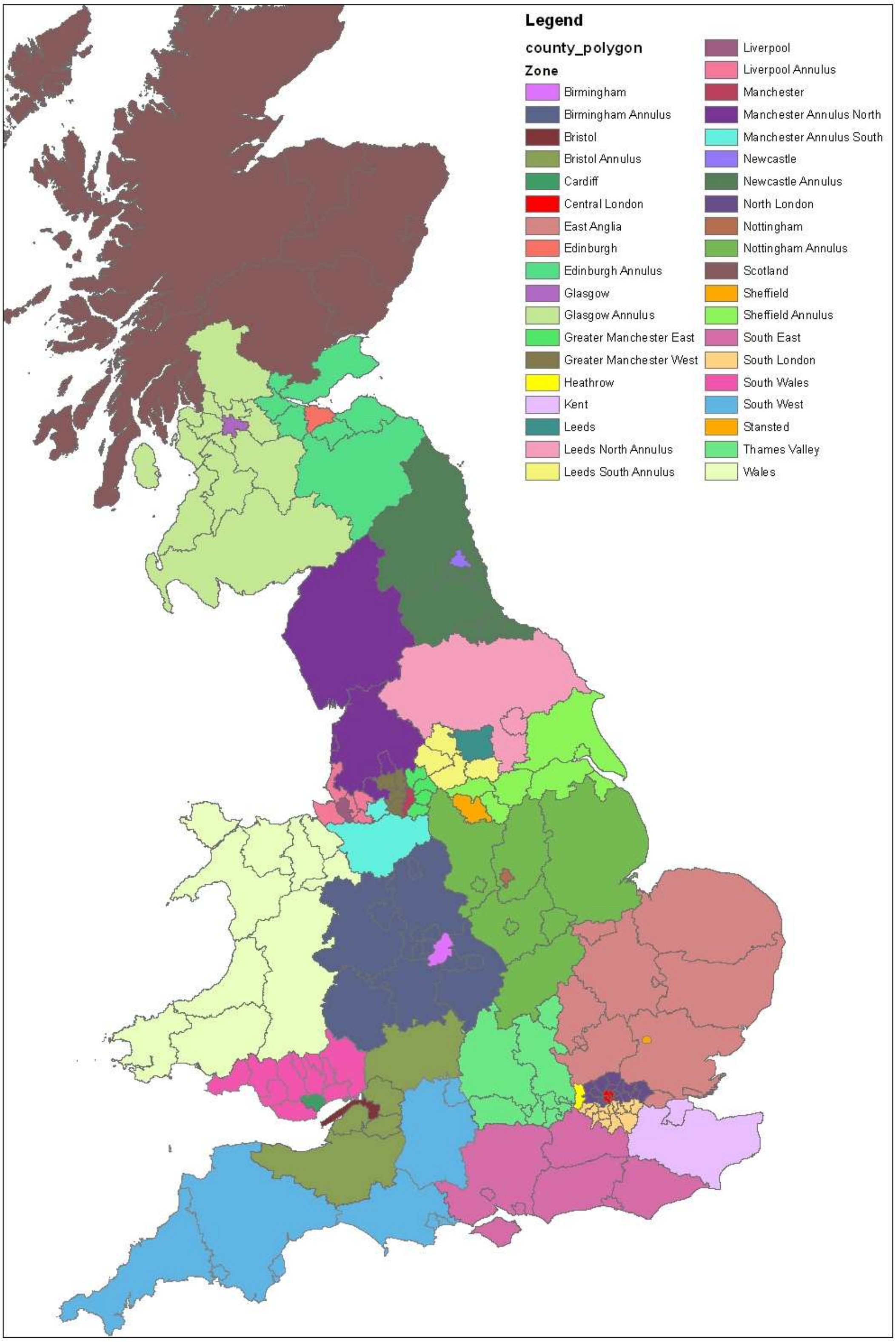
Most rail forecasting in UK is done in a uni-modal way due mainly to the lack of information on car traffic. However, that is clearly inadequate for a major change such as high speed rail. It was therefore necessary to construct a multi-modal long distance traffic matrix and then forecast mode choice in different situations. In addition, the generative impact of a new (or greatly improved) transport mode needed to be taken into account.

High speed rail will compete with air (where such services are provided), car and classic rail (note that in the UK classic rail services are today relatively fast in many corridors, with 200 kph being the common maximum speed). In most cases, coach is not a relevant mode, as it is only used today by those with low values of time, and hence increases in rail speeds are unlikely to attract coach users to switch mode. This one major exception to this is for access to Heathrow, where from much of the country, rail involves a difficult and time consuming interchange across London, and direct coach services are available. Hence, coach was only considered for this market, where it was treated as if it were classic rail.

Rail is generally an attractive mode to/from city centres where stations are typically located and road access (including parking) is difficult. On the other hand for journeys from suburbs or rural areas that might be 30 minutes or more from a high speed rail station, car is likely to remain attractive. The attractiveness of air also depends on accessibility to the airport. We therefore developed an unusual zoning system specifically to address this issue. To keep the forecasting element of the project manageable, we decided to have a modest number of zones (the eventual number was 39), but to focus these on city centres. We thus had a number of relatively small (geographically) city centre zones each with one (or in some cases a few) annuli around them. The very different base mode shares for the different types of zone supported this approach.

A map of the zoning system is shown below.

Zoning system



The base demand data needed processing to these zones.

For rail, the essential demand comes from ticket sales which are clearly on a station to station basis; however, the catchment areas of many large stations extend beyond the city centres. In 2005 the Strategic Rail Authority undertook a substantial survey of rail passengers which included collecting the actual origin/destination of passengers as well as the station used. We used this data for the large stations (filtering on only long distance flows) to allocate demand to city centres and the surrounding areas. We also used this data to provide estimates of business and leisure travel (there is limited long distance commuting, and this was included within business travel).

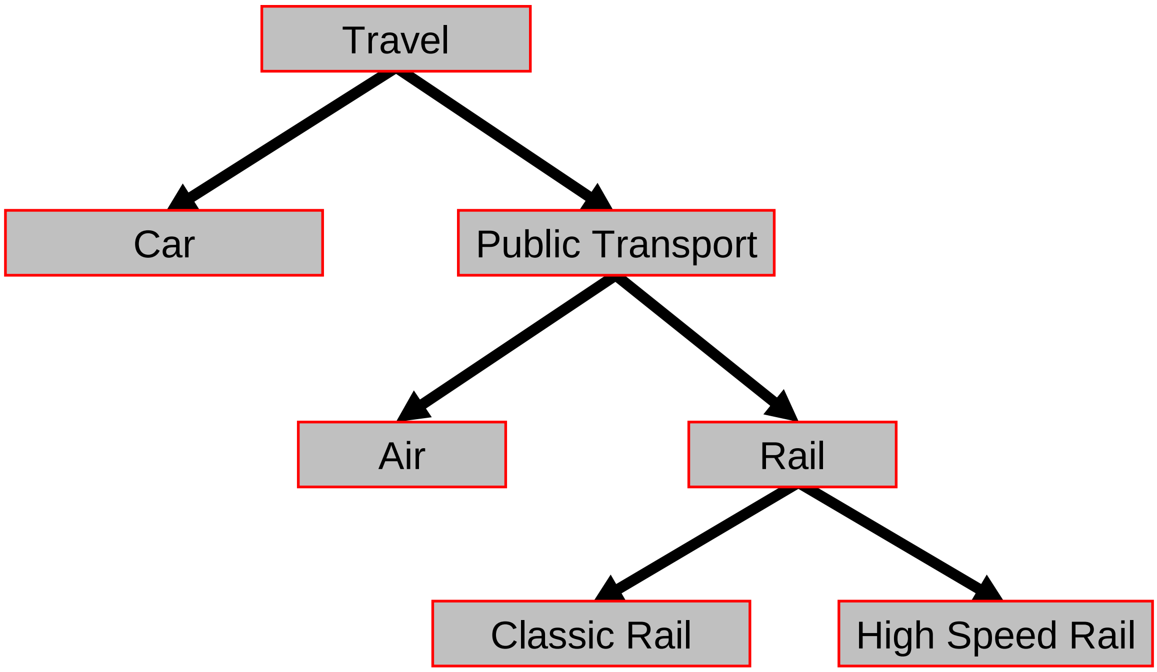
Airport to airport flows were taken from published Civil Aviation Authority (CAA) Statistics. This was then allocated to the various zones using a CAA survey of access/egress to airports. Interlining and point to point air demand could be identified in the base data; we included a specific Heathrow zone for interliners, which is especially important for this airport. The CAA survey also provided the journey purpose information for air passengers and the extent of access to Heathrow by coach from different origins.

There is no survey of long distance car traffic in the UK. To create this element of the database, we started with the Department for Transport's (DfT) National Transport Model. This model contains a synthesised car trip matrix. On examining this data, we established that for long distance trips it contained certain anomalies; in discussion with the DfT, we made some adjustments to provide a more realistic long distance car trip matrix matching our zoning system.

The base demand was grown to future years in line with DfT forecast growth for car travel, and standard rail GDP elasticities for rail; these were also applied to air demand, noting that this assumes that there is no constraint (either capacity or in terms of carbon impacts/pricing) on air travel.

Our mode choice model was a standard hierarchical LOGIT model.

Mode choice model

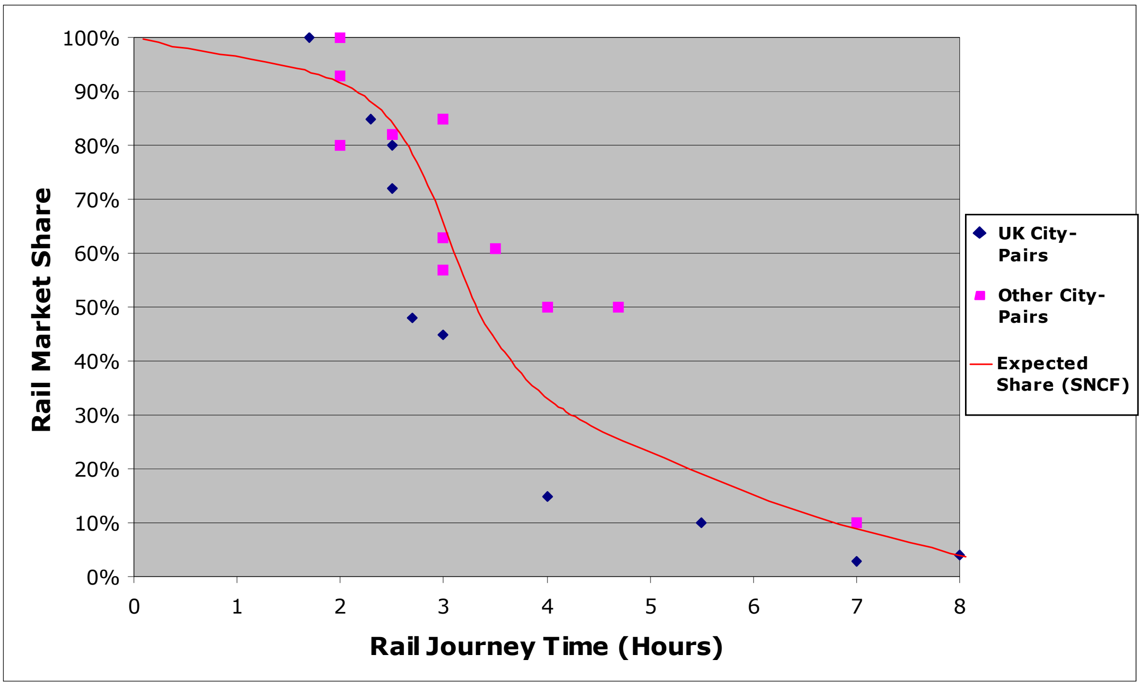


We wished to reflect in our model the likelihood that certain trips might be captive to particular modes. In particular, people with considerable luggage might not consider any mode other than car. In addition, experience indicates that a considerable proportion of the increase in travel on rail does not come from other modes, but is newly generated travel; we sought to model this by considering that some of the rail demand was effectively captive to rail and would not travel in the absence of a rail service, but could increase frequency if the rail service improved (an elasticity to generalised cost of rail formulation was used for this element).

Although we retained the mode captive element in our eventual model, we did not find that it added very significantly to the explanatory power or overall model credibility.

The model was calibrated to achieve both accurate representation of the base mode shares, and appropriate sensitivity of the model to rail and other mode characteristics such as cost and journey time. Elasticities are presented in the Passenger Demand Forecasting Handbook (PDFH) which is maintained by Britain's railways; although these are at the station to station level, and not our zonal level. Furthermore, the PDFH is relatively weak where air competition is concerned, and an alternative source was used for this. There is a well established graph of mode share (rail vs air) which was created originally by French National Railways (SNCF), but has been updated by various parties. This is still considered to be appropriate and presents rail share of the rail plus air market dependent on the rail station to station journey time. It is presented below.

Rail share of Rail/Air market



It is worth noting that this graph implies some very large elasticities at the point where the rail market share is close to 50%.

It is not possible to calibrate either the elasticity for generated demand, or the choice between high speed and classic rail. For the generated demand, we used a relationship that, in the absence of air competition, the increase in long distance rail demand comes broadly equally from abstraction from car and generation of new travel. For the choice between high speed and classic rail, we expect this to be more sensitive than that between rail and air. There is some evidence when there are competing rail services in UK (eg Peterborough – London, Birmingham – London) that if the time difference is greater than 30 minutes, the faster service gets the vast majority of the demand even if fares are higher. The spread parameter for the rail-rail competition was set at twice that of the level above (rail-air) which gave results that were broadly consistent with this.

A final element of the model was the assessment of the suppression of demand due to crowding. This applied to long distance services, both high speed and classic. As our model had an appraisal period of 60 years, and we increased demand up to 2055, there was potential for substantial crowding that would suppress demand. Indeed, in high speed scenarios with only a single line north from London, there was forecast to be substantial crowding on this line from approximately 2040 onwards (despite much larger capacity trains being assumed than today's Intercity trains). The crowding was based on a high level formula that uses a Gamma distribution to predict the proportion of trains that will be full and the extent of suppression of demand on these trains. We have used such models before, and they are included in the DfT's PLANET Strategic model; hence we had parameter values that we could readily use in our model, although it should be noted that the extent of crowding forecast is considerably beyond that experienced today on long distance services.

Economic Appraisal and Business Case

A specific business case model was developed that calculated the revenue, costs, user and non-user benefits, carbon impacts, and incorporated Wider Impacts (previously called Wider Economic Benefits (WEBs)). This model appraises the high speed rail scenarios in a way that is compliant with DfT guidance as presented in WebTAG (Web-based Transport Appraisal Guidance) and the New Approach to Transport Appraisal (NATA). The Benefit:Cost ratio (BCR) is calculated in the prescribed way as the socio-economic benefits divided by the public sector funding requirement. This can be calculated as:

$$BCR = \frac{socioeconomicbenefits}{netrevenue - net\cos ts}$$

The model also allocated the benefits to the appropriate region where this can be done meaningfully (not all benefits are geographically specific).

However, as described earlier in this paper, a high speed rail network is not simply a transport project; it has objectives that are much greater than simply those of other transport schemes. We set down earlier the Guiding Principles agreed by stakeholders for a high speed rail network. Each of the scenarios was appraised against these in addition to the standard appraisal methodology. For some of the Guiding Principles, only a qualitative assessment can be made, but in other cases some quantification could be made.

Additional rail capacity was assessed separately in three categories:

- Additional local passenger services whose benefit is mainly additional capacity for commuters; the reduction in crowding on such services was estimated
- Additional interurban passenger services whose benefit is mainly increased frequency; the user benefits associated with this was estimated

- Additional Railfreight services whose benefit is mainly the reduction in lorry miles and associated carbon and highway congestion impacts.

The crowding benefits of high speed rail, including the effects on long distance and local services were estimated first as demand impacts, and then converted to economic benefits by calculating the equivalent journey time that would have produced the same change in demand.

The regional economic impacts of high speed rail were considered very important by stakeholders. High speed rail is such a large change to the transport system, that it can be expected that individuals and businesses will make locational decisions based on the new service; that is, it will facilitate the regeneration of local and regional economies. To estimate the scale of this, we utilised a Land Use Transport Interaction model built by David Simmonds Consultancy[7] for this study to predict the impact on employment in each of a large number of zones across the country. The attractiveness of each zone for economic activity depends on its accessibility, measured as the weighted average transport generalised cost of travel from that zone. Zones which had high speed rail services gained in accessibility and hence in employment; zones which had no high speed rail typically had no change in accessibility, but lost out slightly in employment because they became relatively less accessible.

These changes in employment, and associated changes in transport generalised cost were processed in the standard way (see WebTAG[8]) to calculate the economic benefits associated with agglomeration and related factors. These benefits were then allocated to regions to identify whether high speed rail could be expected to reduce the north-south regional divide in the UK, as hoped. This was the case, and it is worth noting that the WEBs typically represented about 20% of the journey time benefits.

The demand model readily presented the impact on both car and air travel and the associated carbon effects. The calculation of carbon was made according to work undertaken by the Association of Train Operating Companies (ATOC) as their contribution to the Greengauge 21 study. It is available on the latter's website[9].

The final Guiding Principle refers to an integrated network giving benefits across the nation. This is difficult to quantify, but did lead us to spreading the network geographically, including services running off the core high speed network to destinations on the classic network. It also led us to adopt a policy of no fares premium on high speed rail, although clearly this is something to be decided later by government. No fares premium maximises the BCR and ensures that individuals are not priced out of the benefits of high speed rail; it also reduces the likely extent of competing classic services and hence releases maximum capacity for complementary services, thus maximising the benefits from reduced crowding on the classic network; however, it does increase to some extent the requirement for government funding.

Conclusions and Recommendations

We appraised a large number of scenarios, and as a result were able to draw some important conclusions prior to recommending an overall network:

- high speed trains should operate beyond a core network onto the classic network in many cases

- but a core high speed network can take larger trains – 400m long and double deck; this gives a capacity of approximately 1000 seats per train compared to about 400 for those that operate onto the classic network

- stations need to be in city centres to provide good (public transport) access and to reinforce economic planning policy

- there may be role for specific 'Parkway' stations provided they have good public transport access as well – airports often provide good locations

- HSR can release capacity on existing Intercity trains, and also for local trains (commuters) and inter-regional

- freight can utilise some of the released capacity – particularly on West Coast route

- the total demand for high speed rail north of London is likely to exceed the capacity of a single line by about 2040

- two 2-track routes are likely to give greater benefits in comparison to cost than a single 4-track route

- the strongest case for the initial route is London – Birmingham – Manchester

- the extension to Scotland is particularly strong, given the ability to abstract from air

- an East Coast route to Leeds and Newcastle is needed for capacity and journey time reasons

- the case for extending this route to Scotland rests on a mix of high speed West Coast capacity and connections between Scotland and eastern England

- Heathrow is worth serving (as the airport itself – it enables interlining traffic to be abstracted and potentially hence air services (and associated carbon emissions) to be completely removed); it will also be an excellent transport hub for west London and the surrounding area when current plans such as Crossrail and Airtrack are implemented

- however, Heathrow should not be on the route between London and Birmingham because of the impact on journey time and capacity; it should be served on a spur

- the opportunity this offers is to provide through services to destination south of Heathrow, thus putting Heathrow on a London bypass, much as Charles de Gaulle airport is in Paris; this would allow a higher frequency service to be justified, as several markets can be combined on the same train

- South West and Wales can probably best be served by a partial upgrade to existing route rather than full High Speed Rail

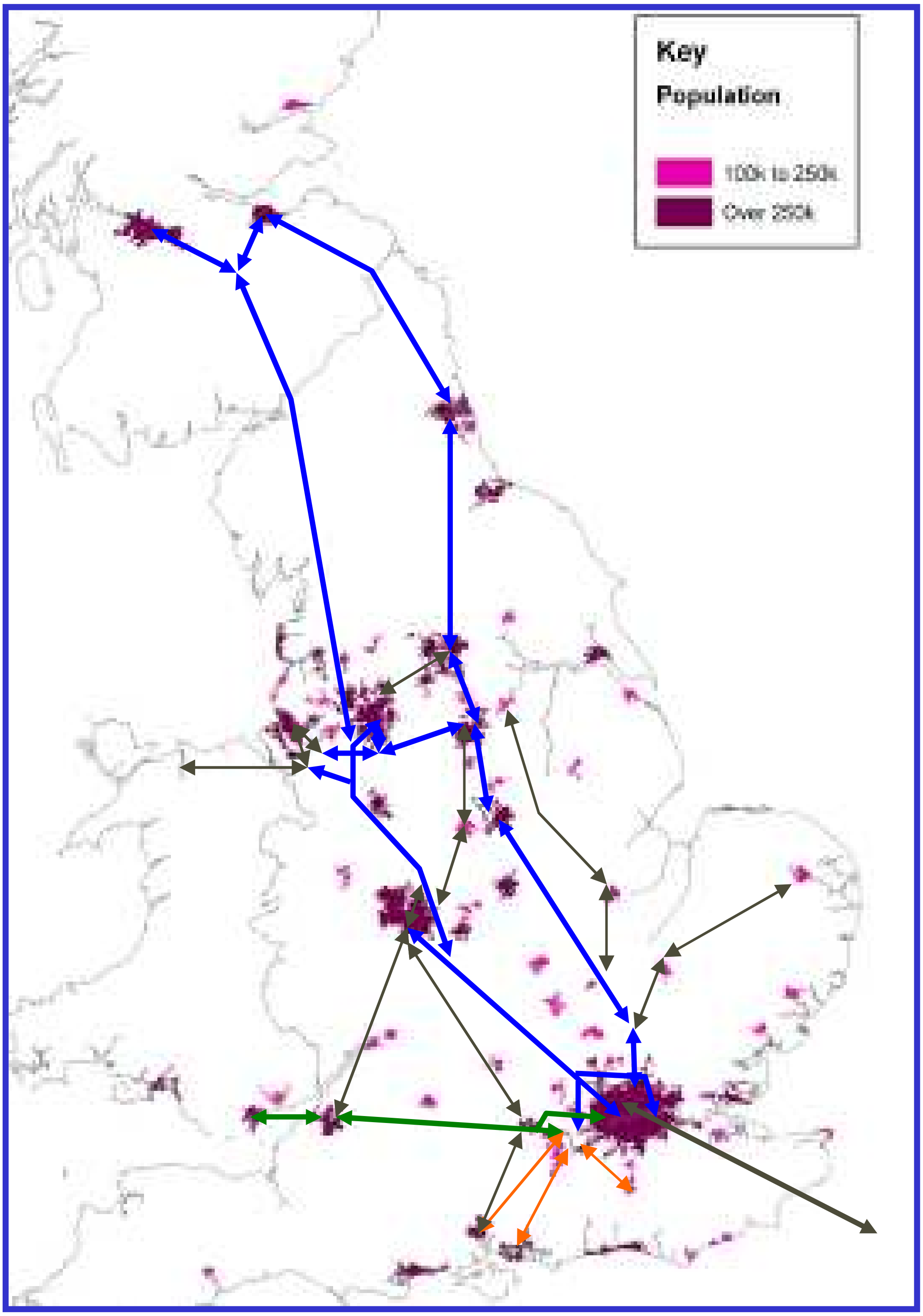
- A link to the Channel Tunnel is worthwhile if it can be provided at reasonable cost.

Recommended High Speed Rail Network

The following map indicates our view of the high speed rail network that best meets the overall needs of stakeholders and gives an excellent BCR. It consists of two routes north of London (one broadly following the West Coast, the other the East Coast route). There is an upgraded route to Cardiff and Bristol, and a Transpennine link that both assists in economic cohesion across the northern region, and provides a number of valuable longer distance links. There are links to Heathrow Airport and HS1.

High capacity trains (1000 seats) operate over the core network between London and Birmingham, Manchester, Glasgow, Edinburgh, Leeds and Newcastle. A wide range of British gauge trains (400 seats) operate on the high speed network and then to destinations on the classic network such as Liverpool, other cities in the North West, Yorkshire, south and north Wales, the South West, East Anglia, and towns south of Heathrow.

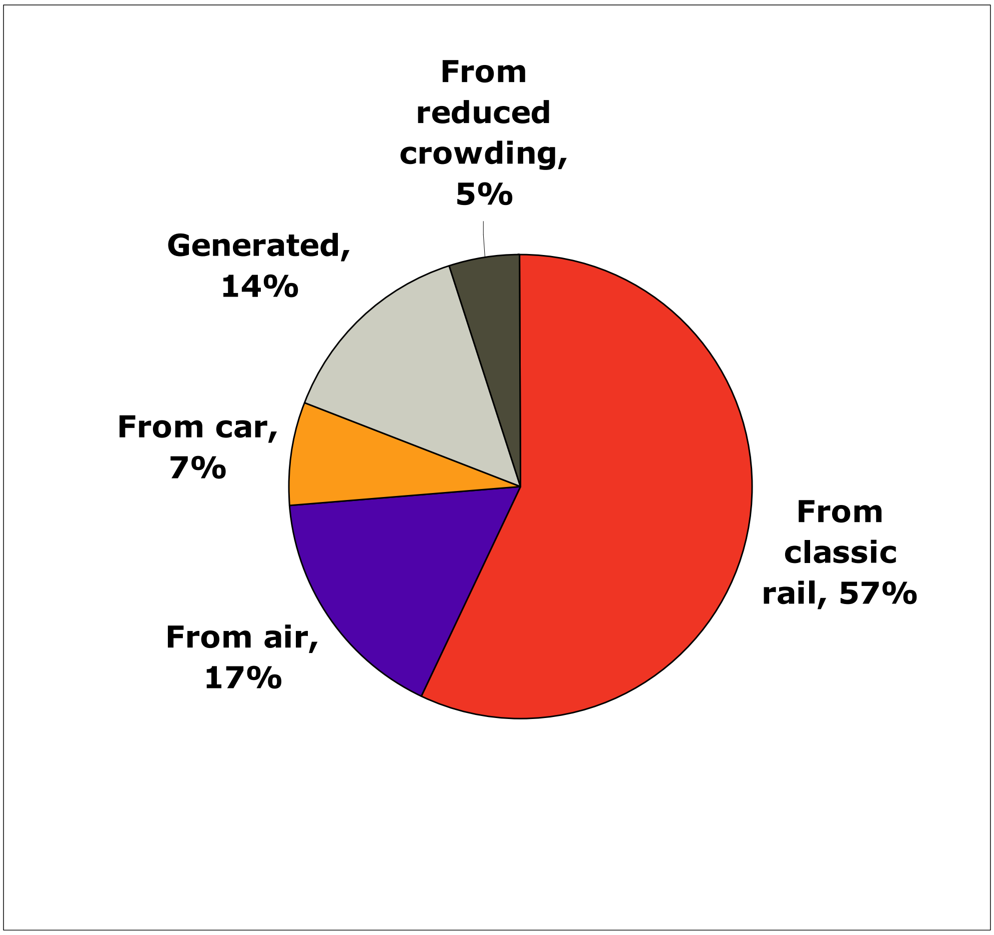
Possible High Speed Rail Network



Impact of the High Speed Rail Network

We estimate that in 2055, 178m trips could be made on a comprehensive High Speed Rail Network. The source of these trips is shown below.

Source of High Speed Rail Trips (2055)

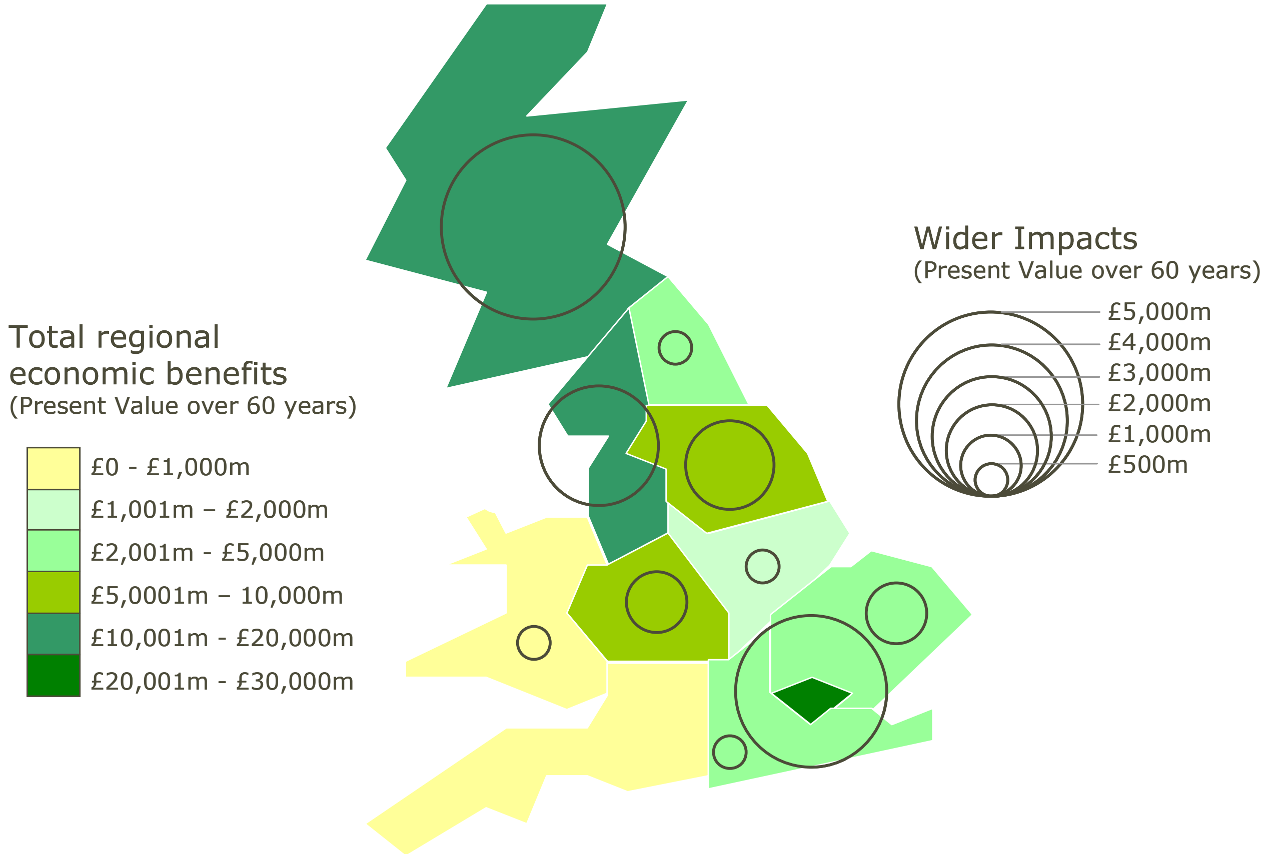


The cost of infrastructure to construct the network would be about £69bn in 2008 prices, including optimism bias. The network would lead to a net increase in rail operating costs of £2.6bn pa, but a net increase in rail revenue of £4.6bn pa. 2.7bn car-km would be removed from the highway network pa, along with 0.4bn HGV-km. 18bn air passenger km would also be removed pa (assuming that there was capacity for such air flows in the absence of high speed rail). Overall, approximately 1 million tonnes of CO_2 would be saved pa.

The business case is built on £89bn NPV of user and non-user benefits and has an excellent BCR of 3.5:1. There are estimated to be an NPV of £11bn of Wider Economic Benefits (WEBs).

The geographical distribution of the economic benefits is shown below. The colour shows the distribution of all economic benefits, the size of the circle that of the WEBs.

Geographical distribution of Economic Benefits



While the economic benefits and WEBs are high for London as it is connected to a large number of places by high speed rail, it is noticeable that the benefits for Scotland are even higher, despite its lower population and smaller economy. The benefits for the North West are also very large, while those for the South West, Wales, the rest of the South East, East Midlands and the East are relatively small. This reflects where the majority of the time savings resulting from high speed rail are achieved.

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[1] Network Rail: New Lines Study: http://www.networkrail.co.uk/aspx/5892.aspx

[2] On-going study by High Speed 2, set up by UK Government to recommend on the case for a high speed rail link between London and Birmingham and beyond. http://www.hs2.org.uk/

[3] http://www.systra.com/?lang=en

[4] http://www.mvaconsultancy.com/

[5] Public Interest group members are: Association of North East Councils, Association of Train Operating Companies, BAA plc, Birmingham City Council, City of Edinburgh Council, City of London Corporation, English Regional Development Agencies, Glasgow City Council, Great Manchester Passenger Transport Executive, Railway Industry Association, South East of Scotland Transport Partnership, Strathclyde Partnership for Transport, Sheffield City Region, Transport for London.
Associate Members are: Channel Tunnel Initiative and Rail Freight Group.

[6] Observers were: Department for Transport, Transport Scotland and the Welsh Assembly Government.

[7] http://www.davidsimmonds.com/index.php?section=1

[8] http://www.dft.gov.uk/webtag/

[9] http://www.greengauge21.net/

